



Improving our understanding of open access: how it relates to funding, internationality of research and scientific leadership

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Abstract

As open publication has become a goal in scholarly communication, interest in how it relates to other features of the research process has grown. This paper focuses on the relationship between funding and open access (OA) in the Spanish National Research Council's Web of Science publications in three scientific fields with different research practices, namely, Biology & Biomedicine (BIOL), Humanities & Social Sciences (HSS) and Materials Science (MATE). Firstly, the three fields are characterised in relation to OA practices (OA status and OA routes) and acknowledged funding (funding status and funding origin). Secondly, the relationship between OA and funding is explored, and the role of additional influential factors, such as the internationality of research and national/foreign leadership of papers, is unravelled through logistic regression. BIOL shows a higher OA share (66%) than do the other two fields (around 33%). Funded research shows higher OA rates than unfunded research in the experimental fields, but not in HSS, where it is related to a shift towards more publications with article-processing charges. The internationality of research, measured through international collaboration or foreign funding, increases OA, albeit with differences across fields. Foreign-funded papers are more likely to be led by foreign researchers in all three fields, but a foreign first author increases the chances of OA publication in HSS only, perhaps because Spanish leaders in this field have not internalised the importance of OA. The research's policy implications are reviewed.

Keywords Open access · Research funding · Internationality · Leadership · Web of science

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Introduction

The so-called Open Access (OA) era started in the early 2000s. It was originally driven by the desire to enhance knowledge dissemination and make research results more accessible to both researchers and the public, a development that should ultimately contribute to the advancement of science. At the same time, however, the need to reform the traditional publishing model became evident in a number of respects. First, the traditional model was called into question due to the exponential increase in publication purchasing prices, which many libraries could not afford to pay (see, for example, Schiermeier & Mega, 2017); second, electronic publishing began transitioning towards a new model taking advantage of the technical possibilities of the Internet to reduce costs and improve knowledge dissemination (Solomon & Björk, 2012a). The combined influence of all these factors provided a breeding ground for the development of the OA movement.

Although the OA publication model met with only modest acceptance at first, it has been gaining ground among authors and publishers over the last decade, and an increasing volume of publishers currently offer some type of open-access option. One sign of the movement's scope is the fact that the number of OA journals covered by the Directory of Open Access Journals (DOAJ) has risen from around 20 in 2002 to more than 18,000 in 2023 (doaj.org). Moreover, the percentage of OA papers included in the Web of Science Core Collection has trended firmly upward from 17% in 2000 to 50% in 2020 (as shown by a search carried out in February 2023; see Table 4 in Appendix).

Increased adoption of the OA model has been driven by numerous policy initiatives, since many funders, institutions and organisations worldwide have developed policies and infrastructures to promote the open availability of scholarly articles (Huang et al., 2020; McKiernan et al., 2016; Pinfield et al., 2016). Some funders, such as the National Institutes of Health in the United States and the Wellcome Trust in the United Kingdom, have developed strict OA mandates-sometimes even including sanctions for non-observance- and have achieved high rates of compliance (Lariviere & Sugimoto, 2018). In Europe Plan S was launched in 2018 by cOAlition S (coalition-s.org) to seek open publication of publicly funded research; it provided important support for the OA movement. An interesting overview of the most important initiatives and platforms from around the world to support OA research dissemination can be found in a recent paper by Simard et al. (2022).

In the OA publication model, papers are available through different routes. The first distinction drawn was between “green” OA (self-archiving) and “gold” OA (published in OA journals) (Harnad et al., 2008). Papers published in OA journals are freely available from the publisher's website, and very often publication costs are borne by the authors through payment of article-processing charges (APC). However, some gold open-access journals do not charge authors or readers any publication fees; these journals are mainly funded by societies, academia or government bodies, which cover the publication costs (this is also known as the “diamond” route) (Bosman et al., 2021). “Green OA” refers to papers that are self-archived by parties other than the publisher, usually the authors themselves, in open institutional or subject repositories (Science-Metrix, 2018). Further OA subtypes or routes have been described, such as “hybrid” and “bronze”. The “hybrid” route corresponds to toll-subscription journals that offer the possibility of making an article freely available if the authors or their institutions pay an APC (Prosser, 2003). Lastly, “bronze” articles are free to read on the web but do not have a licence that guarantees the reuse of their contents; moreover, readers have no way of knowing if the articles are openly available temporarily or permanently (Piwowar et al., 2018).

The OA model based on APC payment has grown rapidly in recent years and is applied in both gold and hybrid journals. Although journals that do not require APC payment are currently predominant in the Directory of Open Access Journals (70% in 2022, Morrison et al., 2022), APC-based journals are gathering an increasing number of OA articles, rising from 56% in 2015 to 69% in 2021 (Crawford, 2022). Simultaneously, an increasing number of traditional subscription-based journals are moving towards a hybrid model (Zhang et al., 2022). The literature suggests that APC values vary by discipline, publisher, OA status and journal impact. Thus, APCs for publication tend to be more expensive in life sciences and health sciences and less costly in social sciences and humanities; similarly, they are more expensive for commercial publishers than for societies/universities, they are more expensive for hybrid journals than for pure gold journals (50% higher according to Maddi & Sapinho, 2022), and they tend to increase with citation impact (Budzinski et al., 2020; Demeter & Istratii, 2020; Morrison et al., 2022; Schönfelder, 2020; Solomon & Björk, 2012b).

Compared with the traditional subscription-based model, the APC-funded OA model transfers the role of funding publications from the subscriber (essentially, university libraries) to the author. To cope with APCs, authors rely on different funding sources, mainly research grants and institutional funding and, more recently, campus or library funds (Solomon & Björk, 2012a; Tenopir et al., 2017; Teplitzky & Phillips, 2016). However, the use of personal funds has also been described, mainly for journals with lower charges and for authors from low-income countries (Solomon & Björk, 2012a).

At all events, it is clear that APC payment is a barrier to publishing and that this barrier is not equal for all. The risk of creating inequalities in researchers' ability to publish has been pointed out: researchers from high-income countries, institutions or teams are in a better position to afford APCs (Smith et al., 2021). To address inequality among countries, some publishers offer the option of reduced fees or full-fee waivers for low-income countries. Moreover, institutional or library funds could be used to reduce the disadvantage encumbering the more poorly funded researchers in a given institution. Having said that, inequalities do persist, and the APC-based publishing model is being called into question by many authors, who consider it is likely to "perpetuate inequalities in knowledge production" (Demeter & Istratii, 2020). Academics from low-income countries and from less-experimental disciplines voice the most negative perceptions of the APC-based publishing model, since they feel it prevents them from publishing in high-impact APC-charging journals (Segado-Boj et al., 2022; Tenopir et al., 2017).

The relationship between open access and paper funding characteristics is, then, a subject of considerable interest. Some paper funding characteristics can be gleaned from publication funding acknowledgements. A number of studies in the literature have shown that funded articles are more likely to be OA than unfunded articles in certain disciplines (Morillo, 2020; Wang et al., 2015) and in certain institutional sectors (De Filippo & Mañana-Rodríguez, 2022). Moreover, a study on Life Sciences observed a greater percentage of grant-funded articles in APC-based journals than in free OA or subscription journals (Wang et al., 2015), which suggests that non-funded scientists may encounter difficulties in dealing with publication costs. Interestingly, international collaboration has been linked to increased OA paper availability (Iyandemye & Thomas, 2019; Morillo, 2020), probably because international collaboration is liable to facilitate access to economic resources and help investigators afford open-publication costs. Accordingly, it seems that the internationality of research, as measured through foreign funding and/or foreign partners, might be associated with higher OA. Moreover, new questions arise about hitherto little-explored aspects, such as to what extent funding is provided by foreign partners in internationally co-authored papers, how often foreign-funded papers are led by a foreign leader (under the

hypothesis that scientific and economic leadership very often go hand in hand) (Cunningham et al., 2014) and whether the origin of funding and the origin of the research leader influence the likelihood of the article's being OA.

