Received: 23 December 2020 | Revised: 15 April 2021 | Accepted: 21 April 2021

DOI: 10.1111/apce.12331

SPECIAL ISSUE

Annals of Public and Cooperative Economics
Annales de l'économie publique, sociale et coopérative

WILEY

The impact of the Italian Space Agency on scientific knowledge: Evidence from academic publications

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Abstract

Industrial and research activities in the space sector involve a heterogeneous group of actors such as private and public firms, universities, research institutes and space agencies, collaborating to different stages of missions' realization. Such collaborations are associated to the creation of spillover effects, proxied in different ways, such as the number of patents recorded, postgraduate students involved, spin-off activities and coauthored papers.

The aim of this paper is to investigate the impact of the collaboration between universities /research institutes and the Italian Space Agency (ASI). To this aim, we focus on papers where the authors acknowledge grants received by ASI. We use data on publications and citations to capture the association between ASI funding of a large number of scientific articles published in the period 1989–2017 and the quality of research, proxied by the number of citations received.

By performing parametric estimates with multiple levels of fixed effects (year, author and coauthors fixed effects), we find that articles mentioning ASI in the funding information are associated to a higher citation impact with respect to articles not financially supported by ASI. Such result suggests a positive impact on the scientific community of public funds granted to universities and research institutes.

KEYWORDS
citation impact, Italian Space Agency, public financial support, public procurement

JEL CLASSIFICATION
C80, O30, H54, H57

1 | INTRODUCTION

University research plays a key role in industrial innovation (Cohen et al., 2002; Mansfield, 1991), especially today that Higher Education Institutions "are being increasingly seen as a source of talent, entrepreneurship and a lead player in regional development" (European Commission, 2018). Differently from the case in which the target of the analysis are non-academic contractors, the effect of public procurement on research institutions mainly consists in knowledge spillovers, occurring when the results of a project generate a stream of knowledge somehow useful for new projects, publications and patenting. In this respect, the key concept in the literature is the knowledge production function, which describes the relationship between innovational output (such as patents and scientific articles), whereas university research and industry R&D represent the inputs in the production of knowledge (ESA, 2012).

The most relevant aspects relative to the partnerships arising in the space sector, usually promoted by national space agencies and involving firms (both private and public) and research institutes, are strictly related to the main features highlighted in University–Industry (U-I) literature, although such stream of research mainly focuses on the knowledge spillover on firms' performance. With regard to the benefits arising in U-I collaboration, Ankrah and Al-Tabbaa (2015) catalogued them as follows:

- economic-related, that is, new products or processes for industry, business opportunities for university, contribution to local economic development and patents/Intellectual Property Rights (IPRs) income for both parties;
- institutional-related, that is, joint publications, training and employment opportunities for students, "test bed" for feedback on research ideas for universities, access to knowledge and leading technologies, access to a wider international network of expertise, hiring of talents and improved innovative ability for industry;
- social-related, that is, service to the community, especially for universities, and enhancement of reputation.

The focus of our analysis is the assessment of the knowledge spillover that researchers enjoy when involved in projects funded by the Italian national space agency. In order to test the impact of funding from public agencies to academia and research institutes, our analysis focuses on the collaboration between the Italian Space Agency (ASI, henceforth) and Universities and Research

Institutes (URI), which represent a large share of the ASI's contractors universe.[1] Our aims are to evaluate: (i) how universities and research institutes benefit from engaging in collaborations with ASI; (ii) to what extent such partnership promote knowledge creation and spillover towards academia. Thus, in our empirical analysis, we shed some light on the effects of collaborations with ASI on the activity of researchers; their ability to collaborate with colleagues and on the learning mechanisms that influence their research quality and productivity.

Our work focuses on the quality of academic research, one of the knowledge outputs adopted in the U-I literature to measure the spillover effect of collaborations on universities' performance. We frame our analysis in the University–Industry (*space industry* in our case) interaction literature as academic research products, acknowledging ASI for its financial support, signal the existence of a partnership / provider agreement concerning a study, a technology implementation / test or a technology development relative to the space industry (so called upstream sector). Universities and research centers partnering with ASI—and mentioning its support—interact with ASI's technicians and supervisor as well as with other research centers and technology providers (private and public firms), collaborating in several phases of the process of new technology creation.[2]

In order to analyze the extent of knowledge spillover raising from the collaboration between research institutes or universities with ASI, we focus on the relationship between funding and the citation impact of publications downstream the collaboration process. Other papers have analyzed the link between funding activity and citation impact of publications, most of which in the nanotechnology field (e.g., Shapira & Wang, 2010; Wang & Shapira, 2011; Jacob & Lefgren, 2011; Gök et al, 2014; Wang & Shapira, 2015; Tahmooresnejad & Beaudry, 2019).

The novelty of our work is in its focus on the funding activity of ASI—that signals the involvement of academia in collaborations in the space industry—and on the adoption of an empirical strategy that allows us to control for a rich battery of fixed effects (year, author and coauthors fixed effects).

The structure of the paper is the following: Section 2 reviews the literature on the University-Industry (U-I, henceforth) link and the spillovers arising from it; Section 3 presents ASI and its funding activities in academic and public institutions research, while Section 4 reports data and methodology adopted in our parametric exercise. The results of our empirical analysis are presented and commented in Section 5. Section 6 concludes.

