Is open access publication useful for all research fields? Presence of funding, collaboration and impact

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Abstract

Open access (OA) to every research result supported by funding bodies is a medium to long-term goal. This work aims to find out whether OA publication is useful for all research fields, regardless of their specific features. As a sample, articles from the WoS databases from two disparate disciplines (one from SSCI and another from SCIE) are selected, and several hypotheses related to the presence of funding acknowledgements, cooperation and citations are tested. A first look at the general distribution of publications shows that collaborative and funded research obtains a higher proportion of cited articles, and that this proportion increases in the case of OA publications. Moreover, the logistic regression reveals that the probability of finding an OA publication is significantly increased in the SCIE discipline, and by the presence of EU funding, international collaboration and citations. This probability rises with some interactions (e.g. presence of international funding and international collaboration, or international funding and citations). Regarding OA types, Green OA publications are the most related to fund recognition, although Gold OA/ Bronze OA articles in international collaboration are also significantly related to financing. Concerning impact, the most likely cited OA type is the Hybrid OA. However, if papers include funding acknowledgements, the Bronze OA and Green OA publications increase their citation likelihood. Similarly, when Gold OA articles include international collaboration, there is a greater chance of citation. With these findings, it is possible to venture that OA publishing will be useful for all research fields, although their specific features should be considered. Consequently, funders should be aware of these particularities to stimulate OA without compromising the quality of the research.

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Introduction

Since the beginning of the twenty first century, different initiatives have emerged to favour open access (OA) to scientific publications. In this context, funding bodies increasingly demand this type of access to publications derived from their sponsored research. The need for OA publication not only has to do with a general right to access knowledge, but is also believed to be related to the greater impact and progress of research. A better access to information will allow advancing in new knowledge based on the existing one (Gargouri et al. 2010; Larivière and Sugimoto 2018; Piwowar et al. 2018; Sotudeh and Estakhr 2018; Van Vlokhoven 2019). Moreover, the growing cost of large toll-access publishers has made different institutions to resort to the OA to maintain their access to essential literature (Piwowar et al. 2018). In this way, the authors can retain control over the integrity of their work and the right to be duly recognised and cited (Martín-Martín et al. 2018). Among the initiatives of OA that have emerged more recently, it is worth mentioning the Plan S.[1] This plan is based on a coalition of research funding organisations from different countries, with the support of the European Commission (EC) and the European Research Council (ERC). It is committed to implementing, from 2021[2] onwards, the necessary measures to ensure that scientific results with funding from participating organisations are published in OA.

In this sense, the plans for the next *Horizon Europe* will include *open science* as the modus operandi. This will require not only scientific publications in OA, but also research data in OA.[3] With regard to the definition of OA, although some define it as any free content for reading and reuse, in line with the CC-BY license, others are less strict and consider it sufficient that there is free access to online reading (Piwowar et al. 2018). Further to this, since the beginning of OA, various options have emerged, ranging from self-archive in public repositories (Green OA) to full access offered by publishers (Gold OA) (Sotudeh and Estakhr 2018). In addition, many institutions have created repositories, available to researchers to ensure compliance with OA policies (Pinfield 2010). The Gold OA option has been the consequence of the adaptation of the editors to the OA requirements of funders and their journals revenue generally comes from article processing charge (APC). According to Björk and Solomon (2015), the subscription prices of journals have not always been linked to scientific quality, while the APCs are more in line with the quality and services offered. However, there are Gold OA journals (also called Diamond OA or Platinum OA) that do not have APC, because they cover all publication costs. Nevertheless, quality publications without APC are not available in all fields. Perhaps for this reason, APC costs are also experiencing hyperinflation, which is not disappearing with competition among publishers (Khoo 2019). Regarding the option of self-archiving, it has been offered by many research institutions as a possible solution to the problem of the growing costs of journals (Martín-Martín et al. 2018). On the other side, the OA can be found through alternative channels that offer a free version of the manuscript (Bronze), generally read only. However, the license of these articles is not clear and access to them may only be for a limited time. Thus, there is a risk of disappearance, which can also be found in OA Green copies filed on personal web pages that sometimes violate copyright rules (Björk et al. 2014).

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[1] Retrieved July 20, 2020, from https://www.coalition-s.org/about.

[2] This is an extension by one year of the initial date 2020 (retrieved July 20, 2020, from https://www.coalition-s.org/rationale-for-the-revisions).

[3] Retrieved July 20, 2020, from https://www.openaire.eu/horizon-europe.