This research analyses the relationship between paper funding and open availability in the scientific output of the Spanish National Research Council (*Consejo Superior de Investigaciones Científicas/CSIC*), the main research institution in Spain, in three scientific fields with different research practices. Firstly, an overview of the three fields is provided, with a characterisation of each field's behaviour in terms of OA practices and acknowledged funding. Secondly, the relationship between OA and funding is explored, and the role of additional influential factors, such as the internationality of the research in question, is examined to gain a deeper insight into how funding contributes to the open availability of papers.

Objectives

The following research questions are addressed in this paper:

- RQ1:** As funding agencies are increasingly demanding that authors publish in open access, we would expect a higher percentage of OA in funded research. Is this assumption confirmed at CSIC? Moreover, is there any relationship between a paper's funding status and the OA route used for its dissemination?
- RQ2:** Is research internationality, measured through the presence of either international collaboration or foreign funding, associated with a higher percentage of OA articles?
- RQ3:** A few issues are examined in the case of internationally co-authored papers: How often is funding provided by foreign sources? Are papers funded by foreign sources more likely to be led by foreign researchers? Are foreign-led papers more likely to be OA? We hypothesise that funding origin may have a decisive influence on who leads the research and ultimately the likelihood of the paper's being OA.

Methodology

The study focuses on CSIC's scientific output in the Clarivate Analytics' Web of Science (WoS) database¹ from 2014 to 2018. The data download took place in February 2020. Research institutes at CSIC are organised into eight scientific fields, which are further grouped into three broad areas: Life, Matter and Society. This study analyses one field from each of these areas, namely, Biology & Biomedicine (BIOL) from Life, Materials Science (MATE) from Matter and Humanities & Social Sciences (HSS) from Society. The method of whole counting is used to calculate the number of publications by field. The overlap between fields is very small: 60 papers are allocated at the same time to BIOL and MATE, and three to MATE and HSS, while there is no overlap between HSS and BIOL. Only

¹ The Science Citation Index Expanded (SCIE), the Social Sciences Citation Index (SSCI) and the Arts & Humanities Citation Index (AHCI) are included in this study.

articles and reviews written in English are considered, since WoS records funding for English-language papers only (Álvarez-Bornstein et al., 2017).

Articles are studied in terms of OA status and OA type, presence and type of funding disclosed by authors and national/foreign research leadership.

OA characteristics of articles

Information on the OA situation of articles is provided by WoS as a result of its partnership with *OurResearch* (previously *ImpactStory*), a nonprofit organisation that has developed a knowledge base of open-access content (<https://ourresearch.org/>). We distinguish between OA status (OA or non-OA) and OA type, which includes the following categories:

- **Gold:** articles published in an OA journal that is indexed by the Directory of Open Access Journals. All journals publishing articles labelled as “gold OA” in WoS were searched for in DOAJ to ascertain if they were charging APCs and the amount involved. A distinction was made between journals that charge for publication (“gold APC journals”) and those that do not (“gold non-APC journals”, also known as diamond journals in the literature). A small number of journals not found in DOAJ were searched for on the web to collect information about their OA status and APC data. Only three journals, which published one paper each, were not found; their papers were excluded from the APC-related analyses.
- **Hybrid:** articles published in a subscription journal which are free to read under an open licence, in exchange for an APC paid by the authors.
- **Bronze:** articles free to read on the publisher page, but without an identifiable open licence.
- **Green:** a freely accessible version of an article located in an OA repository. Only peer-reviewed versions legally hosted in open repositories are covered by WoS (<https://clarivate.com/webofsciencegroup/solutions/open-access/>). WoS distinguishes between “green accepted” and “green published” versions, but both are labelled as “green” in this study. It should be noted that “green submitted” was not collected by WoS at the time of this study.
- **Closed or non-OA articles:** articles published in a subscription journal which are not free to read.

Around 40% of the articles had only one OA type, while 59% had two types and 1.5% had three types. Among the articles with more than one OA category, the most frequent finding was the simultaneous assignment of green and another OA type. However, OA categories are treated as mutually exclusive in our study, so that publisher-hosted content is prioritised over self-archived content. Thus, if different OA types are assigned to a given article, they are prioritised in the following order: gold, hybrid, bronze, green. The overlap between green and the rest of categories is analysed separately to throw light on this aspect.

“APC” is the fee for the publication of an open-access article in an open-access or hybrid journal, and it is usually paid by the author or the author’s funding body or institution. Journals publishing articles labelled as “gold OA” in WoS were searched for in DOAJ to collect data about their APCs in December 2021. Although the APCs were collected in DOAJ using different currencies, the price in euros was used. APCs in other currencies were converted into euros (<https://www.infobolsa.es/>).

The APC-processing procedure laboured under two limitations. First, in some cases the journal's open-access status had changed between the article's publication year and the date when the search was conducted in DOAJ. When this happened, the open-access status of papers at the time of the WoS data download was respected. Second, APCs values may vary over the years (Maddi & Sapinho, 2022), and as a result the charges recorded might be higher than the charges paid by the authors at the time of publication. We were unable to determine from the web sites what the APC was in an article's publication year, but this was not an important limitation since we were not interested in absolute values but in comparisons among fields, and these remained valid in spite of the time lag.

Funding data

Funding data were obtained from the "Funding Acknowledgement" (FA) section of WoS papers. The agencies included in the "Funding Agency" section were normalised and classified with an application created for this purpose (Morillo & Alvarez-Bornstein, 2018). Funding sources were coded, so that each agency was given an identifier number containing information about its origin (national or foreign).² Occasional funding sources (in three or fewer articles) were assigned a code identifying their national or foreign origin without attempting to identify specific funders, as this information was not needed for our purposes. Funding origin was left undetermined in a very low percentage of articles (see Table 5 in Appendix). Each field's funding rate, that is to say, the percentage of articles with funding acknowledgements, was obtained. We distinguished between funding status (funded or unfunded) and funding type (categories by national/foreign origin of funding).

While funding acknowledgements have been recorded in the Science Citation Index since 2008, they have been recorded in the Social Sciences Citation Index only since 2015 and in the Arts & Humanities Citation Index since 2017. To address this limitation, only papers published in years with FA coverage in WoS are analysed in this study.

Scientific leadership

We consider that the first author of a paper is the principal or lead author of the research, since he/she is the author who makes the greatest overall contribution (Lariviere et al., 2016) and very often appears as corresponding author as well (Yu & Yin, 2021). We decided to focus on the first author as opposed to the last author or the corresponding author, who also play a key role in papers, because that is the position on whose importance there is the greatest consensus. While it is true that the last author is the group leader or "senior" author in some disciplines, in others the last author is the author who contributed the least to the paper (if authors are ordered by degree of contribution) (Tscharntke et al., 2007). The corresponding author was originally the person responsible for communicating with the journal during the publication process, and the role of corresponding author is increasingly attributed seniority or leadership significance, but there is no global consensus across countries and disciplines about these additional functions (Willems & Plume, 2021).

² The number of funding sources identified was 609 in BIOL, 450 in MATE and 76 in HSS. They were organised in a thesaurus that lists funders by country and considers four levels of hierarchy.

In the light of the above, internationally co-authored papers are considered nationally or foreign-led depending on the geographical address of their first author. If the first author comes from an institution located in Spain, the paper is considered nationally-led, while if the first author comes from an institution outside Spain, the paper is considered foreign-led. We are aware that we have to assume a certain margin of error in identifying leadership through the signature position. However, some facts do validate our approach: it has been found that the first and last authors have the same address -and therefore, the same country- in many articles (Mattson et al., 2011), and, according to Yu and Ying (2021), the first author's country is the same as the corresponding author's country in over 95% of papers.

We have focused on internationally co-authored papers to explore whether papers with foreign sources are more likely to be led by foreign researchers and whether foreign-led papers are more likely to be OA. Although we cannot ascertain who pays the cost of publication when APCs are required, some studies suggest that the first author or the corresponding author most frequently bears this cost (Gumpenberger et al., 2018). If so, the publication costs would more likely be paid by foreign funding in the case of a foreign first author.

