



# An intersectional approach to analyse gender productivity and open access: a bibliometric analysis of the Italian National Research Council

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## Abstract

Gender equality and Open Access (OA) are priorities within the European Research Area and cross-cutting issues in European research program H2020. Gender and openness are also key elements of responsible research and innovation. However, despite the common underlying targets of fostering an inclusive, transparent and sustainable research environment, both issues are analysed as independent topics. This paper represents a first exploration of the inter-linkages between gender and OA analysing the scientific production of researchers of the Italian National Research Council under a gender perspective integrated with the different OA publications modes. A bibliometric analysis was carried out for articles published in the period 2016–2018 and retrieved from the Web of Science. Results are presented constantly analysing CNR scientific production in relation to gender, disciplinary fields and OA publication modes. These variables are also used when analysing articles that receive financial support. Our results indicate that gender disparities in scientific production still persist particularly in STEM disciplines, while the gender gap is the closest to parity in medical and agricultural sciences. A positive dynamic toward OA publishing and women's scientific production is shown when disciplines with well-established open practices are related to articles supported by funds. A slightly higher women's propensity toward OA is shown when considering Gold OA, or authorships with women in the first and last article by-line position. The prevalence of Italian funded articles with women's contributions published in Gold OA journals seems to confirm this tendency, especially if considering the weak enforcement of the Italian OA policies.

**Keywords** Productivity · Gender differences · Open access publishing · Bibliometric analysis · Italy

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## Introduction

Gender equality in research as well as circulation and Open Access (OA) of scientific knowledge (Open Science—OS) are core themes in the Research and Innovation (R&I) program promoted by the European Union. Both issues are included among the six priorities in the European Research Area (ERA), outlining the key objectives of the European policy to support the creation of an open context in which researchers, knowledge, technologies, scientific institutions and economic agents can freely move. Furthermore, gender and openness are key elements of the Responsible Research and Innovation (RRI) developed within the European framework program, which promotes a research approach based on ethical criteria “to foster the design of inclusive and sustainable innovation focused on individuals and societal needs”. In line with this approach, the current EU funding program, on the one hand, encourages the inclusion of a gender perspective in each project (European Commission 2013, 2016, 2017) and, on the other, requires that research results are freely available in Open Access journals and/or repositories (European Commission 2017a).

All these initiatives consider gender equality and Open Access as two independent and unrelated issues, despite the common underlying targets of fostering an inclusive, transparent and sustainable research environment. This is evident in the context of ERA, which identifies for both issues (Priority 4 and 5b respectively) specific actions to improve their applications, and monitors their uptake selecting relevant indicators to analyse the progress achieved as well as further areas of interventions. A few recent studies (ERAC 2019; European Commission 2019; GENDERACTION 2019) have pointed out the importance of analysing the possible intersections between gender and OA/OS, in order to develop a policy synergy that can benefit both. To reach this aim, it is necessary to explore gender scientific production and Open Access publications in an integrated way, taking advantage of methodologies that have until now been applied in two parallel, separate fields of studies.

OA is still in a transition phase producing different models of free available publications (Gold, Green, Hybrid,) while the steps toward OS are gradually changing the way research is performed, disseminated (collaborative networks, use of social media, Citizen science, etc.) and assessed (Open Peer Review, Altmetrics, etc.). Whether and to what extent these changes may have an impact on women’s scientific production and career progression has not yet been explored. Vice versa, attitudes to adopting OA publications were analysed in surveys, tackling researchers’ propensity (Moksness and Olsen 2017; O’Hanlon et al. 2020; Zhu 2017), but not exploring real publication practices. This paper intends to fill this gap by providing an integrated analysis of gender performance and OA publication modes applying relevant methods of the respective fields of study as well as considering some interrelated variables, such as disciplinary fields and publications’ financial support.

Based on these premises, this paper presents the first, to our knowledge, novel analysis on the scientific production of researchers of the Italian National Research Council (CNR) providing a gender perspective integrated with the different OA publications modes. CNR, the largest governmental research organisation in Italy, provides an interesting sample, as it covers all scientific fields including social sciences and humanities (SSH). The 101 CNR institutes distributed all over Italy prioritise a multidisciplinary perspective in their research and are actively involved in national and international projects. Moreover, this analysis is part of the preparatory study for the forthcoming development of a Gender Equality Plan (GEP).

In the following sections, after a brief analysis of relevant literature, we describe the data and methods. Results are presented constantly analysing CNR scientific production in relation to gender, disciplinary fields and OA publication modes. These variables are also used when analysing articles that receive financial support.

## Literature review

A comprehensive literature review in both OA and gender studies is outside the scope of this paper. Nevertheless, in the following paragraphs the general framework for each of these topics and related issues are described, so to substantiate the methodology adopted providing scientific results produced so far.

## Open access

Open access refers to the immediate availability of scientific knowledge (publications and data) free of charge from the point of view of the users, free for re-use without restrictions related to copyright and licences. This is the definition of the Budapest OA Initiative (BOAI 2002) which is considered the formal beginning of the Open access movement. Right of access and re-use of information have been differently defined in further OA declarations (Berlin 2003; Bethesda 2003) and, most importantly, differently implemented (Laakso and Björk 2012, 2013; McKiernan et al. 2016) by commercial publishers, outlining a complex mix of openness, in terms of rights for authors (copyright, posting version to repositories, delay access) and for readers (immediate access, re-use, embargo periods) (Chen 2013; Johnson et al. 2018). These approaches have produced a variety of OA subtypes, which can be differently classified (Archambault et al. 2014; Chen and Olijhoek 2016; Piwowar et al. 2018; Suber 2008, 2012; Tennant et al. 2016), modifying the OA publishing model introduced by BOAI (2002) based on two pathways—the Gold route and the Green route (Gargouri et al. 2012; Harnad et al. 2008).

Gold OA refers to articles published in Open Access journals and Green OA indicates versions of articles, mainly published in closed journals, submitted in institutional and/or disciplinary repositories. Gold OA removes price barriers for the readers allowing them to access information without paying subscription fees to the journal, while authors and/or institutions are generally required to pay article processing charges (APCs) to support publishers in the transition phase toward the OA model. The Directory of Open Access Journals (DOAJ<sup>1</sup>) is considered the authoritative source of OA journals (Archambault et al. 2014; Gargouri et al. 2012), as this collection select journals on the basis on the types of licences for re-use. The most popular licences are the Creative Commons (CC<sup>2</sup>) that enable readers to re-use the work with few restrictions.

Considering the Green route, publishers' policies on self-archiving (Sherpa/Romeo<sup>3</sup>) highly influence the immediate availability of article versions in repositories, as they establish embargo periods (generally from 6 to 12 months) with the aim of avoiding reductions

<sup>1</sup> <https://doaj.org/>.

<sup>2</sup> <https://creativecommons.org/>.

<sup>3</sup> <http://sherpa.ac.uk/romeo/index.php>.

in subscriptions (Björk et al. 2010; Laakso and Björk 2013; Tennant et al. 2016). Moreover, in the analysis of Green OA practices another aspect to be considered is that articles can be made available in no fixed time and are usually submitted retrospectively, making the analysis of Green articles more difficult. This is true also if we consider that multiple versions can be accessible along with duplication of the same copy archived in different repositories (Johnson et al. 2018). The Green route is also enabled through authors who self-archive papers in Academic Social Networks (ASNs), such as ResearchGate, Academia.edu and Mendely (Archambault et al. 2014) as an alternative to institutional and/or subject repositories (Björk 2016; Penn 2018; Jordan 2019)). Many OA advocates (Jamali 2017; Johnson et al. 2018) argue that providing articles for free in ASNs is not OA at all, expressing their concerns regarding the infringement of licensing terms and copyright law as well as the lack of assurance of long-term preservation.