Nonetheless, large commercial publishers have chosen an intermediate access: the Hybrid OA publishing. In this way, restricted access journals allow authors to publish their articles openly after the corresponding APC. At first, all authors had to face the costs, being forced to use part of their funds of research projects. Subsequently, agreements have been established between some funding agencies and publishers, which cover OA fees so that researchers can publish their results openly and thus increasing this type of publications. This system is not without criticism, since for publishers it does not imply any risk: they keep the subscription income and they charge for each article published in OA. That is paying twice for the same service. There are, however, some success stories in which a publication has completed the transition, moving from Hybrid to Gold OA (e.g. *Nature Communications*) (Björk 2017; Björk and Solomon 2015; Martín-Martín et al. 2018; Pinfield 2010; Sotudeh and Estakhr 2018; Wang et al. 2015b). However, Plan S' principles entail that publication must be done in journals/platforms in compliant OA, which means that authors must retain their copyright and that Hybrid OA is not considered to fulfil this plan, although the plan also considers that funders can reach transitional agreements with Hybrid publishers, defining deadlines, always in order to achieve the full OA model.

In this context, the hazard of market concentration is even greater. Therefore, Khoo (2019) considers that it is necessary to re-examine the evolution of APC after the implementation of Plan S, to analyse whether the prices of academic publications have increased further. The plan states that when there are fees for publishing, the funders will take over, as long as fees are justifiable and proportional. However, Plan S does not establish what it considers justifiable and proportional (Else 2018). In fact, Khoo (2019) considers that there is no reasonable APC. Journals that achieve a certain prestige tend to increase costs based on the number of manuscripts they receive, since only accepted manuscripts have APCs. In addition, the APC implies that scientists are no longer free to decide where to publish because this depends on the funds they receive to meet these new costs (Perianes-Rodríguez and Olmeda-Gómez 2019). Moreover, the access to this system would be restricted to researchers with funds to pay for that space and, at the same time, many researchers would be forced to abandon well-established journals without any viable alternatives. On the other hand, an unwanted consequence of the APC-based OA could be that large publishers stop trying to attract excellent works, which are what give them prestige in the current subscription-based system. However, some studies point to the fact that if a journal loses prestige, authors may decide to send their manuscripts to other journals with more demanding acceptance criteria. This is because authors place greater importance on the quality, validity, impact and review process of a journal than on everything else (Khoo 2019; Sotudeh and Estakhr 2018; Van Vlokhoven 2019).

Given this scenario, various tools have been developed to analyse the growing corpus and have as much information as possible to assess the potential influence of the funders' recommendations in various research areas. On the one hand, several works have studied the results of the requirements of different funding agencies with respect to the open publication of their sponsored findings. In this respect, the paper by Larivière and Sugimoto (2018) presents an analysis of compliance with large-scale OA mandates, identifying more than 1.3 million documents, of which two-thirds are available for reading, although with significant variations between agencies. They conclude that when there are incentives and support, the researchers comply. On the other hand, studies such as Van Leeuwen et al. (2018) focus not only on identifying OA publications (mainly Gold OA), but also on analysing those publications in terms of impact. Their results present lower citation rates for publication in Gold OA, which they think it could be due to the recent incorporation of these journals to the scientific domain, combined perhaps with a less selective criterion of inclusion of new journals in the WoS databases.

Nevertheless, in the study by Piwowar et al. (2018) they observed that, in general, OA usually receive more citations, having experimenting a significant growth in size and impact in the last decade. In an earlier study, Antelman (2004) already observes a greater impact for OA in four different disciplines. Similarly, Sotudeh and Estakhr (2018) find a sustained citation advantage over time among OA versus non-OA publications in all areas, although not all of them are equally benefited.

Apart from that, the citation advantage is usually used as recognition of the validity of OA publication and has been linked to the authors' selection of their best works for OA. However, the study by Sotudeh (2019) concludes that, if the authors' self-selectivity exists, it is not responsible for the OA citation advantage, at least with regard to the selection of topics. Besides, during her data collection, Antelman (2004) observed that it was usual for authors to publish all or none of their articles in OA. In summary, the OA allows users to decide what information they need and cite based on higher quality and not based on access, as also stated by Cintra et al. (2018). Further to citation advantage and differences by discipline, the existence of funding seems to be greater in the research published in OA. Indeed, as well as including open publishing requirements, some agencies offer support for APC (Wang et al. 2015a). On the other hand, some authors have found a relationship between cooperation and OA. This is the case of Valderrama-Zurián et al. (2019), which analyse the OA publication in several disciplines of education (SSCI, period 2010–2016). In their set, they observe a greater international collaboration, especially in the Gold OA publication and assume that this cooperation makes it easier to find a partner that deals with APC. In this line, Breugelmans et al. (2018) study the relationship between impact and OA when there is international collaboration, and conclude that there is a citation advantage. The only exception they find is in the collaboration between sub-Saharan African countries.