The first author's institution of origin could not be identified in around 2% of HSS and BIOL articles and 1% of MATE articles; these papers were left out of analyses concerning this point. The first author claimed double affiliation (affiliation with a Spanish institution and a foreign institution at the same time) in 8% of HSS articles, 6% of BIOL articles and 9% of MATE articles. In such cases, priority was given to the foreign address.

Statistical methods

In order to respond to the research questions posed in this paper, different statistical analyses were performed using SPSS (version 25).

First, a correspondence analysis was used as an exploratory method to examine the associations among variables and produce a biplot, which provides a visual display of associations. We considered the following three variables: field; funding type (three categories: unfunded, national funding only and foreign funding); and OA type (six categories: gold APC, gold non-APC, hybrid, bronze, green and closed). The data were normalised using symmetrical normalisation in order to be able to compare rows to columns.

To study whether there were significant differences between variables, the Chi-squared test was used for categorical variables, and the Mann–Whitney test, for continuous variables (non-parametric distributions). For each statistical test, the differences were considered significant at $p < 0.05$.

Last of all, a logistic regression analysis was applied to explore to what extent different variables helped explain papers' OA status (dependent variable). OA status is a categorical variable with two possible outcomes: OA and non-OA. Independent variables included: (a) variables related to collaboration: number of authors, collaboration type (three categories: one centre, national collaboration only, international collaboration)³ and collaboration with specific top publishing countries (USA, UK, Germany, China) (four dummy variables); (b)

³ Articles with both national and international collaboration were placed in the international category.

Table 1 Number of articles and main data on funding, OA and collaboration by field

	HSS	BIOL	MATE
# Articles	924	8355	7707
# Articles with FA	684 (74.03%)	7767 (92.96%)	7273 (94.37%)
FA type (%)			
No FA	26.23	7.06	5.66
National FA only	34.54	25.59	24.98
Foreign FA	39.23	67.35	69.36
# OA articles	309 (33.44%)	5555 (66.49%)	2670 (34.64%)
OA type (%)			
Gold non-APC	3.79	0.48	1.69
Gold APC	8.33	30.51	8.90
Hybrid	3.35	7.41	3.65
Bronze	4.00	20.86	4.40
Green only	13.96	7.22	16.01
Closed	66.56	33.52	65.36
Collab. type			
No collab	113 (12.23%)	695 (8.32%)	622 (8.07%)
Nat. collab. only	291 (31.49%)	3111 (37.24%)	2102 (27.26%)
International collab	520 (56.28%)	4549 (54.45%)	4984 (64.67%)

journal features: first quartile journal⁴ (0/1) and Spanish journal⁵ (0/1); (c) funding type (three categories: unfunded, national only, foreign)⁶; and (d) origin of leadership (two categories: national, foreign). The number of institutions was not included in the model due to multicollinearity problems. A stepwise regression (forward selection) was run to maintain only relevant variables in the model.

Results

From 2014 to 2018, CSIC scientists published 52,201 articles in WoS. The output limited to the three fields analysed in this study was 1076 articles in Humanities and Social Sciences, 8355 in Biology & Biomedicine and 7707 in Materials Science. Eliminating 152 HSS papers published in AHCI or SSCI journals in years without FA coverage left 924 HSS papers eligible for our study. Around 93–94% of the publications in BIOL and MATE were funded, while 74% of those in HSS included funding acknowledgements (Table 1). Around one third of the publications were OA in HSS and MATE, while 66% were OA in BIOL. The OA share trended upward over the years, rising from 27% in 2014 to around 38% in the last year of the period in HSS and MATE, and from 61% in 2014 to 70% in 2018 in BIOL.

Table 1 shows striking differences between fields in terms of funding type and OA type. Whereas HSS is characterised by a high percentage of unfunded papers (26% vs. less than

⁴ Journal whose impact factor is within the top 25% of its category (JCR).

⁵ Spanish journals were identified through the publisher’s country as described in WoS.

⁶ Articles with both national and foreign funding were included in the foreign category.

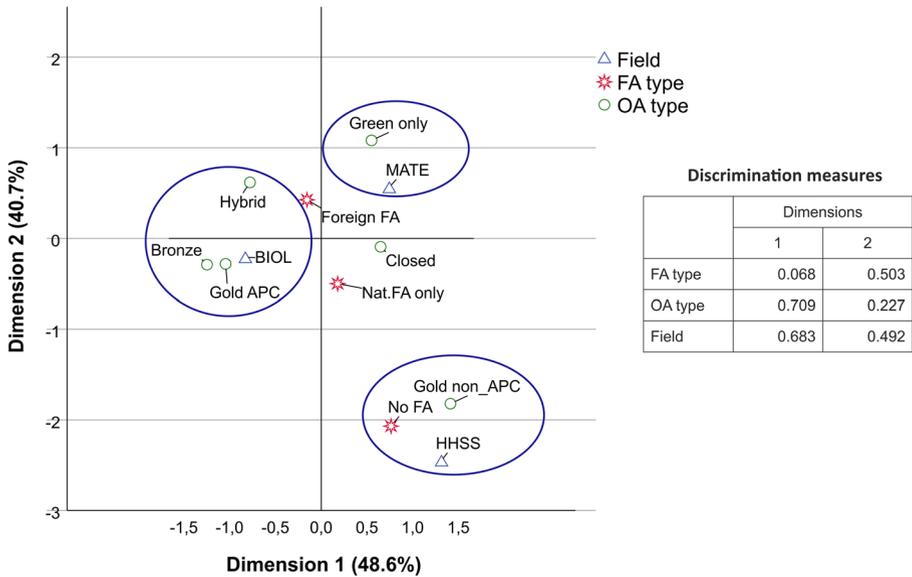


Fig. 1 Multiple correspondence analysis map showing field, FA type and OA type

10% in the experimental fields), BIOL and MATE stand out for their high presence of foreign funding (whether alone or together with national sources). “Green only” was the most frequent OA type in HSS and MATE (around 15%), while gold accounted for a high number of papers (31%) in BIOL, where bronze was also high (21%).

Correspondence analysis was used to facilitate the visualisation of the associations among three variables: field (HSS, BIOL, MATE), funding type (unfunded, national funding only, foreign funding) and OA type (gold APC, gold non-APC, hybrid, bronze, green only, closed). Two dimensions account for 89% of the total variance explained by the model. The distance between any row points or column points gives a measure of their similarity; hence, points that are mapped close to one another have similar profiles, whereas points mapped far away from one another have very different profiles.

OA type contributes heavily to dimension 1, funding type shows high discriminating values in dimension 2, and field attains quite high values in both dimensions (see table on the right of the chart). As can be seen at the bottom right of the plot in Fig. 1, HSS is characterised by a high share of unfunded papers and high values of gold non-APC. On the left is BIOL, with high percentages of bronze and gold APC papers. MATE, which appears at the top right-hand side of the plot, is characterised by a high percentage of green only papers. The labels “national FA only” and “foreign FA” lie quite close to the origin, which means they are less discriminating.

Two findings concerning OA type are particularly interesting. Firstly, based on the data in Table 1, one would be tempted to deduce a lower tendency to self-archive in BIOL, since green only papers are much less frequent in BIOL than in the other two areas. That is not the case, however, looking at all green papers (including those assigned to more than one OA type), 81% of OA papers in HSS and around 86% of OA papers in BIOL and