[1] In Italy, there is a wide and comprehensive "spatial" research system composed by several Universities, Departments, Research Institutes and Agencies, particularly concentrated in the regions of Lazio, Piedmont, Lombardia, Campania, Apulia and Sicily. For example, the Technological National Cluster for Aerospace (CTNA) in Rome is a key organization that unifies aerospace sector's actors, while the Campania's Italian Aerospace for Research (CIRA) is an excellence center in high-speed flow and re-entry vehicle application. Other important research centers of the Italian aerospace industry are the Institute of Microelectronics and Microsystems (IMM) at the National Research Council (CNR), the Polytechnic of Bari, the Space Geodesy Center of the Italian Space Agency, the European Centre for Space Law in Lazio, the Polytechnic of Turin, the Polytechnic of Milan, University of Naples Federico II, Sannio University, University of Napoli Parthenope and University of Salerno (Howe et al., 2016).

[2] To make this point clearer and understand how our approach fits in the U-I collaboration framework, consider the case of AGILE ("Astrorivelatore Gamma a Immagini Leggero") a ASI mission dedicated to the observation of the gamma-ray Universe, one of the most awarded missions realized by the Italian Space Agency. The mission is built and operated in cooperation with INAF (National Institute of Astrophysics), INFN (National Institute of Nuclear Physics), CIFS (Interuniversity Consortium for the Space Physics), and with the participation of several Italian companies such as Carlo Gavazzi Space, Thales-Alenia Space Italia, Rheinmetall Italia, Telespazio, Galileo Avionica and Mipot. Besides the public research institutes mentioned, the project also involved several university departments and also led to the publication of scientific articles most of which are included in our analysis on Scopus in virtue of the presence of the acknowledgement to ASI funds.

2 | SPILLOVER EFFECTS BETWEEN UNIVERSITY RESEARCH AND INDUSTRY: A BRIEF REVIEW OF THE LITERATURE

Most studies, including the very first articles on U-I knowledge link—usually assumed as a process generated by basic research in Research Institutes and flowing to industry—have rooted their analysis on the adoption of patent citation data as a proxy for knowledge spillover, stressing the role of several variables such as: geographical proximity (Jaffe, 1989; Jaffe et al., 1993; Anselin et al, 1997), localization (Fritsch & Slavtchev, 2007), labor mobility (Almeida & Kogut, 1999), diffusion and obsolescence (Jaffe & Trajtenberg, 1996) and barriers to the knowledge flow (Jaffe & Trajtenberg, 1999; Maurseth & Verspagen, 2002). Such evidence has led regional innovation policies to promote the presence of universities and research institutes on the territory, even though networks stemming from U-I collaboration over longer distances do influence knowledge diffusion as well (Ponds et al., 2010).

There are several metrics available to operationalize outputs from U-I link (Perkmann et al., 2011). By distinguishing between different process stages (inputs, in-process activities, outputs and impact), Perkmann et al. (2011) identify—for each stage—a measurement system for U-I collaborations resumed in a "success map". The process and the output of successful partnerships are measurable, for example, by patent applications, patent granted, publications in peer-reviewed journals, number of doctoral and post-doctoral positions offered within the alliance, the number of co-supervision arrangements, the number of new early-stage projects as a result of the alliance, number of solution concepts, trained graduate and post-graduate students building wider networks within the academic and industrial communities. Although conceived for assessing the extent of knowledge flowing from university to industry, Perkmann et al. (2011)'s proxies for measuring successful U-I alliances suit well to studies aiming at measuring knowledge spillover from (space) industrial activities to research institutes/universities/departments.

In their attempt to examine the channels through which academic researchers interact with industry and the factors influencing the variety of interactions, D'Este and Patel (2007) find that the process of knowledge transfer between university and industry in UK occurs through multiple channels such as personnel mobility, informal contacts, consulting relationships and joint research projects. Patenting and spin-offs play a relatively small role because U-I interactions are rarely motivated by the prospect of commercializing products.

In a systematic review of the empirical evidence on U-I relations, Perkmann et al. (2013) identify several determinants such as: the individual, organizational and institutional antecedents and consequences of academic engagement in collaborative research, contract research, consulting and informal relationship with industry. By comparing academic engagement with commercialization, the authors emphasize that participation in commercialization positively affects research productivity, while the consequences of academic engagement are ambiguous; both the typologies of collaboration do not seem to skew academics' research towards more applied topics.

In the attempt to investigate the effects of U-I linkages, Blumenthal et al. (1996) addressed a survey to more than 3,000 academics in 50 USA universities finding that those faculty members with industrial research support were at least as productive as their colleagues and, in contrast with Gulbrandsen and Smeby (2005) on Norway and Boardman and Corley (2008) on the USA, did not tend to shift their research activities toward relatively more applied topics. Such evidence is also verified for Italian academic inventors—those academics who are designated as inventors on patent applications at the European Patent Office—with solid links with industry as these lead to a boost in scientific productivity (Breschi et al., 2007). Relying on a dataset on Italian firms covering the 1995–2006 period, while confirming the role of geographical proximity to product innovation, Maietta (2015) shows that university–firm R&D collaboration positively affects process innovation.

Moreover, Gulbrandsen and Smeby (2005) found that, while shifting towards more applied activities, professors with industrial funding collaborate relatively more with other researchers and report a higher number of both publications and entrepreneurial outputs. A similar finding is also highlighted by Banal-Estañol et al. (2013) in the UK. They show that the quality of projects tends to increase both with the quality of the researcher and firm and with the partners' preferences affinity. Moreover, collaborating with firms with a high scientific level and that share similar interest to the researchers, improve the research output of collaboration. Boardman and Corley (2008) show that the percentage of research work time spent in U-I collaborations is positively associated with collaborations (outside the work group) within the university and negatively with the time spent working alone. One of the most significant benefits realized by faculty members is complementing their own research by securing funds for graduate students and lab equipment, field-testing the practical application of research and by seeking academically valuable insights and new ideas (Lee, 2000).