The current study goal is to analyse the presence of similar outcome in disparate disciplines. In this way, it will be possible to evaluate the measures taken by the funding bodies and suggest additional measures to promote the share of information while maintaining the quality of the research carried out in different fields.

Objectives

This work aims to find out whether OA publication is useful for all research fields, regardless of their specific features. As a sample, articles from the WoS databases from two disparate disciplines (one from SSCI and another from SCIE) are selected, and several hypotheses are tested:

- It is presumed that, in general, there will be a higher proportion of funding acknowledgments (FA) in OA articles, mainly from international and EU sources.
- OA documents are supposed to present greater collaboration, especially of international scope.
- OA items are expected to obtain a citation advantage over non-OA articles, being the Gold OA type the least likely to be cited.

Materials and methodology

Articles written in English in 2017 are selected, because WoS only collects FA when in English. A list of categories with the highest production in SSCI is obtained, choosing the second, *Economics* (*Econ*), and retrieving 20,030 items. The first one (*Public, Environmental & Occupational Health*) is not chosen because is included in both SSCI and SCIE. Likewise, a list of categories is obtained in SCIE, selecting one of similar size and with a greater proportion of OA, *Immunology* (*Immu*), and retrieving 23,988 items. Besides, different characteristics of these WoS articles are analysed including number of authors, addresses, countries, references, pages and citations, usage count, OA and FA. Addresses and countries are used to reveal the existence of collaboration and to separate documents with only national collaboration (Nat Coll) from those that include international collaboration (Int Coll). Furthermore, to allow comparisons between research fields, a citation ranking is carried out, ranging from the absence of citation to highly cited articles. These citations were obtained in mid-2019, so there is a 1.5–2.5-year citation window. However, this allows assessing the presence of early citations in OA articles, which is a characteristic feature of this type of publication. On the other hand, the usage count offers complementary information as a measure of potential interest of the published research. This value represents the number of times a WoS record has been saved or the number of times the full text has been accessed since February 1, 2013.[4] Some authors (e.g. Chi et al. 2019) have observed that there is certain correlation with other measures of research impact, so it is interesting to analyse the influence of this indicator on OA publications.

Taking into account the OA characteristic of WoS articles, the different types are also studied to be able to highlight differences, avoiding duplications. Therefore, in case of concurrence, Gold access prevails, followed by Hybrid, Bronze and Green OA. These are based on WoS multiple versions of OA[5]: DOAJ Gold, Other Gold (Hybrid), Bronze and Green OA. For articles in Green OA, they link to peer-reviewed versions hosted legally in open repositories, both the accepted version and the published version. For all articles in OA, WoS give preference to Gold or Bronze versions when available. On the other hand, these databases make weekly updates to include new OA links and any changes in their status, taking into account everything that Impactstory finds. This is possible because the owner of WoS, Clarivate Analytics, collaborates with Impactstory, a non-profit organisation whose goal is to make the OA content easier to find. For this reason, these databases use Impactstory's improved OA identification technology.

With respect to FA, the WoS articles that include acknowledgements to any financial support are identified. Additionally, the different types of funding sources are analysed, separating the documents that acknowledge European funds (EU FA[6]) from those that include funds from two or more countries (Int FA) and from those that only include national funds (Nat FA). For the identification of the FA types, this study has used the automation processes previously developed by Morillo and Álvarez-Bornstein (2018).

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[4] Retrieved July 20, 2020, from https://images.webofknowledge.com/images/help/WOS/hp_usage_score.html.

[5] Retrieved July 20, 2020, from https://images.webofknowledge.com/images/help/WOS/hp_whatsnew_wos.html.

[6] European Structural & Investment Funds (ESIF) are not considered for the EU FA type because the *EU countries administer the funds on a decentralised basis through shared management* (retrieved July 20, 2020, from https://ec.europa.eu/eip/ageing/funding/ESIF_en).

These processes analyse documents with data in the FA field and extract the main funding bodies along with their place of origin, whenever possible. In the present paper, only the geographical location is processed to distinguish between articles supported by national, international or EU sources.

Further to this, statistical tests are used to reveal which characteristics are associated with an OA article. In particular, the aim is to verify whether the publications in OA present greater FA, collaboration and citation, as well as to determine the differences between fields and between OA types.