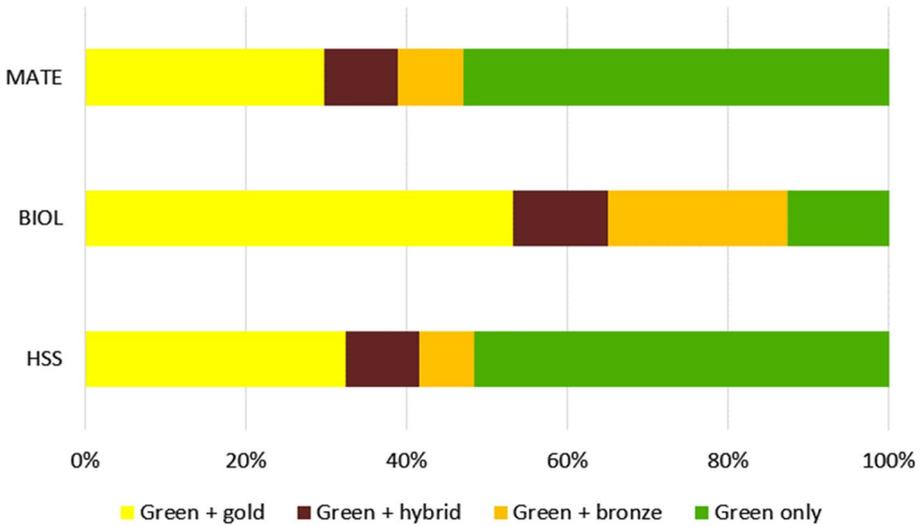


Fig. 2 Types of green OA papers by scientific field

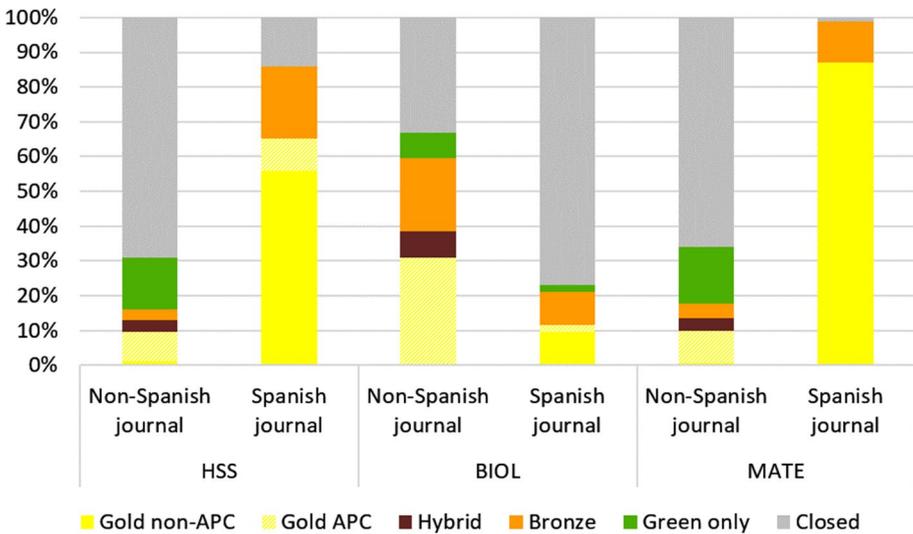


Fig. 3 Distribution of articles by OA type and domestic/international journal origin

MATE are available through the green route.⁷ The OA patterns of BIOL and the other two fields show considerable differences. Papers that are only self-archived account for more than half of the green papers in MATE and HSS, versus just over 10% in BIOL. Using

⁷ If calculated with respect to the total number of papers, 57% of papers were self-archived in BIOL vs. around 30% in MATE and HSS.

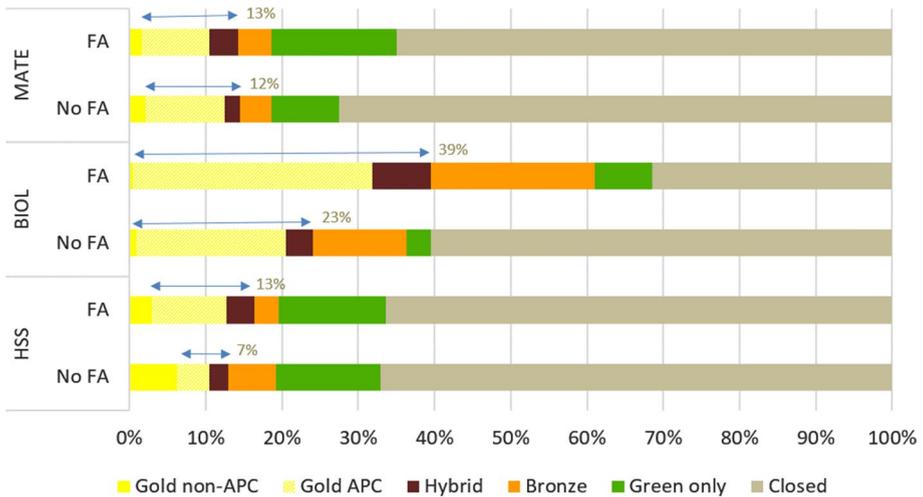


Fig. 4 OA type by article funding status and scientific field. Note: the arrows inside the figure show the percentage of articles published through the payment of APCs (gold APC + hybrid)

various routes simultaneously seems to be the norm in BIOL, where the most frequent practice (in about half of the green papers) is the self-archiving of articles also published via gold (Fig. 2). Interestingly, the share of papers using more than one OA route increases over the years, especially in HSS and MATE.

The second aspect of note concerns the use of the gold route in the different fields. Gold papers account for 12% of all publications in HSS, 11% in MATE and 31% in BIOL. While gold APC is predominant in all three fields, it is especially so in BIOL, where it accounts for 98% of gold papers (vs. 61% in HSS and 84% in MATE). The greatest use of gold non-APC is observed in HSS, as was previously noted in Fig. 1. Since we wondered whether this might be related to the greater use of Spanish journals in this field, the distribution of articles by OA type and domestic/international origin of journals is shown in Fig. 3. Interestingly, the OA pattern of publications in Spanish journals differs from that of other publications, although results should be taken with caution due to the low number of articles published in Spanish journals.⁸ Publications in Spanish journals in HSS and MATE are more likely to be OA (around 75% are OA vs. 30% in non-Spanish journals) and particularly gold non-APC (more than 55% vs. 1% in non-Spanish journals). This behaviour does not apply to BIOL, where papers in Spanish journals are less likely to be OA than in non-Spanish publications. One possible explanation for these differences between fields is that national HSS and MATE journals are mainly put out by academic publishers, while national BIOL journals are more likely to be printed by commercial publishers, most of which have not yet adopted the OA model.

⁸ Forty-three articles in Spanish HSS journals (5%), 78 in Spanish MATE journals (1%) and 52 in Spanish BIOL journals (0.6%).

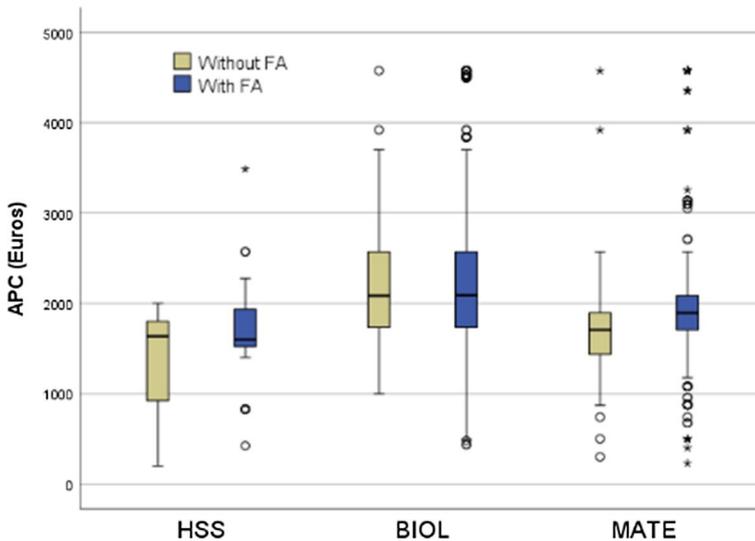


Fig. 5 APCs of gold APC journals by funding status and scientific field

Is funded research more likely to produce OA articles?

Funded research shows a higher percentage of OA papers than unfunded research in all three fields, although the differences are statistically significant only in BIOL (68% vs. 40%) and MATE (35% vs. 27%) ($p < 0.001$), not in HSS (34% vs. 33%).