However, the use of ASNs as well as other social media (LinkedIn, Facebook, blogs, tweets etc.) certainly outline authors' increasingly proactive attitudes toward a broader diffusion of their research results along with a gain in visibility that may increase both their societal and research impact. Whether there is a correlation between these aspects, generally measured through bibliometric indicators (number of publications and citations) and Almetrics (number of downloads, followers, tweets, etc.), has not been fully proved (Ortega 2015). This is probably due to the different sources used for the analysis and the highly context-dependent influencing factors related to the scientific community analysed. Only recently have a few studies included a gender dimension in their analyses, producing interesting results related to women's participation in social media which seems to reproduce gender role stereotypes (Messias et al. 2017), even when it comes to citations (Knobloch-Westerwick and Glynn 2013).

In the last years the hybrid publishing model has been increasingly adopted representing commercial publisher's answer to the current request for a full transition to Open Access. Hybrid articles are published in closed traditional subscription journals that are immediately free to read on the basis of a payment of APCs. This publication mode is often criticised (Archambault et al. 2014) as it determines higher fees than those for full OA articles, a double dipping for the scientific institution that has to pay twice, once for the journal subscription and once for the APC. Moreover, they misrepresent the idea that OA is equal to paying for publishing. This reinforces authors' perception that the hybrid mode is an easy option for complying with OA mandates required by funders and at the same time a possibility to publish in journals indexed by Web of Science (WoS) and Scopus, thus meeting generally adopted evaluation criteria for recruitment and career advancement. Symmetrically, marketing strategies of the current academic publishers' oligopoly are progressively increasing their portfolios of Gold OA journals considerably varying the amount of fees charged, which generally depend on the journal's prestige as well as its indexing in large-scale bibliometric databases. On same lines, but with even more disruptive effects, there is an increase in the so called "predatory journals" (Beall 2012; McCann and Polacsek 2018) in which non-professional publishers make profits with APCs promising speedy publication and visibility which often leads to disseminating articles in ad hoc websites with no quality control.

The ranking imperative that applies to individual researchers, institutions and even countries coupled with a reward system based on journal Impact Factor not only creates strong incentives for researchers to publish in these journals, but also limits the uptake of an Open Science scholarly communication model (European Commission 2019) which could benefit not only female researchers. For these reasons, some recent initiatives such as Plan S (Coalition-S 2018), supported by several funding and research institutions, propose

to revise publisher agreements in terms of subscription and APC prices. The principles advocated by Plan S link to a concept of science as a common good (Merton 1973) which may be accessible and re-usable for all users. Plan S promotes the principle of inclusion limiting the gap between scientists and the general public in the access to knowledge and represents an alternative to the inequality of publishing access for people, included but not limited to women, and institutions with fewer financial resources (Fuchs and Sandoval 2013) and/or related to the use of English as the lingua franca (MoChridhe 2019).

The uptake of OA is still suboptimal needing further support in terms of policies (Registry of Open Access Repository Mandates and Policies—ROARMAP<sup>4</sup>), infrastructures (Tennant et al. 2016) as well as in changing practices for the evaluation of research results (European Commission 2017b, 2019b). Different studies analyse data on OA publications at an international level (Archambault et al. 2014; European Commission 2019a, 2019b; Open Science Monitor 2018), providing mixed results, indicating from 30 to 50% OA of the total published articles. Differences are also due to the diverse subtypes of OA considered (from Gold, Green to Bronze and Hybrid), the source of analysis (Web of Science, Scopus, national registries) and the use of recently developed tools (Unpaywall, oaDOI) which facilitate the identification of OA versions (Bosman and Kramer 2018). In our analysis we will take the ERA results as well as those available in the EU Open Science Monitor as reference points. The first provide a comprehensive framework of the European countries, while the EU Open Science Monitor has the advantage of giving more recent, updated data (2018) also related to the Fields of Research and Development (FORD) disciplinary classification (OECD 2015).

## Gender studies on scientific production

Scientific productivity, primarily measured on the number of papers, books and citations, is a crucial indicator for recruitment, promotion and scientific recognition and is therefore an important part of the cumulative advantages and disadvantages (Merton 1968, 1988; Rossiter 1993) that highly influence career progression and participation in research activities. Since the 70s, an important thread of studies has analysed gender differences in scientific production contributing to the confirmation of the “productivity puzzle” (Cole and Zuckerman 1984) made up of multiple socio-cultural and organizational research factors. A meta-analysis (Caprile et al. 2012) provides a comprehensive overview on research on gender and science outlining how hypotheses regarding female participation in research and lower performance evolve over time, progressively adding concurrent factors which not only pertain to the role of women in society and the family, but also consider how research functions.

In fact, the differential ratio between women’s and men’s productivity is generally analysed considering different variables within two main axes which, to simplify, outline the framework of a vast amount of studies: women’s socio-demographic characteristics and their role and participation in research activities. Regarding the former, family responsibilities are deemed to influence gender performance (Fox 2005; Hunter and Leahey 2010), especially in certain periods of women’s lives which determine breaks in activities and difficulties in being reintegrated into the research process (Armenti 2004;

<sup>4</sup> <https://roarmap.eprints.org/>.

Bonaccorsi and Daraio 2003; Mavriplis et al. 2010). However, these studies come to mixed and often contradictory conclusions (Astegiano et al. 2019; Holman et al. 2018; Huang et al. 2020; West et al. 2013). Considering the female role within research institutions, the main correlations of women's performance are with the academic rank and career progression (Marini and Meschitti 2018; van den Besselaar and Sandström 2017), access to resources (European Commission 2009; Witteman et al. 2019) and national and/or international collaboration (Abramo et al. 2019; Ozel et al. 2014; Hernández-Martín et al. 2019). Generally, these analyses focus on specific countries (Abramo et al. 2009; Söderlund and Madison 2015) and/or institutions (Bordons et al. 2003; Hidrun et al. 2012), in many cases considering specific disciplinary fields and/or well-defined research communities (Dehdarirad et al. 2015; Jadidi et al. 2018; Macaluso et al. 2016). They highlight specificities that often reveal novel interconnections of concomitant factors, identifying hidden social norms and stereotypes as well as structural conditions of the scientific system at national, institutional and/or community level.

To complete this brief literature review, even if not considered in our analysis, it is worth mentioning the important thread of studies pertaining to gender differences in research impact and visibility, traditionally measured in terms of citations received, and more recently considering women's use of ASNs and social media. The often-claimed lower number of citations received by female-authored publications (Larivière et al. 2013; Maliniak et al. 2013; Caplar et al. 2017) has been contradicted several times by an equally large number of studies (Borrego et al. 2010; Kretschmer et al. 2012; Sotudeh and Koshian 2014). This can probably be explained by the complex mix of factors influencing patterns of citations as suggested by Tahamtan et al. (2016) who, on the basis of an extensive literature review, categorizes them in author-related factors, among which gender, age and race, as well as paper and journal-related ones. Similarly, when it comes to OA publishing, the so called OACA (Open access citation advantage) (Suber 2008; McCabe and Snyder 2014; Archambault et al. 2014; Piwowar et al. 2018), has not always been confirmed (Gargouri et al. 2010; Davis and Walters 2011), while a certain gain in visibility in social media does not always produce an increase in citations. Only recently has the gender dimension been introduced in a few studies outlining mixed, spotted effects on citations (Sotudeh et al. 2018) and social media visibility (Mikki et al. 2015; Dehdaridat and Didegah 2020).

There is still the necessity of collecting systematically sound sex-disaggregated data on a standard basis, encompassing demographic and career data, allocation of funding, as well as mobility and compositions of teams and scientific networks. The lack of large-scale, longitudinal analysis comparing data across countries is partially filled by the She Figures publications, released every three years since 2003, which provide a Pan-European evolution on Gender equality in Research and Innovation. It is interesting to note that in She Figures there is a gradual addition of indicators such as mobility during PhD, middle and senior career stages, part time/temporary employment, patterns of collaboration in same-sex or mixed-sex teams, which highlight some cumulative advantages influencing scientific performance. Specifically focused on publications, the recent reports by Elsevier (Elsevier 2017, 2020) also rely on a large scale, longitudinal, cross country comparison of published articles. Within the traditional distribution of publications by subject areas and countries, the report introduces a promising way of analysing productivity, distinguishing authors' short and long publication history as well as continuity of publications over time (thus overcoming the lack of demographic data not available in large databases). Moreover, the analysis considers authorship position,

grant awards, mobility (based on affiliation outside the author's country of origin), and collaboration patterns based on the affiliated co-authorship.