Logistic regression

Several logistic regression models are applied with all the variables of interest, obtaining both the main effects and the interactions between them. In order to determine the goodness of fit of the models, the Nagelkerke pseudo-R2 statistic is used. Finally, the Wald test is applied to calculate the statistical significance of the model parameters, establishing a *p* value less than 0.05. To avoid multicollinearity problems, the number of authors, addresses, countries and pages are excluded. Descriptive statistics of dependent and independent variables are shown in Tables 1 and 2. Logistic regression models are constructed with the presence/absence of OA as the dependent variable (Table 3). That is, the probability of finding a WoS article published in OA, based on selected independent variables, which include FA types, collaboration types, citation quartiles, number of references, usage count and field (*Immu* vs. *Econ*). Likewise, similar models are applied using the presence/absence of FA as the dependent variable (Table 4), with OA types, collaboration types, citation quartiles, number of references, usage count and field (*Immu* vs. *Econ*) as independent variables. Finally, logistic regression models are constructed with the presence/absence of citations as the dependent variable (Table 5), including OA types, FA types, collaboration types, number of references, usage count and field (*Immu* vs. *Econ*) as independent variables. Furthermore, the interactions between several variables are also evaluated and their influence on the different dependent variables (see "Appendix").

Results

General data

A preliminary analysis of the data reveals the differences between the selected disciplines, not only in terms of the presence of publications in OA (50% in *Immu* and less than 15% in *Econ*), but also in terms of FA (79% vs. 48%). These figures are related to the characteristic traits of each research field, as well as those observed in collaboration (85% in *Immu* versus 67% in *Econ*) and in citations (85% versus 64%). In the case of collaboration, it should be taken into account that, after processing the information of the two selected disciplines, it is observed that there are 100 articles whose addresses or authorship are unknown. For this reason, logistic regression models only analyse 43,918 items (Table 1).

On the other hand, the detailed information offered in Table 1 for OA types allows to see that publications in *Econ* are disseminated mainly in Bronze OA, while for *Immu* Gold OA is the most frequent. Besides, international collaboration is 52% of the total collaboration for *Econ* and less than 36% for *Immu*. As for citations, they have been

Table 1 Dependent and independent variables used in logistic regression models

			Econ		Immu		Total Art	
Access	No OA		17,129	85.5%	11,910	49.6%	29,039	66.0%
	OA	Green OA	601	3.0%	1671	7.0%	2272	5.2%
		Bronze OA	910	4.5%	3775	15.7%	4685	10.6%
		Hybrid OA	879	4.4%	1458	6.1%	2337	5.3%
		Gold OA	511	2.6%	5174	21.6%	5685	12.9%
		Total OA	2901	14.5%	12,078	50.4%	14,979	34.0%
	Total art		20,030	100.0%	23,988	100.0%	44,018	100.0%
Funding	No FA		10,445	52.1%	5073	21.1%	15,518	35.3%
	FA	Nat FA	7594	37.9%	14,897	62.1%	22,491	51.1%
		Int FA	1246	6.2%	2931	12.2%	4177	9.5%
		EU FA	745	3.7%	1087	4.5%	1832	4.2%
		Total FA	9585	47.9%	18,915	78.9%	28,500	64.7%
	Total art		20,030	100.0%	23,988	100.0%	44,018	100.0%
Collaboration	No coll		6608	33.1%	3572	14.9%	10,180	23.2%
	Coll	Nat coll	6401	32.1%	13,115	54.7%	19,516	44.4%
		Int coll	6944	34.8%	7278	30.4%	14,222	32.4%
		Total coll	13,345	66.9%	20,393	85.1%	33,738	76.8%
	Total art with data		19,953	100.0%	23,965	100.0%	43,918	100.0%
	(No data)		77		23		100	0.2%
Citation quartiles*	No cited		7306	36.5%	3498	14.6%	10,804	24.5%
	Cited	Low cited	4579	22.9%	7181	29.9%	11,760	26.7%
		Medium cited	2731	13.6%	7547	31.5%	10,278	23.3%
		Highly cited	5414	27.0%	5762	24.0%	11,176	25.4%
		Total Cited	12,724	63.5%	20,490	85.4%	33,214	75.5%
	Total Art		20,030	100.0%	23,988	100.0%	44,018	100.0%

*Citations have been distributed as evenly as possible to allow comparisons. Low cited: 1 citation for *Econ*, 1-2 citations for *Immu*. Medium cited: 2 citations for *Econ*, 3-6 citations for *Immu*. Highly cited: >=3 citations for *Econ*, >=7 citations for *Immu*