Differences in OA pattern by funding status can be observed in Fig. 4. In the case of HSS, although there is hardly any difference in the overall OA share according to funding status, funded research leads more frequently to APC-based publications (including both hybrid and gold APC), since APC-based publications account for only 7% of unfunded papers, versus 13% of funded papers. This is also the case in BIOL, where 23% of non-funded papers were published after paying APCs, versus 39% of funded papers. A relatively high share of gold APC papers was found among unfunded research in BIOL and MATE. This proved surprising, as one would expect to find some funding reported to deal with publication costs. In MATE the share of gold APC publications is even higher among unfunded research than among funded papers. To gain an understanding of this finding, we looked for differences in the APCs of the gold journals used for publication according to paper funding status (Fig. 5). Researchers may tend to publish their unfunded research in journals with lower APCs out of greater concern for publication costs. This was confirmed in MATE (Mann–Whitney test, $p < 0.05$), where funded research not only is more often OA, but also targets journals with higher publication costs. Anyway, our data suggest that researchers have financial sources other than those disclosed in their articles to pay for the costs associated with publication.

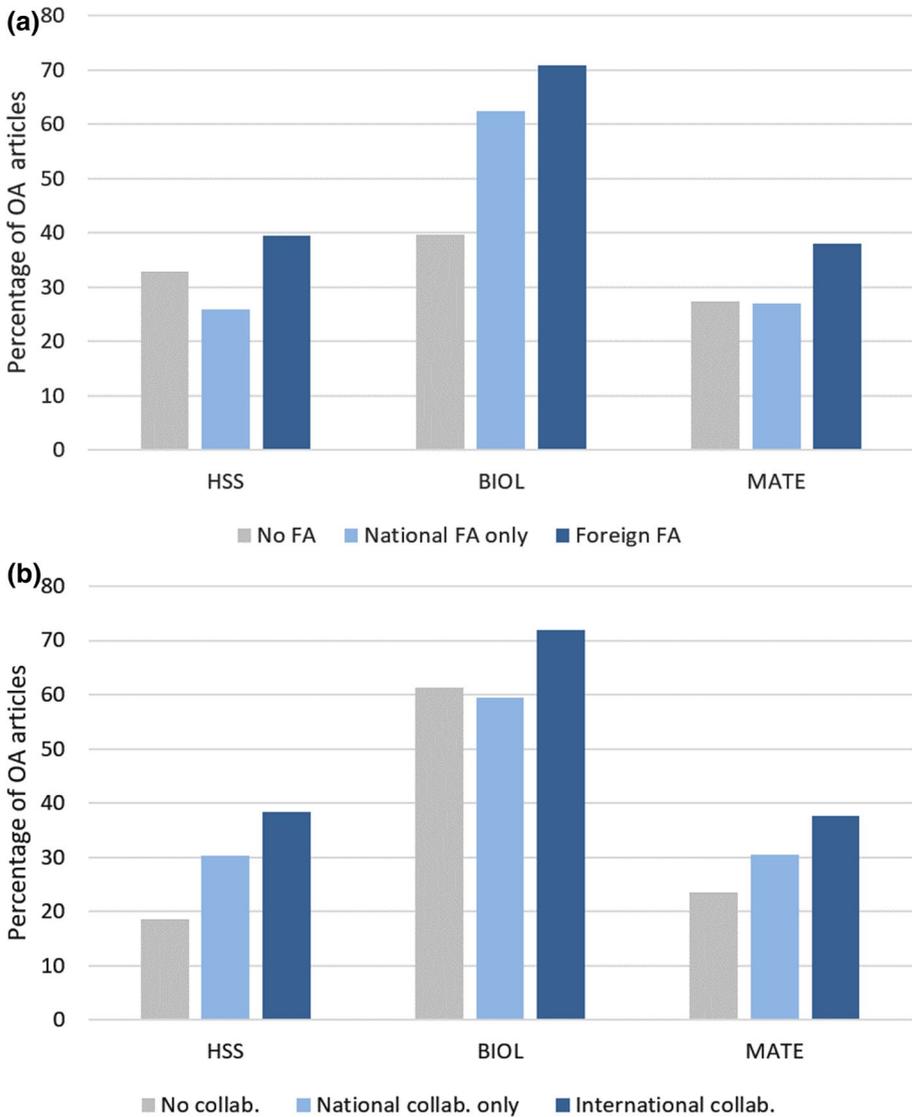


Fig. 6 Percentage of OA papers by scientific field and: (a) funding type; (b) collaboration type

OA and internationality of research

We explored whether research internationality, measured by the presence of international collaboration or foreign funding, is associated with higher levels of open publication. Our results show that in all three areas foreign funding is associated with a higher share of OA papers than national funding or no funding at all. Around 39% of foreign-funded papers were OA in MATE and HSS versus 71% in BIOL (Fig. 6a).

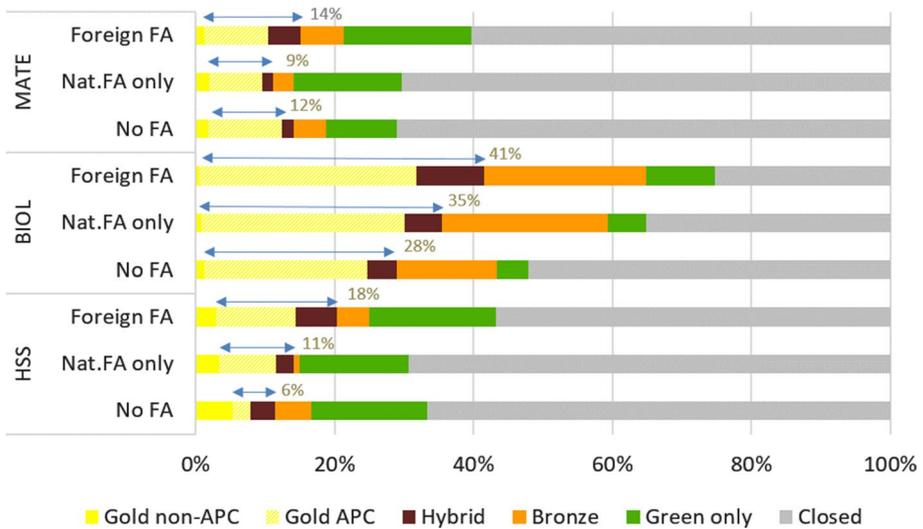


Fig. 7 OA type in internationally co-authored papers, by funding type and scientific field. *Note* the arrows inside the figure show the percentage of articles published through the payment of APCs (gold APC + hybrid)

Table 2 Origin of first author by funding type and scientific field (papers produced in international collaboration only)

	No FA	National FA only	Foreign FA only	Nat.&Foreign FA	Total
HSS					
Spanish Au1 (230)	42.34	65.00	22.64	47.65	45.36
Foreign Au1 (277)	57.66	35.00	77.36	52.35	54.64
Total	100% (111)	100% (120)	100% (106)	100% (170)	100% (507)
BIOL					
Spanish Au1 (2120)	36.40	75.92	7.89	54.13	47.14
Foreign Au1 (2377)	63.60	24.08	92.11	45.87	52.86
Total	100% (261)	100% (544)	100% (836)	100% (2856)	100% (4497)
MATE					
Spanish Au1 (1831)	26.15	66.45	7.87	40.21	37.11
Foreign Au1 (3103)	73.85	33.55	92.13	59.79	62.89
Total	100% (283)	100% (617)	100% (851)	100% (3183)	100% (4934)

Moreover, internationally co-authored papers display a higher percentage of OA than do papers with national collaboration or no collaboration at all, in all three fields. Around 38% of internationally co-authored papers were OA in HSS and MATE versus 72% in BIOL. Non-collaborative papers were less frequently OA than collaborative papers in HSS and MATE (Fig. 6b).