Evidence that U-I interactions lead to new ideas and motivations for new research projects is also provided by Perkmann and Walsh (2009) who, through a qualitative research approach on UK universities, take into account both the indirect and the direct effects of industry engagement on academic publishing. The authors found that joint research with industry often results in academic publications, while this is less true for relationships in more applied fields (when contract research or consulting are put in place). The latter, however, tend to involve far closer collaboration between academic and industry partners.

A key element for evaluating the effects of U-I partnership is to take into consideration the time lag required for knowledge spillover to emerge and to be captured by analyses. Scandura (2016), for instance, shows that the impact of collaboration on two variables such as the share of R&D employment and the R&D expenditure per employee is positive and requires two years to become evident. Evidence of the role of time is also provided by Bastianin et al. (2021) who show that the increase in the number of patent applications that firms experiment after becoming a supplier of CERN requires a relatively long gestation lag in the range of five to eight years.

3 | ASI FUNDING ACTIVITY TO INDUSTRY AND RESEARCH

Established in 1987, ASI has since then played a crucial role as Procurement Agency in the Space Industry promoting technological innovation and knowledge creation. Although most of the funding activity involves firms in the upstream sector, the amount of direct[3] research activities are very recently gathering more financial support, as reported in Table 1.[4]

[3] Besides the activities promoted, ASI contributes to those realized by the European Space Agency (ESA). During the financial year 2017, for example, ASI's contribution to ESA's activities amounted to 150 million of euros (*source*: ASI's Balance Sheet, 2017).

[4] The values reported in Table 1 consider "Research contracts and agreement with Universities, Observatory, National Research Council, with other Public Research Institutes and other national and international Institutes", "Contracts with national and foreign industries for space program's study, planning and realization", "Capital expenditure for research contracts and agreements with Universities, Observatory, National Research Council, with other Public Research Institutes and other national and international Institutes" and "Capital expenditure for contracts with national and foreign industries for space program's study, planning and realization"

TABLE 1 ASI's expenditure for Industry and Research contracts between 2008 and 2017

Year	Industry		Research		Total
2008	230,964,019.94 €	82%	49,059,859.88 €	18%	280,023,879.82 €
2009	137,766,919.18 €	79%	36,797,787.79 €	21%	174,564,706.97 €
2010	178,624,340.65 €	86%	29,006,751.93 €	14%	207,631,092.58 €
2011	222,524,336.93 €	89%	26,430,510.12 €	11%	248,954,847.05 €
2012	149,759,619.17 €	88%	19,724,147.88 €	12%	169,483,767.05 €
2013	172,519,728.35 €	89%	20,339,300.06 €	11%	192,859,028.41 €
2014	139,540,947.12 €	88%	19,467,674.40 €	12%	159,008,621.52 €
2015	173,682,958.33 €	90%	18,456,531.36 €	10%	192,139,489.69 €
2016	135,124,464.25 €	87%	19,379,483.62 €	13%	154,503,947.87 €
2017	185,460,339.98 €	87%	28,534,073.94 €	13%	213,994,413.92 €
Total	1,725,967,673.90 €	87%	267,196,120.98 €	13%	1,993,163,794.88 €

Source: ASI's Balance Sheet 2017.

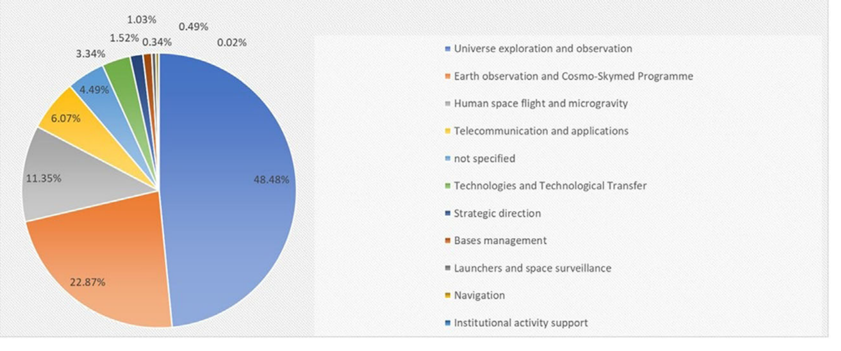

FIGURE 1 Amount of financial support to universities and Research Institutes
Source: authors' elaboration based on Archimede dataset
[Colour figure can be viewed at wileyonlinelibrary.com]

In the period 2008–17, ASI has invested in research contracts an average of 26.7 million of euros per year, an amount equal to about 15 percent of yearly expenditure for Industry contracts. Despite a remarkable increase of ASI institutional activity in 2017 with respect to the previous five-years period, the value of 28.5 million of euros is markedly below the levels of 9 years before.

By relying on ASI's Archimede Dataset, it is possible to collect information on the amount and description of the contracts between the Agency and Research Institutions. During the period 1996-2018,[5] ASI has funded research contracts for an amount of about 614 million of euros (at current value), mainly targeting activities related to 'Universe Exploration and Observation', as reported in *Figure 1*.