Both She Figures (European Commission 2019d) and the Elsevier reports (Elsevier 2017, 2020) reveal a certain overall progress in the ratio of women's to men's production in recent years, especially in some disciplinary fields (medicine and agriculture) and with regard to women with a short publication history. However, the collaboration approaches mirrored in internally co-authored articles as well as differences in mobility seem to bias women's scientific production.

## Materials and methods

The Web of Science was the data source for this analysis, as it represents one of the largest bibliographic databases, which include different types of scholarly outputs (peer-reviewed articles, books, conference proceedings, patents and data) in all disciplinary fields, thus covering the scientific results of a multidisciplinary research organization like CNR. Even if humanities and social sciences are underrepresented, especially as far as journal articles are concerned, the WoS is the data source used in many bibliographic studies and in particular in the ERA progress report to monitor the advancement of gender equality in Research and Innovation (Priority 4). Moreover, since 2017 the WoS has started indexing OA publications, indicating for each one the different types of OA versions available. This additional feature was implemented through a partnership with the non-profit organization "Our Research", which developed the Unpaywall database which gathers information on the different publication modes for more than twenty-five million articles (Clarivate Analytics 2019a, b). The benefits of using a single source for the analysis are, however, counterbalanced by some limitations. The first concerns the well-known WoS journal's selection criteria which restrict per se the coverage of scientific journals and even more journals listed in DOAJ. This means that our set of data does not fully represent the complete scientific production of CNR researchers and provides partial rates of their OA adoptions. The second limitation pertains to the Green OA route, retrieved in part by the WoS due to missing oaDOIs or to a partial harvesting of preprint archives and institutional repositories. However, the use of the WoS allows us to compare our analysis with the ERA progress report (Priority 5a), that relies on the WoS data to monitor the OA uptake.

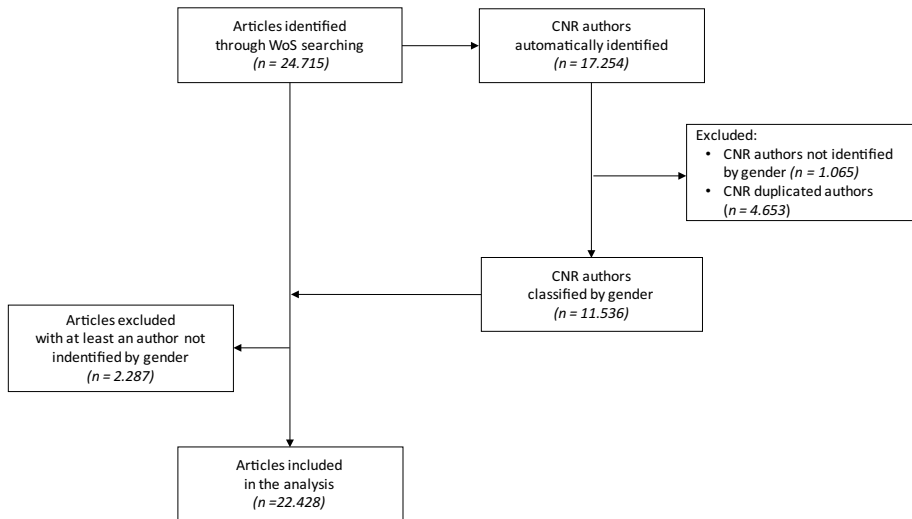
Data were gathered from the "Web of science core collection" which makes it possible to search for the author's affiliated organization in a specific field (i.e. Organisation enhanced) linking all possible variants of the organization name. In our case the search string Consiglio Nazionale delle Ricerche allowed us to retrieve the acronym CNR and its variants.

This bibliometric analysis focuses on journal articles, which are one of the main products evaluated in research quality assessment and also represent a good proxy for the OA adoption in the currently transforming editorial landscape. The analysis covers the publication years 2016–2018. Data were retrieved in October, 2019.

Figure 1 shows the flow diagram that summarizes the results of the WoS search to select the relevant articles produced by CNR as well as the steps to determine the author's biological gender.

We retrieved 24,715 articles published by at least one CNR author in the years 2016–2018. To identify the number of authors for each article, the WoS affiliation field was searched to distinguish CNR authors from those affiliated to other institutions. In case of





**Fig. 1** Flow diagram summarizing the WoS data retrieval

double affiliations, we prioritised the CNR, thus identifying 17,254 CNR authors. The next step was the author gender identification performed automatically<sup>5</sup> on the basis of their full names. Given the difficulties in coding gender at an international level, the classification by biological gender was performed only for CNR authors. For 1065 authors who were named in the WoS using only the initials of their first names, it was not possible to determine their biological gender, even via an additional search in the internal administrative CNR databases. Additional manual controls were performed to remove duplicate authors normalizing authors' names when they presented different variations. The resulting 11,536 authors classified by their biological gender were then associated with the produced articles, 2287 articles presenting not classifiable CNR author were discarded. The final set of our analysis was composed by 22,428 articles.

Many publications are multi-authored and the number of authors significantly differs across disciplines. The two most often-used methods to analyse multi-authorship are full counting and fractional counting (Korytkowski and Kulczycki 2019; Larsen 2008; Waltman and van Eck 2015). In the former each researcher receives full credit for the co-authored papers, while the latter permits a proportionally fractionalizing attribution of credits across all the contributing authors. Women's contributions in the multiple authors' articles was computed by applying the fractional counting on the basis of formula 1 which also balances the contributions of authors outside CNR collaborating for each article.

$$FI_i = \frac{f_i}{t_i} \quad (1)$$

<sup>5</sup> <https://www.nomix.it/>.



where  $FI_i$  is the Female Index, representing the women’s contributions in the publication  $i$ ;  $f_i$  is the number of female authors in the publication  $i$ ;  $t_i$  is the total number of authors in the publication  $i$  including also authors outside the CNR.

The fractional counting was applied in this paper firstly to capture the total number of articles with women as contributing authors adopting formula 2.

$$FI = \sum_{i=1}^n \frac{f_i}{t_i} \tag{2}$$

where FI is the Female Index;  $n$  is the total number of articles.

The Female Index computed using the formula 2 has been subsequently specified to capture the women’s contributions on the basis of the disciplinary field, the type of publication and the type of funding. In particular, to analyse gender differences of contributions in disciplinary fields, the five WoS subject categories (Clarivate Analytics, 2019a) were mapped into the six major fields of the FORD classification developed by the Organisation for Economic Co-operation and Development. The use of this classification makes it possible to compare our results with data available in She Figures. For articles published in journals belonging to more than one field of classification, we counted the articles in each relevant major field, thus applying a full-counting method computed on the basis of formula 3.

$$FI_x = \sum_{i=1}^{n_x} \frac{f_i}{t_i} \tag{3}$$

where  $FI_x$  is the Female Index for the discipline  $x$  (e.g. natural sciences);  $n_x$  is the total number of articles published in the discipline  $x$ .

This analysis was also performed considering the position of women in the list of all contributors taking into account the above-mentioned disciplinary fields. As previously reported, articles published in journals belonging to more than one field of classification were included in each relevant major field applying a full-counting method. In this case the female indexes were computed as the ratio between the number of publications with a female first and last authorship and the total number of publications with a CNR scientist in the first and last articles by-line.

Considering contributing authors in each discipline along with the OA publishing modes, the formula 4 was applied.

$$FP_x^y = \sum_{i=1}^{n_x^y} \frac{f_i}{t_i} \tag{4}$$

where  $FP_x^y$  is the Female Index for the discipline  $x$  (e.g. natural sciences) and the type of publication  $y$  (e.g. Gold OA);  $n_x^y$  is the total number of publications for the discipline  $x$  and type of publication  $y$ .