We are aware that international collaboration and foreign funding are interrelated to some extent, as papers with foreign funding are more likely to include international collaboration and vice-versa. Specifically, there is foreign funding in 54% of the internationally

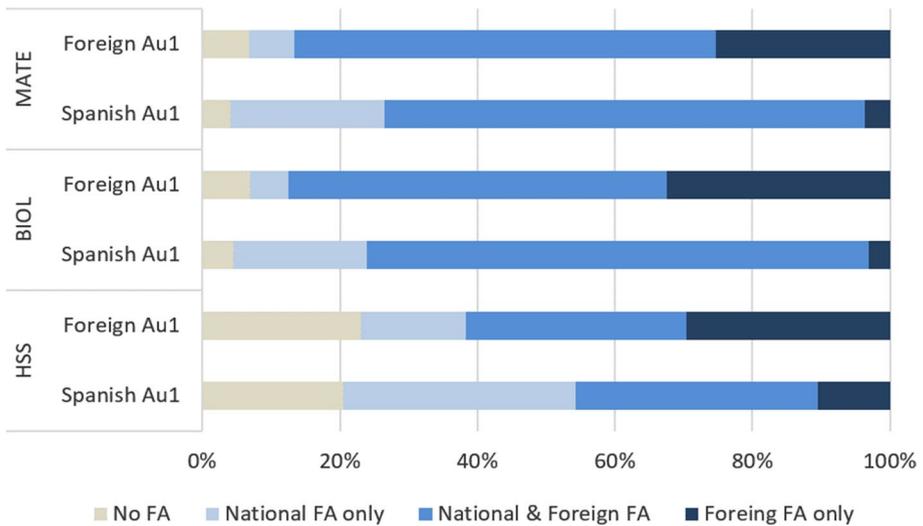


Fig. 8 Funding pattern of publications by Spanish/foreign origin of first author and scientific field (papers produced in international collaboration only)

co-authored papers in HSS and in around 80% of internationally co-authored papers in BIOL and MATE. The comparative influence of both variables is studied further in this section.

Figure 7 shows the OA pattern of internationally co-authored papers according to their funding type. In all three areas, foreign funded papers are more likely to be OA, with OA percentages at least 10 points higher than papers with no funding or national funding only. The effect of foreign funding is very striking in BIOL, where foreign-funded papers display an OA percentage more than 25 points higher than that of unfunded publications. One interesting result shared by all three fields is that the percentage of papers published after the payment of APCs (lumping hybrid and gold APC together) peaks in the case of foreign funding.

Matching scientific leadership and funding origin

Focusing on internationally co-authored papers, we explored whether there might be a relationship between the origin of the first author of the paper and the national or foreign origin of funding.⁹ As shown in Table 2, articles with a foreign first author predominate slightly (HSS and BIOL) or strongly (MATE) over articles with a Spanish first author in the overall output of each area (last column in Table 2). Eleven to fifteen percent of the papers (depending on the field) claim a first author with addresses both in Spain and abroad. These may be researchers who spend time at a foreign institution or researchers

⁹ In this analysis, a distinction is drawn between international FA and mixed FA because differences were expected in the frequency with which these two FA types have a foreign or Spanish first author (as was later confirmed).

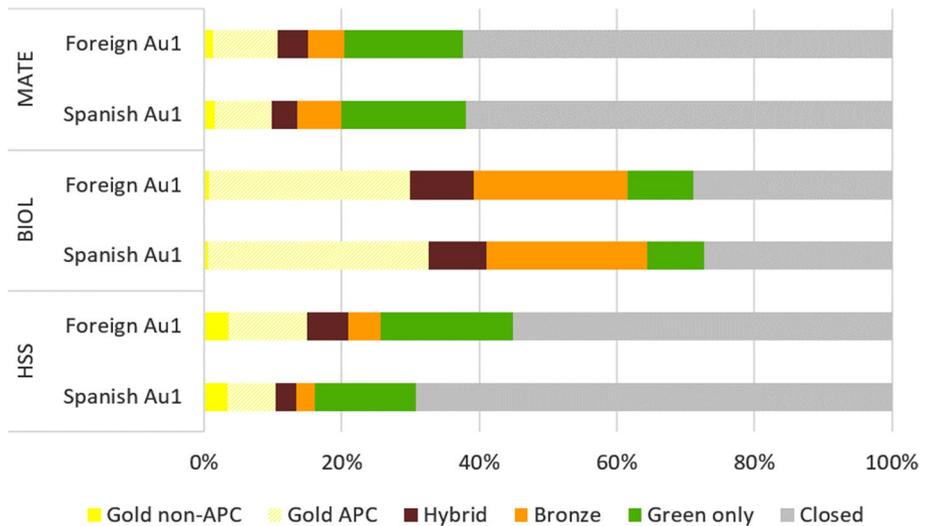


Fig. 9 OA share and type by origin of first author and field (papers produced in international collaboration only)

with a more permanent double affiliation. In this analysis, all such authors are classed in the “Foreign” category.

Our data show that in all three fields a Spanish first author appears in at least two thirds of papers with national funding only. A foreign first author is listed in at least 75% of the papers with foreign funding only; the percentage rises to over 90% in the case of MATE and BIOL (in italics in Table 2). This suggests that scientific leadership and economic leadership tend to converge, especially in the case of research with foreign funding only. In the case of papers with both national and foreign funding, scientific leadership is more equally distributed among national and foreign authors. While a Spanish first author predominates in BIOL, a foreign first author is more frequent in HSS and is particularly likely in MATE.

While Table 2 puts the emphasis on the first author’s origin according to the type of funding, Fig. 8 complements Table 2 by showing differences in funding patterns depending on whether the paper is led by a Spanish or foreign author. Thus, we can see the important weight of mixed funding (national and foreign), which predominates in the two experimental fields—it appears in more than half of the papers- and rises when the first author is Spanish. Mixed funding is half as frequent in HSS. On the other hand, funding from only foreign sources is higher among papers with a foreign first author in all three fields (appearing in around 30% of the papers), while national funding alone is far more frequent among papers with a Spanish first author. Curiously, the share of unfunded papers is slightly higher among articles with a foreign first author in all three fields.

Are papers led by foreign authors more likely to be OA?

A foreign first author was found in 53%, 55% and 63% of the internationally co-authored papers in BIOL, HSS and MATE, respectively (Table 2). We explored the frequency of

Table 3 Logistic regression to explain OA

	HSS			BIOL			MATE		
	B	Wald	Exp (B)	B	Wald	Exp (B)	B	Wald	Exp (B)
Team size		20.445			8.371			45.331	
Medium size	0.742***	13.163	2.099	0.007	0.013	1.007	-0.049	0.595	0.952
Large size	0.929***	19.271	2.531	0.157**	6.596	1.170	0.351***	24.143	1.420
Spanish journal	2.998***	36.240	20.053	-1.246***	12.306	0.288	5.468***	29.322	236.930
UK_Collab	1.049***	27.155	2.854	0.735***	70.241	2.085	0.842***	92.958	2.321
Foreign AuI	0.554***	10.977	1.741						
Q1				0.686***	164.240	1.985	-0.118*	4.389	0.889
USA_Collab				0.841***	122.400	2.319	0.700***	69.351	2.015
FA type					134.100			51.826	
National FA only				1.051***	95.555	2.862	0.220	2.598	1.246
Foreign FA				1.177***	134.080	3.245	0.617***	23.306	1.853
GER_Collab							0.433***	30.548	1.542
Collab_type								16.129	
National col-lab. Only							0.452***	14.780	1.571
Foreign collab							0.302**	6.674	1.353
Constant	-1.782	99.383	0.168	-1.129	117.010	0.323	-1.695	110.160	0.184

(1) Team size is based on the number of authors. There are three categories (small, medium, large) set by terciles in each field

(2) The reference category is the first category for all variables (“Small size” for Team size, “No funding” for FA origin, “No collaboration” for Collaboration type)

(3) Exp (B)=Odds ratio

(4)* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

open papers, comparing papers with a foreign first author to papers with a Spanish first author. Figure 9 shows significant differences only in HSS ($p < 0.01$), where the share of OA papers ranges from 30% in research led by a Spanish author to almost 45% in research led by a foreign author.

Differences in OA type according to the first author’s origin are limited to the HSS field, where having a foreign first author is associated with a higher percentage of hybrid, gold APC and bronze papers. Overall, 10% of papers with a Spanish first author were published after paying APCs (hybrid or gold APC) versus 17% in the case of a foreign first author.

Explaining OA through a multivariate model

A logistic regression was run in each field to determine to what extent funding might go to explain OA taking into account the effect of other potential influential variables, as described in the Methodology section above. The results are shown in Table 3. The dependent variable was correctly predicted with this model in 72% of the cases in HSS and in 68% of the cases in BIOL and MATE. The Nagelkerke R^2 values range from 0.10

(MATE) to 0.13 (BIOL) and 0.18 (HSS). These values are not very high, which means that the model is useful for explanatory purposes but its predictive power is low.