Almost half of expenditure is dedicated to Universe exploration and observation, while 22.87% (equal to about 140 million euros) are dedicated to Earth observation and Cosmo-Skymed program

[5] The Archimede Dataset reports data for contracts with firms, universities, and Public Institutes. All contracts reported are assigned to the year in which they are signed. Contracts signed with universities and Public Institutes range from 1996 to 2018.

activities. Human space flight and microgravity expenditure represents a remarkable share of the pie with over 11%, and contracts for telecommunications and application sum to over 6%, almost 37 million euros.

Starting from the next section we shift the focus of our analysis on the product of research activity: scientific publications. Although not all the projects funded lead to the publication of articles on scientific outlets, we consider that papers' scientific quality can effectively proxy for the quality of their upstream research activity. In particular, by analyzing all articles published by authors involved in projects supported by ASI, we aim at measuring whether it emerges a citation impact premium of ASI financial support.

4 | DATA AND METHODOLOGY

Our research design aims at estimating whether scientific articles, financially supported by ASI, increase authors' research output quality. The researchers included in the analysis are those credited as authors of journal articles formally citing a financial support by ASI (indifferently exclusive or concomitant with support from other funding agencies). As proxy for the quality of articles, we adopt the number of scientific publications' citations.

The number of citations is taken to represent the relative scientific significance or "quality" of papers (Cole & Cole, 1973) and citation indicators are sometimes presented as measures of scientific quality (e.g., Wang & Shapira, 2015; Abramo & D'Angelo, 2011; Durieux & Gevenois, 2010). There are in the literature pros and cons on such proxies of scientific quality. According to King (1987), the adoption of citations to represent the quality of a publication should be treated carefully because of field differences, biases in the process of peer review, the existence of so-called "citation clubs", and the possibility of negative as well as positive types of citations. On one hand, the norms of science oblige researchers to cite the work upon which they draw, and in this way acknowledge or credit contributions by others (Merton, 1979). On the other hand, the citation process is influenced by several incentives such as creating visibility through self-citations or citing a journal editor's work to enhance the chances of acceptance for publication (Aksens et al., 2019; Bornmann & Daniel, 2008). Moreover, also technical issues, such as discrepancies between target articles and cited references and mistakes in the indexing procedures, conducted by publication repositories, may confuse citation analyses as well as extensive self-citation rates (Aksens et al., 2019).

Nevertheless, negative citations tend to be rare (Catalini et al, 2015) and the larger the citation data set being used, the higher the confidence level of the results (Welljams-Dorof, 1997) which may allow to overcome technical issues. Moreover, citations—together with journal impact factor—are frequently used as an indicator for assessing the publication outputs of scientists and their research groups, by promotion and tenure committees and in studies of the performance of research institutions and nations (Wang & Shapira, 2015).

In this paper, in order to overcome any issue related to field differences and any sort of heterogeneity bias between publications, as highlighted in this section, we adopt author, co-authors and year fixed effects.

In order to perform our analysis, we rely on Elsevier's SCOPUS database as bibliometric source (data downloaded in May 2020). The core of our strategy is the identification of scientific articles, written in English, that: (i) report, among the funding information, the words "Italian Space Agency" or "Agenzia Spaziale Italiana", and (ii) are published between 1989 and 2017.

Such query provided us with a total of 3,141 articles reporting a DOI (the Document Online Identifier) for a total number of authors amounting to 13,690. The next step was the identification of all scientific articles—written in English and published in the period 1989–2017—credited to the above-mentioned 13,690 researchers. Such research ended up with a total number of articles—with a DOI—equal to 305,174. In our final dataset each entry contains all combinations of articles' DOIs and authors' IDs (total of 832,551 article–author pairs).

By including a large array of fixed effects, the organization of the dataset in DOI-authors pairs allows us to investigate our research question: whether the citation impact of the authors, included in our data set, is higher for articles funded by ASI.

In other words, our empirical analysis aims at assessing whether—ceteris paribus—articles related to projects that received financial support by ASI are, on average, qualitatively superior to all the articles published in the same period by the same pool of authors. In this respect, we proxy the quality of a paper by the number of citations that it has cumulated:

$$cit_{pi} = \beta_{asi} asi_p + \beta_X X_{pi} + \eta_y + \chi_a + \zeta_c + \varepsilon_{pi}, \tag{1}$$

where cit_{pi} is the number of times the article p, authored—or coauthored by—researcher i, has been cited, asi_p is the dummy variable equal to 1 when the paper p is the research product of a project funded—exclusively or co-funded—by ASI and X_{pi} represents the vector of paper- / author-specific covariates (such as the number of coauthors in the paper and the seniority of a researcher). The inclusion of the number of coauthors controls for the case in which the number of citations is inflated by self-citations. The authors' seniority aims at controlling whether the increase in the number of citations of paper-author combination increases because the author(s) has increased the quality of her research deriving by experience accumulated. The seniority of author a of the article p is then computed as the difference between the year of publication of article p, and the year of publication of author a's first paper since 1989. By including this variable, we expect to control for the increase in author's quality due to the experience she developed, independently from the financial support we aim to measure.

In order to drive out all confounder effects, we include η_y, χ_a and ζ_c representing year, author, and coauthors fixed effects, respectively. All fixed effects are performed adopting fixed effects absorbing models that allow to deal with a high number of controls (e.g., authors fixed effects are over 13,000).