As in the previous analysis, the women’s attitude to adopting OA publishing was explored taking into account the first and the last author of each article. In particular, considering that conventions in author’s position on the by-line varies widely across disciplines and even in research groups, we chose to select articles published in journals classified in only one discipline. In this way we can obtain a possibly more homogenous subset for the analysis and limit the even more distorting effects which may derive from

articles published in multidisciplinary journals. The female indexes were computed as the percentage of articles with women as first/last authorship published in OA.

Finally, considering contributing authors in each discipline, OA publishing modes and the type of funding (i.e. European, Italian, other, no funding), the formula 5 was applied.

$$FI_x^{yz} = \sum_{i=1}^{n_x^{yz}} \frac{f_i}{t_i} \tag{5}$$

where  $FI_x^{yz}$  is the Female Index for the discipline  $x$  (e.g. natural sciences) and the type of publication  $y$  (e.g. Gold OA) and the type of funding  $z$  (e.g. European projects);  $n_x^{yz}$  is the total number of publications for the discipline  $x$ , the type of publication  $y$  and the type of funding  $z$ .

Considering the publication modes, besides the previously mentioned limitations, the WoS provides a nuanced, multiple classification which captures the OA status of the articles (Gold, Bronze and Green) and the multiple versions available in the Gold and Green categories. In this way, the changing status of OA articles over time is traced for instance in the category of *Green accepted* for the articles submitted to an institutional and/or disciplinary repository in the final peer-reviewed version, while the *Green published* category indicates its free availability as the final publisher version in an open archive. Moreover, the distinction between Gold DOAJ and other Gold, which reflects the so-called editorial market transition phase, identifies articles published in journals indexed in the DOAJ, while *other Gold* refer to articles published in traditionally closed journals which however host OA articles through a publication fee (APC). These journals are generally identified as Hybrid journals. Finally, a recently adopted classification, the Bronze one, identifies an in-between OA category that includes journals with no clear licence, which however provides articles free to read on the publisher website. In this case, no transparent information is provided on the article reuse and on permanent availability. For the purpose of our analysis, we maintained the Gold DOAJ category (hereafter called Gold), and aggregate Other Gold and Bronze in a new category called Hybrid. This distinction allows us to draw a cut-off line between the journals which adhere to OA principles and those that share only some attributes of openness. This solution is also based on the WoS multiple classification which never associates Gold DOAJ with Other Gold and Bronze, while other Gold and Bronze are often coupled together. Concerning the Green modes, we aggregated the Green published and Green accepted in one category (hereafter called Green), while we excluded the Green category when associated with the other ones. While this may lead to an underestimation of the number of Green articles, this solution makes it possible to identify virtuous attitudes towards OA in authors who publish in closed access journal, but provide free access of their articles in open archives.

Moreover, the WoS provides information on articles, which received funding. Although this information is not standardized, it was nevertheless possible to track and classify the different types of funding agencies and grants according to three broad categories: European, Italian and other funds. The first one includes articles resulting from European projects (FP7 Program, H2020, Marie Curie, ERC, and COST actions), while the Italian ones comprise funds provided by a varied set of governmental agencies at national, regional and local level as well as by a small number of private companies. In the third category there is a wide variety of funding, ranging from bilateral international agreements, most of them outside Europe to projects supported by international agencies, such as the World Health Organization, the National Science Foundation, NASA and NATO. In this category we also included articles funded by more than one project. However, when a European project

was reported along with other types of funds, we coded the article in the European funds, as a proxy indicator for the accomplishment of EU policy toward OA. Moreover, the gender perspective of this analysis is considered a proxy indicator for female access to funds as well as of participation in collaborating networks. As reported in several studies (Elsevier, 2017, 2020; European Commission 2019c), these aspects highly influence female scientific production.

## Results

The unit of analysis in this study is a set of 22,428 articles published by at least one CNR scientist. An overview of the main features of the selected articles is given in Table 1. The articles are written by 11,536 CNR researchers, most of whom are male (55.4%).

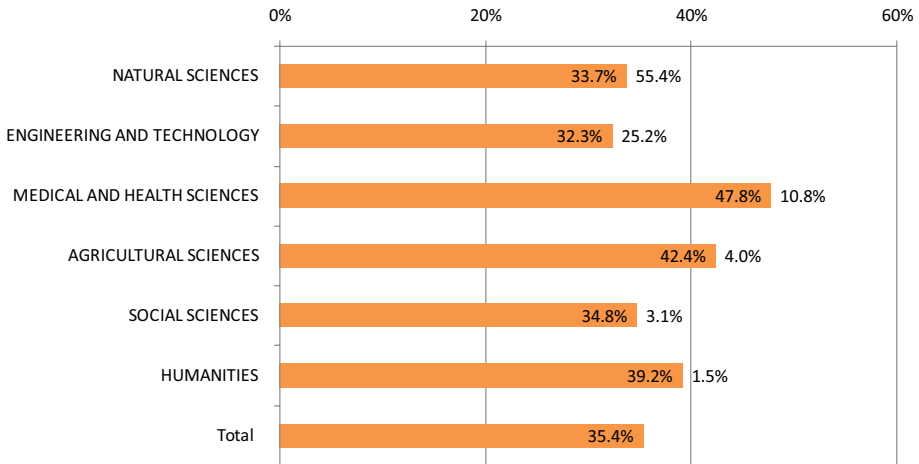
The majority of articles are signed by multiple authors (97.9%), while there is a small percentage of single author papers (2.1%), mostly produced by male researchers. On the basis of fractional counting, the number of articles with contributing authors outside CNR is 12,119.8, while the number of articles signed by CNR contributing authors is 6670.2 (29.7%) for men and 3638.0 (16.2%) for women.

**Table 1** Main features of the CNR articles retrieved in the WoS

	No.	%
<b>Authors</b>	11,536	
Men	6396	55.4
Women	5140	44.6
<b>Papers</b>	22,428	
<i>Contributing authors</i>		
CNR men	6670.2	29.7
CNR women	3638.0	16.2
Other institution	12,119.8	54.1
<i>Single author papers</i>		
Men	475	2.1
Women	378	79.6
Women	97	20.4
<i>Multiple author papers</i>		
2–5	21,953	97.9
6–10	8603	38.4
11–99	9530	42.5
≥ 100	3762	16.8
≥ 100	58	0.2
Extra-mura authored	19,259	85.9
Intra-mura authored	3169	14.1
Eu funds	5065	22.6
Italian funds	7952	35.5
Other funds	2737	12.2
No fund	6674	29.8
Oa	8046	35.9
Closed	14,382	64.1

**Table 2** Article’s contributing authors by gender and year of publication

Year	Men		Women		Total	
	No.	%	No.	%	No.	%
2016	2333.1	64.8	1266.2	35.2	3599.3	34.9
2017	2219.1	65.2	1183.2	34.8	3402.3	33.0
2018	2118.0	64.1	1189.6	35.9	3307.6	32.1
Total	6670.2	64.7	3638.0	35.3	10,308.2	100.0

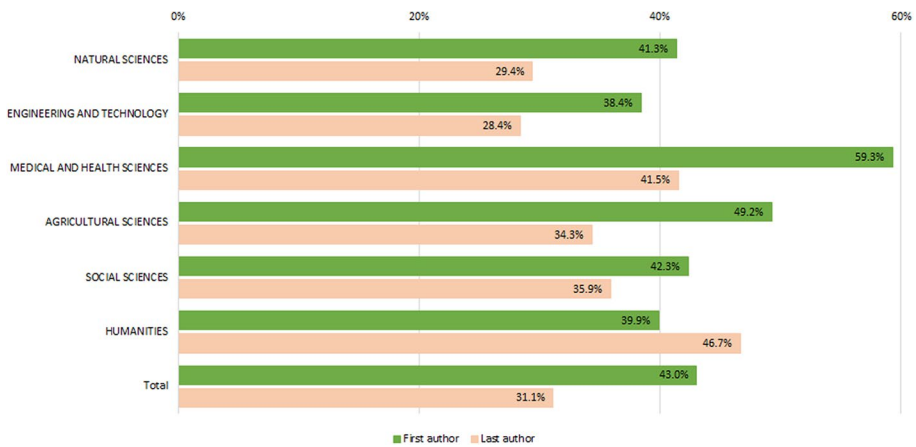


**Fig. 2** Articles by women as contributing authors by disciplinary fields

If we consider co-authorship, most articles are written by groups of authors ranging from 2 to 5 and from 6 to 10 (38.4% and 42.5% respectively). A small percentage of articles (0.2%) are written by more than a hundred scientists (up to 700), outlining the presence of hyper-collaborations in our set of analyses (European Commission 2019d). Where scientific collaboration is concerned, an article is considered extramural if at least one author does not have a CNR affiliation. Extramural collaboration is a good proxy to analyse propensity to collaborate (Abramo et al. 2013; Aksnes et al. 2019) and the results show that CNR scientists collaborate at large (85.9%) with extramural colleagues, both domestic and international.