A significant, positive, zero-order relationship between funding type and OA was observed in all fields. When the additional variables were considered, there was no association between OA status and funding type in HSS, yet research funded by foreign sources was more likely to be OA in the other two fields. In particular, papers with foreign funding were over three times more likely to be OA in BIOL and 1.8 times more likely to be OA in MATE.

Collaboration-related variables contribute to OA in different ways, depending on the field. Articles produced by larger teams are more likely to be OA in all three fields, probably because there is greater chance that one of the authors can afford the APCs (Valderama-Zurián et al., 2019). Yet collaboration type is significant only in MATE: collaboration with national partners increases the likelihood of being OA by 57%, while collaboration with foreign partners increases the likelihood of being OA by 35%. Some specific forms of international collaboration are relevant in all fields. OA likelihood is higher in cases of international collaboration with selected countries, e.g., the UK (in all three fields), the USA (in BIOL and MATE) and Germany (in MATE).¹⁰ Having a foreign first author is significant in HSS, where it increases the likelihood of a paper's being OA by 74%.

Finally, an interesting significant association was found between OA status and journal-related variables. Articles in Spanish journals are more likely to be OA than articles published in other journals: 20 more likely times in HSS and 237 times more likely in MATE. On the other hand, publication in a Spanish journal decreases the likelihood of being OA in BIOL by 71%. This is consistent with our previous finding that, while many of the HSS and MATE publications in Spanish journals are OA (in particular, non-APC gold), this is not the case in BIOL publications. Finally, while publication in Q1 journals almost doubles the likelihood of being OA in BIOL, it reduces the likelihood in MATE by 11%. One possible explanation is the fact that there are more high-impact OA journals in BIOL as a result of the field's longer OA tradition.

Discussion

This study analyses the relationship between paper funding and open availability, focusing on the scientific output of CSIC, the main research institution in Spain, in three scientific fields with different research practices: Biology & Biomedicine, Materials Science and Humanities & Social Sciences.

First of all, we would like to note that the OA levels we observed are lower than those described in some other studies. Varying criteria for the delimitation of OA publications may explain these differences. While open versions of papers shared by the authors themselves on sharing platforms, such as ResearchGate and Academia.edu, are considered in some studies (e.g., Science-Metrix, 2018), they are not collected by WoS, because copyright compliance is not assured in such cases and much of the content could be illegally posted (Jamali, 2017). In addition, use of the green route may be underrepresented in this research, because it includes “green published” and “green

¹⁰ Collaboration with China is not shown in Table 3 because it was not significant in any of the fields.

accepted” items, but not “green submitted” papers, which started to be identified and collected by WoS in 2020. This study limitation should be borne in mind.

Our study shows differences in the OA share and main OA routes used by researchers across fields. BIOL accounts for the highest share of OA papers (66%), almost twice as much as the other two fields (around 33%), a finding consistent with the greater acceptance and longer tradition of OA in the life sciences, where APC-based publications were first introduced (Björk & Solomon, 2012). Although the lowest incorporation of OA practice has been described in literature addressing the social sciences and particularly the humanities (Bosman & Kramer, 2018; Science-Metrix, 2018), our study found that OA levels in MATE are as low as in HSS. This can be explained in light of the results of Severin et al. (2020), who conducted a review of large-scale bibliometric studies and reported the lowest OA uptake levels for chemistry and engineering, which are key components in the production of new knowledge in materials science.

BIOL not only has the highest level of OA papers, but also stands out for its high percentage of gold APC (30% vs. less than 9% in the other fields). This may be linked to the greater number of OA journals in the life sciences (Mañana-Rodríguez & Guns, 2022) and suggests the availability of economic resources to help researchers cope with APC-based publications. The high share of bronze papers in the field could be related to the social impact of biomedical research, which may sway publishers to publish in OA; this opening may also be a marketing strategy, though, to improve publisher image (Brasil, 2022).

Researchers in MATE and HSS follow quite similar OA routes, but HSS posts a higher use of gold non-APC (5% vs. less than 2% in the other fields). This finding is in line with the results of Bosman et al. (2021), who observed the dominance of Humanities and Social Sciences journals among diamond DOAJ titles. Interestingly, self-archiving (total green) is observed in more than 80% of OA papers in all fields, which means this is an important route. Use of the green route is enhanced by the existence of the institutional repository Digital.CSIC, which was rolled out in 2008 (Baquero-Arribas et al., 2019). Even so, there is still a long way to go to comply with current institutional OA recommendations, which became mandatory in 2019 and require that the full text of publications be made available in the institutional repository as soon as possible (<https://digital.csic.es/handle/10261/179077>). The fact that BIOL papers are more often disseminated using several routes in parallel than are papers in the other two fields may be linked to the longer trajectory of OA in the life sciences, and it indicates that institutional self-archiving recommendations were also followed in cases where articles were made freely available on the publishing journal’s site.

Funding is acknowledged in more than 90% of the BIOL and MATE papers and falls to 74% in the case of HSS. This finding may reflect the lower level of funding usually available in the latter domain. That said, however, an upward trend is observed in the field, and the level of funded research in the last year of the study period rose to 81%, which means HSS is gradually catching up with the experimental areas.

RQ1 In reply to *the first question* posed at the beginning of this paper, our data show that funded research is associated with higher OA levels in BIOL and MATE as well as with changes in the OA pattern in all three fields. The increased OA of funded research is consistent with the growing number of OA mandates from CSIC, the Spanish government and national and international funders. The HSS field showed no significant differences in the percentage of OA papers by funding status, but funded authors have a greater percentage of APC-based publications.

Despite the above, our study reveals that there is a relatively high share of gold APC papers among unfunded research, which suggests that researchers have financial sources other than those disclosed in their articles to pay the costs associated with publication.

Although researchers very often use research grants to pay APCs (Solomon & Björk, 2012a; Tenopir et al., 2017; Teplitzky & Phillips, 2016), agreements between institutions and publishers are becoming increasingly frequent. These agreements allow researchers from the signatory institutions to read and publish in OA in journals from the signatory publisher (Borrego et al., 2020). The CSIC itself has an Open Access Publishing Support Programme (Baquero-Arribas et al., 2019), which started in 2008 with a single agreement and by 2021 already included more than 20 open-access agreements with a wide range of scientific publishers (<http://bibliotecas.csic.es/es/publicacion-en-acceso-abierto>). Interestingly, the CSIC area with the second-highest number of articles funded through this programme in 2021 is Materials Science (<http://bibliotecas.csic.es/es/programa-apoyo-2021-destacado-historico>), a fact that helps explain the relatively high rate of unfunded articles published in fee-paying journals. Thanks to these reading and publishing agreements, which are an important milestone in the CSIC strategy of promoting open access, even unfunded papers by CSIC researchers can be published in APC-based journals. Thus, a growing number of factors besides agencies' mandates is coming into play and encouraging researchers to publish openly, thereby gaining visibility for their research and complying with institutional recommendations. It is by no means trivial to point out that compliance with open-access recommendations is now a point to reckon with in some academic evaluations (e.g., Mckiernan et al., 2016) and at CSIC (<https://digital.csic.es/handle/10261/179077>).

RQ2 The second question addressed in this paper is whether research internationality-measured by the presence of international collaboration and/or foreign funding- is associated with greater OA. Our study confirms that it is and reveals that foreign funding is a very relevant factor in explaining OA in BIOL and MATE. Although international collaboration and foreign funding are both linked to a higher percentage of OA papers in all three fields (bivariate analysis), when the influence of several additional independent variables on OA is taken into account (multivariate analysis), a more accurate picture is provided, in which the scope of collaboration does not help explain OA in two of the fields. This is partly due to the fact that some of the information provided by the scope-of-collaboration variable is also included in funding origin, since internationally co-authored papers very often include foreign funding. All in all, foreign funding is revealed as playing an important role, since it is associated with an increased percentage of OA articles, particularly APC-based publications (gold APC and hybrid).