By controlling for authors and coauthors fixed effects, the dummy variable asi_p will be able to capture the quality premium deriving from collaborating with ASI. We perform both Ordinary Least Squared fixed effect estimates (Correia, 2014) and Poisson Pseudo Maximum Likelihood fixed effect estimates (Correia et al., 2019). In the first case we transform our dependent variable in logarithm, while in the latter our dependent is a count variable.

Figure 2 panel (a) reports the pace of the number of papers citing financial support by ASI in the period 1989–2017. The yearly number of articles increases almost all years until 2003 (peak of 157 articles), before decreasing for five years in a row. The first year with a number of publications higher than the value in 2003 is 2011 (171). After three years of ups and downs, the number of articles has markedly increased, reaching the maximum value in 2017, up to a number of 273 funded articles. Figure 2 panel (b) shows the relative distribution of the authors' countries of origin. We find a strong home bias, since 2,935 authors have an affiliation institute located in Italy. 854 authors have their affiliation in the United States, Germany and France follow in the ranking, with 484 and 462 authors, respectively.

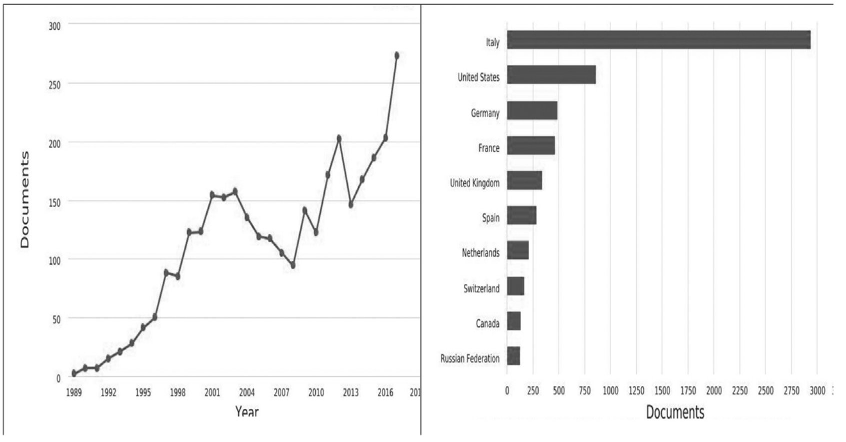

FIGURE 2 Articles that received financial support by ASI. Panel a) reports the distribution over time, panel b) reports by country distribution.
Source: Scopus Database

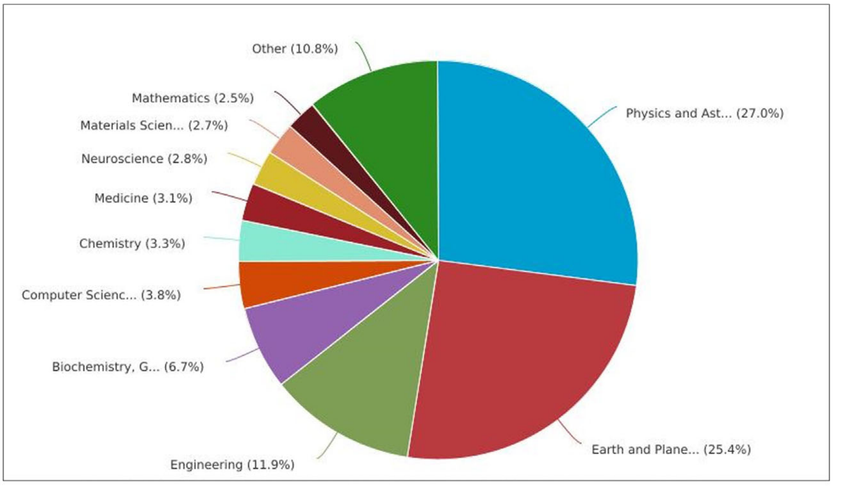

FIGURE 3 Articles that received financial support by ASI, distribution by subject area.
Source: Scopus dataset
[Colour figure can be viewed at wileyonlinelibrary.com]

The distribution of the papers by subject area is reported in Figure 3. More than half of them pertain to two areas: 27% of papers (1,610) are articles in "Physics and Astronomy"; 24.4% (1,512) are papers in "Earth and Planetary Sciences"; "Engineering" and "Biochemistry, Genetics and Molecular Biology" follow with 11.9% and 6.7%, respectively. The residual area, reported in green, collects the remaining 17 subject areas and represents 10.8% of total observations. Among these, four articles are papers in "Economics, Econometrics and Finance".

Besides the home bias related to the authors' affiliation country revealed by Figure 2 panel (b), it is worthwhile to note on Figure 4 how—excluding the National Research Council (CNR) that has different branches, for different research areas, in all the Italian territory—three out of the first

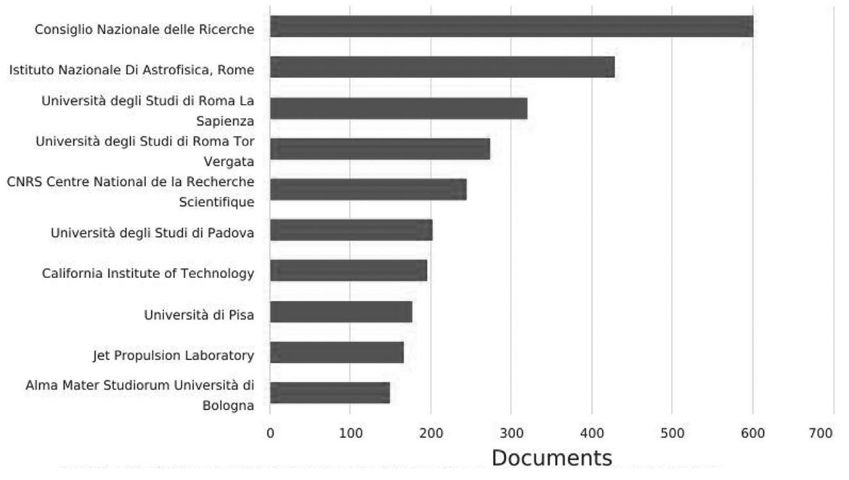

FIGURE 4 Articles that received financial support by ASI, distribution by affiliation.
Source: Scopus dataset