Moreover, 70.2% of articles are published thanks to funds deriving from Italian projects (35.5%) followed by European (22.6%) and other international projects (12.2%). This is also considered a proxy for collaboration as well as an indication of access to external funds. Finally, 35.9% articles are published in Open Access. This percentage is lower than the national average (about 40%) considering data provided by the ERA report (European Commission 2019a) and the European Open Science Monitor (Open Science Monitor 2018).

Table 2 shows the distribution of articles (fractional counting) published by male and female CNR researchers as contributing authors in the 3-year period which was analysed. Given the aim of this analysis, the contributing authors with no CNR affiliation are not considered as far as gender distribution is concerned. Generally, the number of publications



**Fig. 3** Articles by women as first (green bars) and last (orange bars) authors and by disciplinary fields

slightly decreases from 2016 to 2018, with a maximum value in 2016 (34.9%). When contributing authors are considered, the number of publications differs significantly: men’s production (64.7%) is higher than women’s (35.3%). However, considering the distribution of results in the three years, while men’s contributions decrease from 2016 to 2018, the women’s show a slight growth (35.2% in 2016 vs. 35.9% in 2018).

To determine whether the gender gap in CNR scientific production is related to disciplinary fields, articles were classified in the six fields of R&D (FORD) (Fig. 2). In our sample the majority of articles are in the STEM fields (80.6%) followed by articles related to medical and health sciences (10.8%). A small percentage of them pertains to social sciences and humanities (SSH) (4.6%). This result depends on the WoS database which indexes a limited number of journals in these disciplinary fields (Chavarro et al. 2018; Martín-Martín et al 2018), but also reflects the fact that SSH scientific outputs are frequently published in books.

Considering differences among contributing authors, there is a high variability across disciplines. The lowest percentage of articles with women’s contributions is to be found in engineering and technology (32.3%) natural sciences (33.7%) and social sciences (34.8%). In humanities women’s contributions (39.2%) are slightly higher than the general value (35.4%). In agricultural and medical and health sciences the gender gap in the production of articles is significantly smaller, as shown in particular by the similar rates (47.8% vs. 52.2%) of the articles published by men and women as contributing authors in medical sciences. These results are in line with She Figures reporting that in the EU countries the average ratio of women to men was higher in the fields of medical and agriculture sciences (European Commission 2019) and confirm previous findings (Larivière et al. 2013) which indicate a higher number of women in disciplines associated with “care”.

To examine the gender gap in scientific production, articles with women as first and last authors (Fox et al. 2018) are analysed. These contributing roles imply both credit and accountability and are generally used as criteria to evaluate promotion and award grants as well as for the allocation of funds (Mauleón et al. 2013; Larivière et al. 2016; Lapidow and Scudder 2019). As shown in Fig. 3 women are generally more highly represented as first authors (43.0%), but less frequently as last authors (31.1%). This is in line with previous results (Macaluso et al. 2016). This trend is evident in all disciplines with the exception of

humanities, where the number of women as last authors is consistently higher than those in the first by-line position. Considering first authorship a significantly smaller gender gap can be found in medical and agricultural sciences, as shown by the relevant rates (respectively 59.3% and 49.2%). Along with social sciences, these disciplines also have relatively higher rates of women in last by-line position when compared to the other fields of study (respectively 35.9%, 41.5%, 34.3%). The lowest percentage of articles is in engineering and technology for women both as a first (38,4%) and a last name (28,4%). In disciplines related to medical sciences, it is generally a common practice to assign first author positions to early career researchers, while last authors tend to be senior researchers who coordinate and/or supervise the study and are sometimes responsible for funds (Helgesson and Eriksson 2019). Our results in medical and health sciences, which in our sample represent the discipline with more balanced women’s contributions, could confirm female discriminations when it comes to authorship and therefore visibility, probably biasing promotions and career paths. It is not possible to extend this hypothesis to all the other disciplinary fields in the absence of guidelines and norms that would ensure a common interpretation of authors’ role in the authorship position (McNutt et al. 2018; Fox et al. 2018). Nevertheless, a few studies in various disciplines, such as ecology (Fox et al. 2018) and STEM (Holman et al. 2018), highlighted the same tendency, but clearly additional analyses are required.

### Open access

In the data collected in the WoS the CNR articles available in Open Access constitute 35.9% and as, already mentioned, this percentage is lower than the national average (about 40%) (European Commission 2019a; Open Science Monitor 2018). This result is probably influenced by the institution’s limited support of Open Access policies as well as by a partial development of an OA-compliant institutional repository.

Considering women’s and men’s attitudes in publishing open articles (Fig. 4), a small difference indicates that articles with women’s contributions are published at a higher rate in OA (32.4% vs. 67.6%) compared to their male counterparts (31.4% vs. 68.7%).

The proportion of articles distributed by the different OA subtypes is similar both in women’s and men’s publications. Generally, Gold OA represents the most frequent option

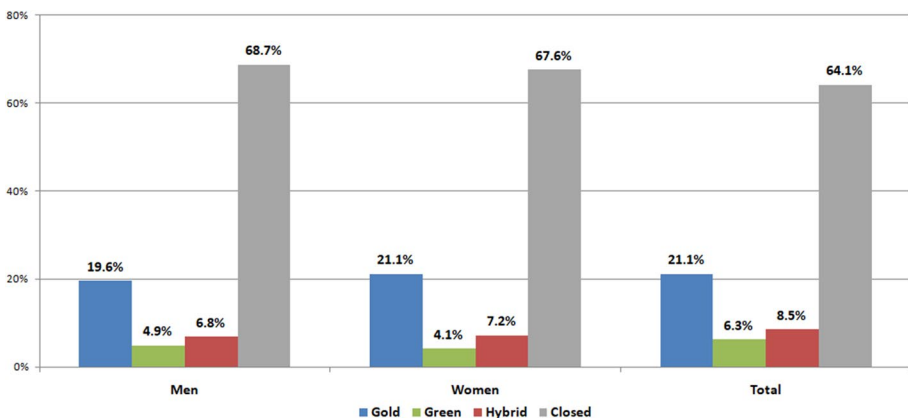
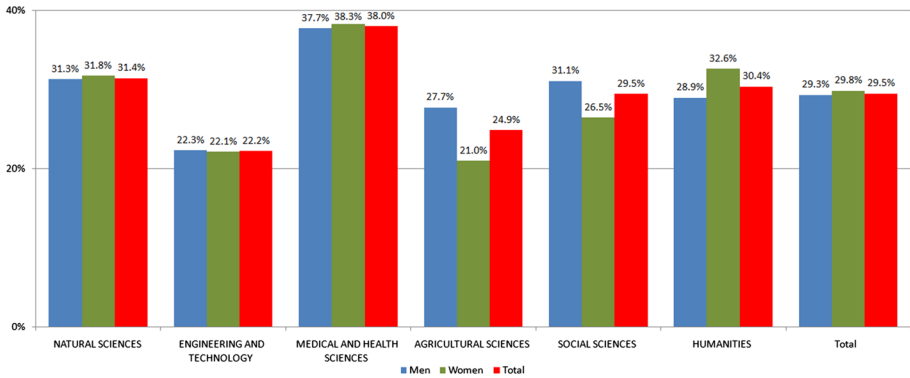
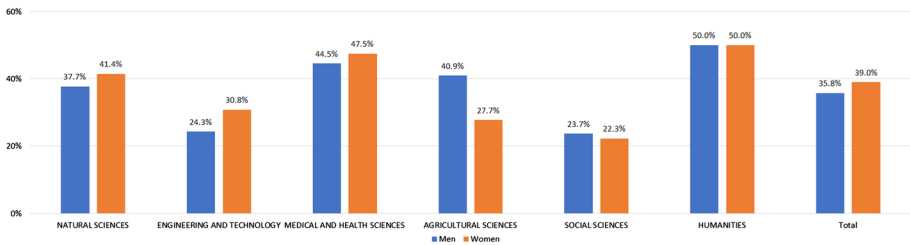