One interesting result is that the origin of foreign partners matters. Collaboration with particular countries, such as the UK, USA or Germany, which are countries highly involved in the OA movement (Moskovkin et al., 2021), clearly increases the probability of an article's appearing in OA (with differences by field). Collaborating with some leading scientific countries may thus be beneficial, not only in terms of research excellence, but also in terms of better OA dissemination, perhaps through getting involved in partners' commitment to OA, sharing the payment of APCs or benefitting from partners' transformative agreements.

Lastly, the number of authors is important. In all three fields, as the number of authors increases, so does the likelihood of OA dissemination, probably because there is an increased chance that one of the authors can pay the APCs or the paper can be self-archived (Science-Metrix, 2018; Valderrama-Zurián et al., 2019).

RQ3 The third question focuses on internationally co-authored papers and raises the issue of whether foreign-funded papers are more likely to be led by foreign researchers and to what extent foreign-led papers are more likely to be OA. Our study shows two important findings. Firstly, foreign-funded papers are more likely to be led by a foreign researcher, particularly if only foreign funding is available. This finding supports the fact that economic leadership and scientific leadership tend to converge, and it highlights the relevance of funding to scientific leadership in research. Secondly, having a foreign leader increases the chances of publishing openly only in HSS. In BIOL and MATE, in contrast, foreign-funded papers are more likely to be OA regardless of the origin of the first author. In HSS it is observed that having a foreign leader has a positive effect on OA, above and beyond the effect of the scope of collaboration and funding origin, which were left out of our model. One possible explanation is that Spanish leaders in the field have not yet internalised the importance of OA. Then again, it may also be that a foreign leader enhances access to funds to cover the cost of OA publication in this field, where funding is usually less available.

Finally, some features of the publishing journals influence OA in different ways, depending on the field. Firstly, although researchers in both BIOL and MATE publish around 70% of their papers in Q1 journals, publishing in Q1 journals increases the likelihood of being OA in BIOL but decreases the likelihood in MATE. One possible explanation is that, given the longer tradition of OA in BIOL, more Q1 journals have evolved toward an OA model in this domain (or more OA journals have gained enough of a reputation to rank in the first quartile) (Demeter et al., 2021) and can therefore be selected by BIOL researchers to publish their papers. On the other hand, it can be difficult to find appropriate, high-prestige OA journals in fields where OA is less accepted.

Secondly, differences by field in the role of domestic journals in the OA landscape are in evidence. Whereas publishing in domestic journals increases the likelihood of a paper being OA in HSS and MATE, it is nevertheless associated with a lower probability of being OA in BIOL. In fact, 80% of papers published in domestic journals in HSS and MATE are OA, with a predominance of non-APC journals published by academic institutions. In the case of BIOL, commercial publishers are more the norm. They have not yet adopted the OA model in Spain. Accordingly, publication in domestic journals is an interesting choice when it comes to publishing openly without associated costs in MATE and more particularly in HSS, given the more-local nature of some research topics in the latter field.

This study has a number of limitations, some of which have already been mentioned. Firstly, it should be noted that OA articles have been identified according to the methodology followed by WoS at the time of download. This means accepting the WoS methodology's possible limitations, such as its incomplete coverage of green OA papers, as mentioned above. Secondly, we consider that a paper is nationally or internationally led on the basis of the institutional address of the first author. This may not always be true, and our assumption means we accept a certain margin of error. Lastly, the method used to analyse convergence between the economic and scientific leadership of research is somewhat rough, as it is limited to the analysis of national/international scope. No more precise match could be established between funding origin and author origin using the information available in WoS. At all events, this is a first step towards the study of scientific and economic convergence. Better results could be obtained using more-precise measurements in future, perhaps by drawing from a wider range of information sources so that links can be established between authors and funding sources.

Concluding remarks

As previously shown in the literature (Severin et al., 2020), the practice of OA is discipline dependent. Our study shows that, even within an institution, discipline-specific publishing practices lead to different degrees of OA adoption. Two main issues follow from here. Firstly, the need to take this into account when implementing or monitoring OA mandates and recommendations, since the difficulty of achieving specific targets can vary significantly from one field to another. Secondly, normalised indicators of OA, which compare an institution's OA share with the OA share of the world average by discipline, may be advantageously used by multidisciplinary institutions, particularly in the case of global OA rates, to correct for differences in disciplinary practices (Maddi, 2020).

Internationality of research, where “international research” is considered as research with foreign funding and/or international collaboration (particularly collaboration with leading OA supporter countries), increases the chances of OA publication at CSIC. Interestingly, the national/foreign origin of the leader does not seem to influence OA share or OA pattern in the experimental fields, but having a foreign leader is indeed linked to greater OA share in HSS. Arguably, Spanish leaders in the field may not yet have internalised the importance of OA. However, another possible explanation is that a foreign leader may enhance access to funds to cover the cost of OA publication in a typically less well-funded field. Further research on this issue is called for.

Depending on the field, funding is associated with a higher OA share and/or changes in the OA pattern, sometimes increasing APC-based publication. However, APC-based publication is sometimes used to disseminate unfunded research. It seems that CSIC researchers have financial sources other than those disclosed, possibly under institutional agreements with publishers, which are not always included in the acknowledgements. Further studies on the role and impact of these institutional agreements are needed, as the number of institutional agreements has risen significantly in recent years, leading to a major change in the open publishing landscape. Additional analyses could be of interest to ascertain to what extent such agreements are covering the cost of OA publications for CSIC researchers in the different fields. Mandatory acknowledgement of OA-publishing supporting sources in papers, preferably collected in a specific section such as the “OA-paying affiliation” field suggested by Gumpenberger et al. (2018), would enhance progress along this line of study.

Finally, it should be noted that the results reported here refer to a specific institution and specific scientific fields. More research is thus needed to ascertain whether the results are extrapolatable to other contexts.

Appendix

See Tables 4, 5.

Table 4 Evolution of the number and percentage of OA world publications in WoS (SCIE + SSCI + AHCI)

Year	# Art.& Reviews		% OA
	Total	OA	
2000	830,964	138,106	16.62
2010	1,250,764	382,399	30.57
2020	2,184,294	1,094,246	50.10

Search run on 13 February 2023

Table 5 Description of the variables included in the logistic regression

	HSS		BIOL		MATE	
	N (924)	%	N (8355)	%	N (7707)	%
Collab.type						
No collab	113	12.23	695	8.32	622	8.07
National collab. only	291	31.49	3111	37.24	2101	27.26
Foreign collab	520	56.28	4549	54.45	4984	64.67
FA type						
No FA	240	25.97	588	7.04	434	5.63
National FA only	316	34.20	2130	25.49	1914	24.83
Foreign FA	359	38.85	5607	67.11	5315	68.96
Missing	9	0.97	30	0.36	44	0.57
First author origin						
Spanish Au1	628	67.97	5813	69.58	4535	58.84
Foreign Au1	281	30.41	2386	28.56	3110	40.35
Missing	15	1.62	156	1.87	62	0.80
Q1						
No Q1	443	47.94	2377	28.45	2321	30.12
Q1	441	47.73	5837	69.86	5318	69.00
Missing	40	4.33	141	1.69	68	0.88
Spanish journal						
Non-Spanish journal	881	95.35	8303	99.38	7629	98.99
Spanish journal	43	4.65	52	0.62	78	1.01
Team size						
Small team	278	30.09	2730	32.68	2263	29.36
Medium team	362	39.18	2409	28.83	3322	43.10
Large team	284	30.74	3216	38.49	2122	27.53
China_Collab						
No (0)	914	98.92	8227	98.47	7441	96.55
Yes (1)	10	1.08	128	1.53	266	3.45
GER_Collab						
No (0)	861	93.18	7508	89.86	6800	88.23
Yes (1)	63	6.82	847	10.14	907	11.77
UK_Collab						
No (0)	774	83.77	7263	86.93	7033	91.25
Yes (1)	150	16.23	1092	13.07	674	8.75
USA_Collab						
No (0)	840	90.91	6839	81.86	6981	90.58
Yes (1)	84	9.09	1516	18.14	726	9.42

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Declarations

Conflict of interest All authors declare that they have no conflicts of interest.

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