TABLE 2 Descriptive statistics of variables included in the parametric analysis

Variable	Obs.	Mean	Std. Dev.	Min	Max
No. of citations	892,551	65.145	188.125	0	13298
ASI (= 1 if research activity has been funded by ASI)	892,551	0.040	0.196	0	1
No. of coauthors	892,551	236.192	596.738	0	5153
Author's seniority	892,551	13.047	7.739	0	28

Source: Authors' elaborations on data from Scopus.

four affiliation institutes are located in Rome. As the ASIs Headquarter is located in the Capital city, this suggests that geographical proximity is a key element to establish and develop collaborations in the space sector. 600 authors of the articles identified as funded-by-ASI are affiliated to the CNR, 428 authors are affiliated to the National Institute of Astrophysics (INAF), 319 authors are from 'Sapienza', University of Rome and 273 are from University of Rome 'Tor Vergata'. The total number of affiliation institutes is 160.

5 | RESULTS

Table 2 reports the descriptive statistics relative to the variable employed in our parametric analysis. The total number of observations included in the analysis is 892,551 with the value of our dependent variable ranging between 0 and 13,298. The number of observations relative to article-author pairs that received financial support by ASI is 4% of the total. The number of coauthors reaches the maximum of 5,153 and is characterized by a high standard deviation. In our analysis, such variable is transformed in logarithms.[6] The average authors' seniority is 13 years.

[6] As for the dependent variable in the OLS models, in order to keep as many observations as possible, the transformation is performed as follows: $lx = \ln(x + 0.1)$.

TABLE 3 OLS fixed effects estimates. Dependent variable: ln of scientific citations

Dep. var: scientific citations (in ln)	**(1)**	**(2)**	**(3)**	**(4)**
ASI	**0.032*****	**0.017****	**0.085**	**0.171*****
	(0.008)	(0.008)	(0.134)	(0.043)
No. of coauthors (ln)	0.206***	0.402***	−2.914	−3.179*
	(0.001)	(0.002)	(5.584)	(1.883)
Author seniority	−0.042***	−0.003	0.001	0.014
	(0.002)	(0.003)	(0.026)	(0.013)
Observations	892,551	892,551	892,551	97,621
R-squared	0.12	0.26	0.93	0.59
Year FEs	yes	yes	yes	yes
Author FEs		yes		yes
Coauthors FEs			yes	yes

Robust standard errors in parentheses. ***/**/* significance level at 1% / 5% / 10% respectively. The number of observations decrease when considering the full set of fixed effects because of the presence of nonsingleton observations. Apart from increasing the *R*-squared statistics and the number of observations, maintaining singleton groups does not change our results.

By estimating our model by OLS and adopting our dependent variable in logarithms, we obtain the results reported in Table 3. The four columns differ from each other by the type of fixed effects included in the analysis. With the exception of column (3)—in which we do not take into consideration the authors' fixed effect—the coefficients associated to the dummy that identifies which papers have been financially supported by ASI is positive and statistically different from zero. Such results suggest that, controlling for years, author and coauthors' fixed effects, papers representing the downstream scientific product of a project supported by ASI receive a higher number of citation and are, thus, characterized by a higher quality level. In particular, as evidenced by the coefficient in column (4), papers funded (exclusively or also) by ASI and published between 1989 and 2017 receive a number of citations 17% higher than papers published by the same authors in the same period. The number of coauthors results significant and positive when we do not include the array of coauthors fixed effects. After their inclusion, the covariate loses its relevance. Contrarily to our expectations, our proxy capturing the authors' seniority does not explain our dependent variable's variability.

Table 4 reports estimates of our model from equation (1) when employing a Poisson pseudo-maximum-likelihood model (PPML, henceforth) with fixed effects. As our dependent variable, the number of citations of a paper, is a count variable, the implementation of a Poisson model is recommended as applying least-squares regressions on outcome variables of the form log(y) would lead to inconsistent estimates in the presence of heteroskedasticity. Except for results in column (2), the specification with year and author fixed effects, the coefficient of our variable of interest becomes negative and statistically significant. However, the inclusion of coauthors' fixed effects leads to results in line with those found in Table 3, although slightly lower. According to the coefficient reported in column (4) of Table 4, statistically significant at 10% level (although associated with a *t*-statistics equal to 1.94), papers supported by ASI are associated to a 14.2% increase in the quality of papers as measured by the number of citations ($\exp(0.133) - 1 = 0.142$).[7] No evidence

[7] As the number of coauthors in all the papers published by the 13,690 authors of articles funded by ASI is extremely high, we have assigned a univocal identifier to each combination of coauthors IDs. Absorbing our model's estimates on such

TABLE 4 Poisson pseudo-maximum-likelihood estimation with fixed effects. Dependent variable: no. of scientific citations