Fig. 4 Articles’ contributing authors by gender and publication modes



**Fig. 5** Articles' contributing authors by gender, OA and disciplinary fields



**Fig. 6** Articles' first authorship by gender, OA and disciplinary fields

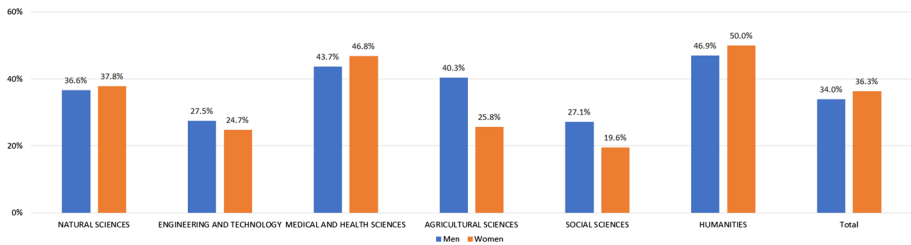
among subtypes with a percentage slightly higher in articles with women's contributions (21.1%) than in those with men's (19.6%).

Considering OA Hybrid and Green articles these values do not vary significantly. The percentage of articles published in Hybrid journals is slightly higher in articles with women's contributions (7.2% vs. 6.8%), while Green articles available in institutional and/or disciplinary repositories are on average higher in articles with men's contributions (4.9% vs. 4.1%).

Several studies (Bosman and Kramer 2018; Severin et al. 2020) underlined that practices and propensity to publish in OA correlate with research disciplinary fields. In our sample (Fig. 5) articles available in OA are more frequent in medical and health sciences (38.0%) followed by natural sciences (31.4%), confirming that these two disciplines have a leading role in adopting OA practices (Piwowar et al 2018; Martin-Martin et al. 2018; Science Matric 2018). Social sciences (29.5%) and humanities (30.4%) have similar values and are closed behind natural sciences. Particularly in humanities the results of our sample do not match with other studies (Bosman and Kramer 2018; Martin-Martin et al. 2018; Piwowar et al. 2018). The lowest ratio of OA publications is in engineering and technology (22.2%) tendentially closed disciplines (Severin et al. 2020). In agricultural sciences the proportion of OA outputs is very low (24.9%) in contrast with international results, which indicate some of their related sub-disciplines as particularly open (Open Science Monitor 2018).

Considering articles with both men's and women's contributions no relevant differences are shown in natural sciences, engineering and technology and medical and health





**Fig. 7** Articles' last authorship by gender, OA and disciplinary fields

**Table 3** Articles' contributing authors by gender, OA subtypes and disciplinary fields

	Natural sciences		Engineering and technology		Medical and health sciences		Agricultural sciences		Social sciences		Humanities	
	M	W	M	W	M	W	M	W	M	W	M	W
Gold	19.3	20.8	13.6	14.7	17.1	19.2	20.1	15.2	17.9	19.7	25.4	28.6
Green	5.1	4.0	3.9	3.1	6.5	5.8	3.2	2.0	6.7	5.1	1.9	2.4
Hybrid	6.8	7.0	4.7	4.3	14.1	13.3	4.5	3.8	6.4	1.6	1.6	1.6
Closed	68.7	68.2	77.7	77.9	62.3	61.7	72.3	79.0	68.9	73.5	71.1	67.4

sciences. In the other disciplines data are relatively varied: OA articles with women's contributions are quite high in humanities (32.6%), while in agricultural sciences the level of female openness is the lowest among all disciplines (21.0%). Moreover, in social sciences the women ratio is remarkably low (26.4%).

Looking at authorships, OA articles with women as first authors (Fig. 6) are slightly higher in natural science (Women: 41.4%, Men: 37.7%), engineering and technology (30.8% vs. 24.3%) and medical and health sciences (47.5% vs. 44.5%), while in Agricultural and Social sciences the rates are the lowest among all disciplines. A similar and quite high percentage of OA papers is present in humanities for both men's and women's first authorship. These results are partially confirmed considering the rates of OA articles with women in the last position (Fig. 7): a higher percentage of OA contributions is present in natural sciences (37.8% vs. 36.6%), medical and health sciences (46.8% vs. 43.7%) and in humanities (50.0% vs. 46.9%), while the lowest rates are in engineering and technology (24.7% vs. 27.5%), agricultural sciences (25.8% vs. 40.3%) and social sciences (19.6% vs. 27.1%). Moreover, there is a women's slightly higher propensity toward OA when considering the total number of papers (36.3% vs. 34.0%).

Table 3 focuses on the distribution of publications by the three types of OA publishing in the six FORD categories. Data highly vary across disciplines. Nevertheless, in all fields Gold OA is usually the predominant subtype with a percentage which is higher than the sum of Hybrid and Green OA. Moreover, in all disciplines the proportion of Gold OA articles with women's contributions is higher than those of men's, with the exception of agricultural sciences. Articles in Gold OA with women's contributions are relevant especially in two disciplinary fields: humanities and natural sciences. In the first one the percentages of OA Gold both for men and women reach the highest overall values (25.4% vs. 28.6%) compared to the other disciplines. Note that there is a relatively high percentage in both

**Table 4** Articles' contributing authors by gender, modes of publication and types of fund

FUNds	OA		Closed		Total	
	M	F	M	F	M	F
European	43.2	44.3	56.8	55.7	22.3	18.0
Italian	32.0	35.0	68.0	65.0	34.0	41.2
Other	36.2	38.4	63.8	61.6	8.3	6.4
No funds	21.9	21.9	78.1	78.1	35.4	34.4
Total	31.3	32.4	68.7	67.6	100.0	100.0

men's (20.1%) and women's Gold OA production (15.2%) in Agricultural sciences which in our sample are closed disciplines.

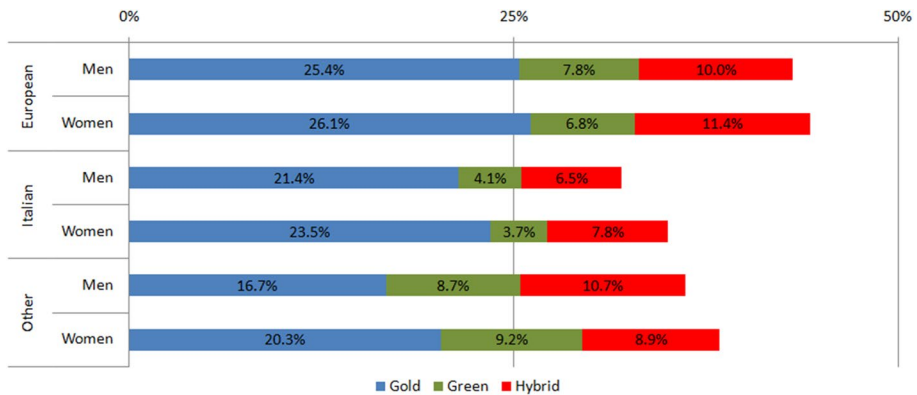
Moreover, for OA Hybrid and Green subtypes there are important differences among all fields. OA Hybrid presents the highest level in the medical and health sciences, while the lowest one is in humanities with similar ratio in men's and women's production (13.3% vs. 14.1% and 1.6% vs. 1.6%). Only in social sciences there is a completely different behaviour between male (6.4%) and female (1.6%) researchers in the adoption of OA Hybrid: articles with women's contributions have the lowest percentage compared to other disciplinary fields, which could presumably be connected with a limited access to funded research.