Dep. var: scientific citations	(1)	(2)	(3)	(4)
ASI	**0.172*** **	**−0.060*** **	**0.103***	**0.133***
	(0.011)	(0.011)	(0.062)	(0.069)
No. of coauthors (ln)	0.218***	0.525***	−1.585**	−1.520***
	(0.001)	(0.004)	(0.709)	(0.562)
Author seniority	−0.061***	−0.036***	0.018*	0.009
	(0.003)	(0.006)	(0.011)	(0.020)
Observations	892,551	892,515	98,309	97,303
Pseudo R-squared	0.12	0.30	0.60	0.68
Year FEs	yes	yes	yes	yes
Author FEs		yes		yes
Coauthor FEs			yes	yes

Robust standard errors in parentheses. ***/**/* significance level at 1% / 5% / 10% respectively. The number of observations decrease when considering the full set of fixed effects because of the presence of nonsingleton observations. Apart from increasing the R-squared statistics and the number of observations, maintaining singleton groups does not change our results.

that authors' seniority influences the number of citations received by a paper when controlling for year, coauthors and authors fixed effects.

In order to give robustness to our analysis and exclude the possibility that our results are driven by a small sample of papers coauthored by thousands of authors, we have re-estimated the models with the full set of fixed effects by excluding publications credited to a high number of authors.

The reason behind the opportunity to perform such robustness check relies on the risk that papers with many coauthors might be overrepresented in our dataset composed by author–paper combinations, although many of them are already excluded because singleton. Table 5 shows the results for both OLS and PPML estimates with high-dimensional fixed effects.

By performing our estimates on a subsample of author-paper combinations, we find that our results hold and are, in particular for the OLS columns, statistically significant. PPML estimates are robust when excluding papers with a number of coauthors higher than the 95th and the 75th percentile (p-value associated with the coefficient ASI equal to 0.055) while, when focusing on papers with less than 16 authors, our main covariate turns nonsignificative, albeit positive.

Further support to our findings is provided by the estimates reported in Tables 6 and 7. Similarly to Table 5, we have gradually excluded papers with a high number of coauthors. However, differently from all previous empirical results, we adopt a new main covariate: instead of including a dummy variable equal to 1 when a paper acknowledges ASI for supporting its research, we use a dummy equal to 1 when a paper acknowledges ASI as its unique funding agency (and 0 otherwise). Thus, such setting allows us to understand whether the citation premium associated to papers linked to projects funded by ASI is magnified by co-funding or not.

categorical variable is equivalent, for the purpose of our analysis, to including all the combinations of N dummy variables (N is the total number of the 13,690 "ASI" authors' coauthors) reporting value 1 when the single coauthor is credited for the paper and 0 otherwise. The only limit of our approach of absorbing coauthor fixed effects by using coauthors combinations' IDs, that is beyond the purpose of our analysis, is the impossibility of isolating the single coauthor's intercept.

TABLE 5 Estimations with fixed effects when excluding publications with a high number of coauthors

	OLS No. coauthors <95th percentile	OLS No. coauthors <75th percentile	OLS No. coauthors <0th percentile	PPML No. coauthors <95th percentile	PPML No. coauthors <75th percentile	PPML No. coauthors <50th percentile
ASI	**0.171*** **	**0.170*** **	**0.145*** **	**0.133***	**0.133***	**0.088**
	(0.043)	(0.043)	(0.044)	(0.069)	(0.069)	(0.073)
No. of coauthors (ln)	−3.179*	−3.169*	−3.028	−1.520***	−1.519***	−1.448***
	(1.891)	(1.893)	(1.896)	(0.562)	(0.562)	(0.536)
Author seniority	0.013	0.015	0.024*	0.009	0.009	0.014
	(0.013)	(0.014)	(0.014)	(0.020)	(0.020)	(0.021)
Observations	96,687	95,201	87,658	96,377	94,883	87,359
R-squared	0.59	0.59	0.57	0.68	0.68	0.66
Year FEs	yes	yes	yes	yes	yes	yes
Author FEs	yes	yes	yes	yes	yes	yes
Coauthors FEs	yes	yes	yes	yes	yes	yes

Robust standard errors in parentheses. ***/**/* significance level at 1% / 5% / 10% respectively. Dependent variable varies according to the estimator adopted. OLS: nr of citations (in ln); PPML: no. of citations.

TABLE 6 OLS fixed effects estimates. Dependent variable: ln of scientific citations. Publications acknowledging only ASI

Dependent variable: no. of citations (Ln)	OLS Full sample	OLS No. coauthors <95th percentile	OLS No. coauthors <5th percentile	OLS No. coauthors <50th percentile	OLS No. coauthors <25th percentile	OLS No. coauthors <10th percentile
Only-ASI	**0.360*** **	**0.360*** **	**0.360*** **	**0.384*** **	**0.332*** **	**0.328*** **
	(0.059)	(0.059)	(0.059)	(0.061)	(0.065)	(0.076)
No. of coauthors (ln)	−3.179*	−3.179*	−3.169*	−3.027*	−3.009*	−3.028*
	(1.776)	(1.776)	(1.772)	(1.723)	(1.704)	(1.672)
Author seniority	0.014	0.014	0.015	0.024	0.030*	0.024
	(0.015)	(0.015)	(0.015)	(0.015)	(0.016)	(0.018)
Observations	96,687	96,687	95,201	87,658	73,631	49,821
R-squared	0.59	0.59	0.59	0.57	0.56	0.55
Year FEs	yes	yes	yes	yes	yes	yes
Author FEs	yes	yes	yes	yes	yes	yes
Coauthors FEs	yes	yes	yes	yes	yes	yes

Robust standard errors in parentheses. ***/**/* significance level at 1% / 5% / 10% respectively.

TABLE 7 Poisson pseudo-maximum-likelihood estimation with fixed effects. Dependent variable: nr of scientific citations. Publications acknowledging only ASI

Dependent variable: no. of citations	**PPML*** **Full sample**	**PPML*** **No. coauthors <95th percentile**	**PPML** **No. coauthors <75th percentile**	**PPML** **No. coauthors <50th percentile**	**PPML** **No. coauthors <25th percentile**	**PPML** **No. coauthors <10th percentile**
Only-ASI	**0.291**	**0.291**	**0.291*** **	**0.297*** **	**0.273*** **	**0.350*** **
	(0.000)	(0.000)	(0.095)	(0.096)	(0.105)	(0.123)
No. of coauthors (ln)	−1.519	−1.519	−1.518***	−1.448***	−1.427***	−1.425***
	(0.000)	(0.000)	(0.562)	(0.536)	(0.532)	(0.548)
Author seniority	0.008	0.008	0.009	0.014	0.013	0.020
	(0.000)	(0.000)	(0.020)	(0.021)	(0.022)	(0.028)
Observations	96,377	96,377	94,883	87,359	73,415	49,666
Pseudo R-squared	0.68	0.68	0.68	0.67	0.66	0.65
Year FEs	yes	yes	yes	yes	yes	yes
Author FEs	yes	yes	yes	yes	yes	yes
Coauthors FEs	yes	yes	yes	yes	yes	yes

Robust standard errors in parentheses. ***/**/* significance level at 1% / 5% / 10% respectively. * estimations with variance matrix nonsymmetric or highly singular: standard errors not computed because of the relative scarcity of observations with "Only-ASI" value equal to 1.

Results in Tables 6 and 7 strongly support the evidence that publications acknowledging ASI for financial support receive—ceteris paribus—a higher number of citations. Such citation premium is even higher: papers originating from projects receiving support solely from ASI gain, on average, a citation premium of 32–38% with respect to papers not supported (neither in exclusive nor concomitant way) by ASI and realized by the same author. The value ranges between 33% and 41% when adopting the PPML estimator. These results suggest that the collaboration between ASI and research institutes is beneficial and that the spillovers are broader when the collaboration in a project is exclusive. This might be due to the fact that, in projects funded only by ASI, the link between ASI and researchers is narrower and allows to reap higher benefits from the collaboration.

The number of coauthors is negatively associated to the number of citations obtained. This suggests that publications with a lot of coauthors have a lower impact on the academia with respect to papers with a limited number of coauthors.

6 | CONCLUDING REMARKS

The empirical investigation shows that scientific publications supported by ASI, one of the main space agencies in the world, perform better than their counterparts in our sample, when quality is proxied by citations. Although the analysis of citations is not an unusual approach to investigate the impact of funding on research output, to the best of our knowledge, this is the first time that such empirical strategy is employed at the paper–author level by controlling for year, author and coauthors fixed effect. Our approach is also new in the context of the space industry and the analysis of publications citations as it allows to measure the impact of public funds on the quality of research. In principle, if data on the entity of financial support were available, after controlling from several covariates and fixed effects, our data would allow to compute the marginal effect of one euro of public funds in terms of citation impact of scientific publications supported by such fund.

Since research activities acknowledging ASI for its financial support usually involve several actors employed in the space industry, ranging from ASI's technicians to private firms and public research institutes, our analysis allows to assess the scope of knowledge spillover arising from University – Industry collaborations experienced by the academic community working in the space sector.

By controlling for the heterogeneity associated to the year of publication, the author paired with the publication and the pool of coauthors, the empirical analysis shows the existence of a 'quality premium' in favor of articles financially supported by ASI: papers funded by ASI have, on average and *ceteris paribus*, a citation impact 11–17% higher than publications not funded.

The citation impact is even higher when focusing on publications deriving from projects funded by ASI in exclusive way (citation premium up to 36%) probably because of a closer collaboration between ASI and research institution.

Our approach potentially opens up a new stream of research, as it would be possible to measure the cost-effectiveness of public funds in terms of citations compared across different funding agencies in the same scientific community: for example, comparing the research supported by ASI with the research supported by the European Space Agency, the NASA, or other national space agencies. Apart from the difficulties related to the bulk download and data management, our approach can be extended to other sectors as well, particularly in the life sciences, in a relatively easy way by simply substituting the keyword used in the Scopus query and, thus, analyzing other funding agencies' effectiveness or the impact of any bibliographic characteristic recorded in the online repositories.

ACKNOWLEDGMENTS

We would like to thank Massimo Florio for his comments on a previous version of the paper, all the participants to the XVIII edition of the Milan European Economy Workshop (25–26 June 2020) as well as the participants to the XXXII SIEP WEB Conference (17 September 2020). The authors are also grateful to the Italian Space Agency and University of Milan for their support to the project "Cost-benefit analysis of public policies in the space sector". This paper should not be reported as representing the official views of ASI or any third party. Any errors remain those of the authors.

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How to cite this article: Vurchio, D., & Giunta, A. The impact of the Italian Space Agency on scientific knowledge: Evidence from academic publications. *Ann Public Coop Econ*. 2021;*92*:511–529. https://doi.org/10.1111/apce.12331