Finally, OA Green articles are in low proportion in our sample, probably mirroring the limits of the WoS in tracking repository submissions. They are relatively frequent in natural sciences, medical and health sciences and in social sciences. This is probably due to the availability of well-known and trustworthy disciplinary repositories (arXiv, PubMed central, SSRN etc.), which may drive researchers to consolidated common practices of self-archiving in these fields. Women's adoption of Green OA is lower than men's in all disciplines, except for humanities (2.4% vs. 1.6%).

### Funded articles

In this section the results of the analysis on articles published with different types of funds are reported as proxy for collaboration and networking as well as for access to funded research. Previous findings showed that women collaborate internationally to a lesser extent than men, resulting in articles with a lower number of co-authors (Elsevier 2020) and with a limited number of extramural collaboration (Abramo et al. 2019). All these factors influence female scientific production with a probable negative effect on career progression, or vice-versa may be the consequence of not having reached the appropriate professional rank, thus outlining a series of cumulative disadvantages (Elsevier 2017).

In our sample articles with both men's and women's contributions are generally published with funding support at similar rates (64.6% vs. 65.6%). However, articles with women's contributions (Table 4) receive less European funding than their male counterparts (22.3% vs. 18.0%) and this is true also for the other international funds (8.3% vs. 6.4%). The inverse situation occurs for articles funded by Italian agencies with 41.2% articles with women's contributions versus 34.0% of the men's production. This clearly suggests that CNR women scientists collaborate less than men at European and international level. These findings are coherent with the hypothesis that suggests there is a "glass fence" which limits female international mobility and their possibility of establishing collaboration with international colleagues (Elsevier 2017, 2020).



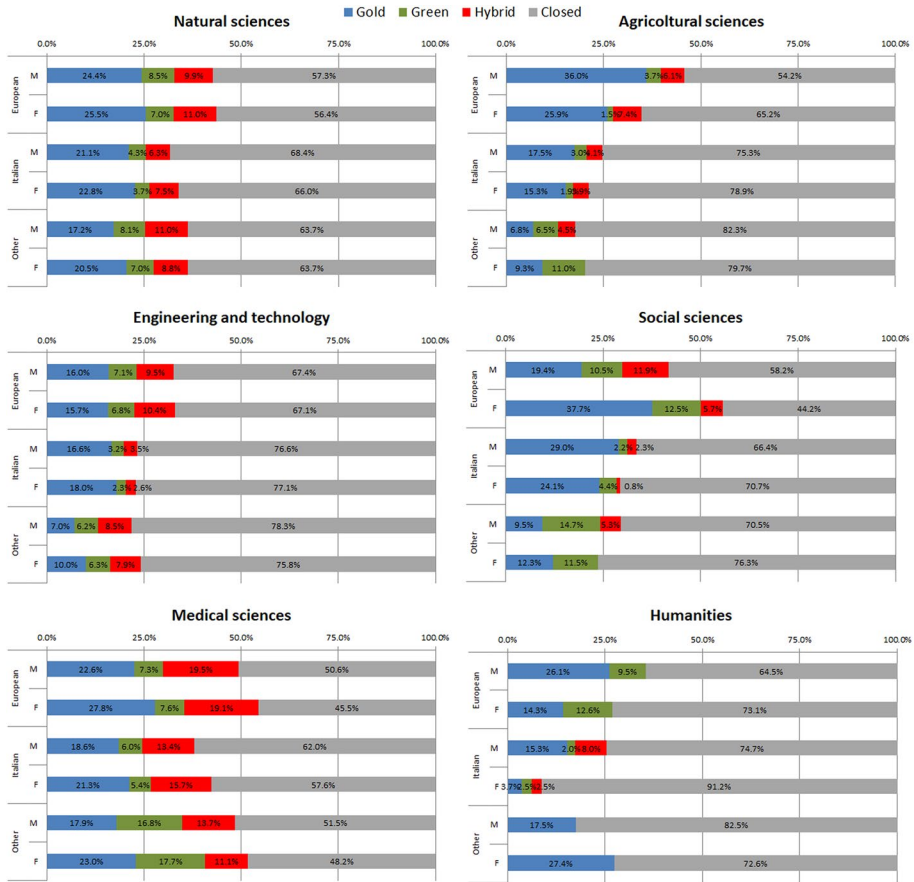
**Fig. 8** Articles' contributing authors by gender, OA subtypes and types of funds

The distribution of funded articles published in OA was analysed to explore, whether European Open Access mandate and/or specific supporting OA policies adopted by research institutions have an effect on OA practices. As previous detailed (cf. Figure 3), articles with women's contributions are generally published slightly more in OA (32% vs. 67.6%) compared to their male counterparts (31.3% vs. 68.7%). Interestingly, this is shown in all OA types of women funded scientific production and it is slightly higher in the European funded articles than in the other ones (44.3% vs. 43.2%). Articles supported by Italian agencies are generally accessible in OA to a minor extent, with differences in favour of articles with women's contributions (35.0% vs. 32.0%). This is probably due to a weak enforcement of OA at national level where only 24 research institutions have registered their OA policy in ROARMAP. Consider also that in 2013 CNR signed, along with other research institutions, a position statement on OA concerning research outputs. However, CNR policy toward OA is not fully enforced yet, the current registry of researchers' production has mainly an administrative function, thus limiting the visibility and access of publications to external users. Therefore, we suppose that OA practices could reflect a personal propensity toward OA along with attitudes depending on the disciplinary fields and related networking collaborations.

Moreover, other aspects have to be considered when analysing the relation between funded research and the choice of OA sub-types. In particular, two aspects should be considered: (a) the funder's OA policies and mandates, which differ in terms of OA routes (i.e. Gold and Green) and the timelines when beneficiaries need to provide OA, (b) whether funds may be used to pay APCs for publications. For instance, in Horizon 2020 APCs' costs are eligible for reimbursement during the duration of the project as part of the overall project budget.

Figure 8 shows the distribution of articles with both men's and women's contributions by OA subtypes and types of funds. For the articles funded by the European projects, gender differences among contributing authors are not relevant, presumably due to the EU robust OA mandate which specifies actions to implement OA.

On the contrary, analysing articles funded by other international agencies, the ones with women's contributions are higher than their male counterparts in Gold OA (20.3% vs. 16.7%) and less in Hybrid OA (8.9% vs. 10.7%). Green OA articles with both men's and women's contributions present the highest values (8.7% vs. 9.2%) in all types of funds.



**Fig. 9** Articles' contributing authors by gender, subtypes of OA, types of fund and disciplinary fields

These variations likely reflect the different OA policies and mandates enforced by financial funders included in this category.

In the articles published with the support of Italian agencies, the rate of Gold OA is significantly high considering the weak mandate toward OA, with a prevalence of articles with women's contributions (23.5% vs. 21.4%), underlying researchers' awareness and propensity to make their results available in OA. The proportion of Hybrid is quite low for both men and women, probably due to a lower degree of financial support by Italian agencies. A similar pattern is evident in Green OA for both men and women, representing the lowest rate compared to the other types of funds (4.1% vs. 3.7%) and probably reflecting the current CNR difficulties in implementing the OA Green route.

Looking at the distribution of funded articles by the three OA subtypes in the six FORD categories (Fig. 9) data vary highly across disciplines. For the European funded articles, gender distribution of OA subtypes shows similar values in natural sciences and engineering, while medical and agricultural sciences differences are highly marked: Gold articles with women's contributions have a higher rate in medical sciences (27.8% vs. 22.6%), while the opposite is shown in agricultural sciences (25.9% vs. 36.0%). In social sciences and

humanities men's and women's scientific production supported by external funds shows a particular scattered trend, especially if compared with STEM. The limited number of articles in these disciplines highly biases the analysis and does not allow comparability across fields, so that also outlier results such as the different percentage of articles published by men and women in Gold OA supported by European projects (19.4% vs. 37.7% in social sciences, 26.1% vs. 14.3% in humanities) should be considered with caution. The Green OA option is more often adopted by men as contributing authors across all disciplines, while the Hybrid OA shows the opposite pattern, with a prevalence of women's contributions. Medical and health sciences represent an exception in both Green and Hybrid modes.

Considering articles published with the support of other international agencies, differences are still remarkable. Women as contributing authors publish Gold OA at a higher rate in all disciplines, but with high variation among percentages ranging from 2 to 5. In Green OA there are only few cases in which gender differences are significant, such as in agricultural sciences (11.0% vs. 6.5%). Interesting to note is that Hybrid articles with women's contributions in agricultural and social sciences equal zero.

Finally, Italian funded articles also reveal different trends across all disciplines, but with small variations if we consider the distribution by gender. In Gold OA the percentage of articles with women's contributions is higher than their male counterparts in natural sciences, engineering and medical sciences. In Green OA the rates of articles with men's contributions are generally higher than the women's ones in all disciplines, while the Hybrid OA with women's contributions are higher in natural and medical sciences.

## Conclusion

The analysis of CNR scientific production provides a starting point in order to reflect on the inter-linkage between gender performance and Open Access adoption and their reciprocal synergies. We used a novel intersectional approach which considers gender disparities in scientific production constantly analysing it in relation to OA publication modes and disciplinary fields. This allows us to outline disciplines with minor gender gap in scientific production as well as those which tend to adopt the AO routes more extensively. Moreover, funds to support publication are also considered as interconnected factors which, on the one hand, influence the choice of OA publication and, on the other, are proxy indicators for participating in collaboration networks.

We conducted a bibliometric analysis based on 22,428 articles published by 11,536 CNR scientists from 2016 to 2018. We found that despite a similar percentage in men and women authors (55.4% vs. 44.6%), there are notable gender differences in production: articles with women's contributions are fewer than their male counterparts (35.3% vs. 64.7%). Although a gender productivity gap persists in some STEM research fields, in medical and agricultural sciences the ratio of women's production is the closest to parity, confirming a general positive international trend (European Commission 2019c; Elsevier 2017, 2020). In humanities, generally considered a male dominated field (Larivière et al. 2013), CNR women's performance is higher than in other international analyses (European Commission 2019c).

Although the overall percentage of CNR OA publications is less than the national one (35.9% vs. 40.4%), when looking at gender differences, results suggest that women researchers tend to adopt Gold OA slightly more than their male counterparts (21.1% vs. 19.6%), in all disciplines except agricultural science. This seems to be confirmed when

analysing women's position in article by-lines. Considering the overall percentage, women as both first as last authors tend to adopt OA modes more than men (39% vs. 35.8% in the first by-line position and 36.3% vs. 34.0% as last named-authors). Medical and health sciences show a particularly interesting example, as authorship order commonly mean that first authors are generally early career researchers, while last-named ones tend to be comparatively senior and/or in supervising positions. Therefore, we can presume that last authors have a say in choosing the publication mode. In our sample, although women are underrepresented as last author, they adopt OA modes more extensively than men (46.8% vs. 43.7%).

The influence of discipline-specific practices combined with publications supported by funds is evident especially in engineering and technology as well as in natural and medical sciences. In these research fields the adoption of open publication follows similar patterns among women and men, while in agricultural and social sciences and humanities, which do not present this mutual influence, the level of OA adoption varies both in terms of gender preferences and choice of OA subtypes.

Considering the prevalence of Gold OA articles among other OA subtypes in all disciplines, the proportion of articles with women's contributions is generally higher than their male counterparts. This is true in all research fields, except for agricultural sciences, in which the higher proportion of men's contributions is probably influenced by the high rate of EU funded articles which are prevalently written by men. Other factors should, however, be more fully explored when analysing the authors' choice of the Gold mode, which apart from funds, may be also related to subdisciplines' common practices and/or the availability of journals with a high Impact Factor.

The analysis of Hybrid articles is closely related to research funds, since the required APCs are generally higher than the Gold articles. They are often connected with a high Impact Factor and therefore relevant for career progression and scientific prestige. This is evident particularly in medical sciences and humanities seen as two opposite publication patterns. In the first one, Hybrid articles reach the highest values along with a substantial number of funded publications, while in humanities the lowest adoption of the Hybrid mode may be related to fewer research funded articles. This is in line with other international results (Solomon and Björk 2012). In terms of gender, there are no remarkable differences between women's and men's output, with the exception of social sciences, where the high number of Hybrid articles with men's contributions seem to relate to EU funded articles. However, this result may depend on the underrepresentation of this discipline in the WoS. Hybrid journals are worth analysing further to correlate their availability in each disciplinary field, Impact Factor, APCs cost with research funds and gender preferences.

Even if we chose to underestimate the Green route, the low percentage (4.0%) of the overall number of Green articles also has to take other aspects into account, such as the embargo period fixed by publishers, the so call "backfilling" phenomenon (Piwowar et al. 2018) which delays their availability in repositories. Probably, incentives to adopt the green route are determined by the presence of well-known, reliable disciplinary repositories as in the case of natural, medical and social sciences, which have the highest rates of Green articles compared to other disciplines. Among contributing authors, men generally tend to use the Green route more than women. Moreover, among funded Green OA, articles published with Italian grants have the lowest rates, probably reflecting the partial development of an OA-compliant institutional repository at CNR. It would be necessary to analyse the connection between Green articles and repositories in detail, as well as the policies adopted

at institutional and/or research funding level to better understand authors' attitudes towards choosing the Green route.

The European OA supporting policy, even if it does not cover all funded articles, has a beneficial effect on the availability of free-to-read publications with no gender differences also regarding the choice of OA subtypes. However, variations in OA adoption is remarkable across disciplines as well as among men's and women's contributions outlining a non-homogeneous trend, not ascribable to the openness of the research field. When considering articles funded by Italian and other international agencies women researchers have higher rates in choosing OA articles, confirming the women's propensity towards OA, especially if we consider the weak enforcement of the Italian and CNR OA policies.

Although the percentage of funded articles are similar for men and women researchers, differences in the types of grants show a prevalence of Italian funded articles with women's contributions. This partially confirms that women tend to collaborate less than men at an international level, probably due to mobility constraints which may limit collaboration. Of course, a more limited access to well financed and large collaborating networks usually connected with international projects may negatively influence women's scientific production.

In conclusion, our results suggest that discipline-specific publishing practices together with funding support positively influence the adoption of OA. When these interconnected factors converge in disciplines where the gender performance gap is smaller, a propensity to Open Access is shown, especially in women as contributing authors. This is true in particular in medical and health sciences, which are disciplines with a well-established culture of openness, availability of OA journals and repositories, strong support by funding agencies. In this case women researchers choose the open option for their publications to a larger extent than men. This identifies a positive dynamic which needs further analyses to explore whether these concurrent factors have a beneficial effect on gender productivity.

In the future we intend to integrate the analysis of gender production at CNR with demographic, career and mobility-related data to further explore factors shaping OA publishing practices and their mutual relationship. In this way we can further contribute to the CNR Gender Budgeting and Equality Plan, hoping to provide input for the development of CNR strategies to achieve gender equality. In our view, OA as well as Open science's transparency and inclusive principles can contribute to increasing women's scientific production and visibility. Therefore, at present, our descriptive analysis intends to encourage CNR to strongly support OA both reinforcing its commitment and improving the institutional repository. This can enhance visibility of overall scientific production, included but not limited to women. Moreover, the forthcoming Gender Budgeting and Equality Plan should foresee gender positive actions to support women's participation in international projects also in terms of improving their work-life balance.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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