Table 2 Continuous independent variables used in logistic regression models

		Econ	Immu	Total
References	Mean	44.15	51.67	48.25
	Median	40.00	42.00	41.00
	Percentile 75	56.00	59.00	57.00
Usage count	Mean	10.26	6.21	8.05
	Median	7.00	4.00	5.00
	Percentile 75	13.00	8.00	10.00

distributed as evenly as possible to allow comparisons. Therefore, for *Econ*, the highly cited category includes articles cited at least 3 times, while for *Immu*, this category comprises articles cited 7 times or more. Finally, with respect to the continuous variables, *Immu* stands out for its higher number of references, while *Econ* has a greater usage count (Table 2).
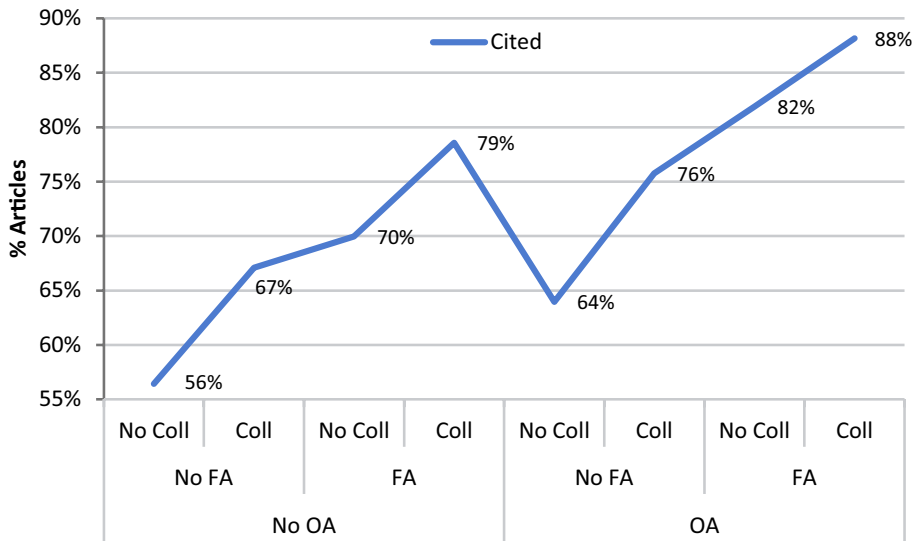
Fig. 1 Percentage of cited articles for OA by FA and collaboration

If the general distribution of publications is analysed, it is possible to observe that collaborative and funded research obtains a higher proportion of cited articles (Fig. 1). In the case of OA items, it seems that this proportion increases, so it is particularly interesting to study which are the most significant variables for this type of publication.

Logistic regression

With the aim to find out what characteristics OA publications have, several logistic regression models are built. Using the OA presence/absence as the dependent variable, which represents 34% versus 66% of the articles (Table 1), its best explanatory variables are the existence of FA (mainly from the EU sources), international collaboration, highly cited publications and *Immu* research. This is shown in Table 3, which presents a Nagelkerke's R^2 of 0.243, an OR 2.88 ($p < 0.001$) for OA publications with EU FA, great international collaboration (OR 1.35, $p < 0.001$), highly cited research (OR 1.84, $p < 0.001$) and a larger representation of the *Immu* field (OR of 4.54, $p < 0.001$).

Furthermore, the likelihood of finding an OA publication rises with the presence of some interactions (see "Appendix"). For instance, Fig. 2 shows how the mean predicted probability for OA increases with the synergy between funding and collaboration. This connection is particularly strong and significant with international funding and international collaboration (OR 1.71, $p < 0.001$). In addition, there are also interactions between the presence of funding and citations (Fig. 3), being significant those that occur with international (OR 1.49, $p < 0.001$) and only national sources, but not those that occur with EU FA, with high presence in OA publications, regardless of citations. Moreover, it is interesting to note the importance of the synergy between funding and *Immu*, especially with the international FA (OR 1.93, $p < 0.001$), possibly explained by the large proportion of documents with this type of funds in this discipline (Fig. 4). Likewise, the probability

Table 3 Logistic regression for the OA presence/absence

	LR for OA			
	B	S.E.	Sig.	OR
No FA versus				
Nat FA	0.651	0.027	0.000	1.918
Int FA	0.817	0.042	0.000	2.264
EU FA	1.058	0.057	0.000	2.880
No coll versus				
Nat coll	0.010	0.031	0.742	1.010
Int coll	0.297	0.033	0.000	1.346
No cited versus				
Low cited	0.056	0.034	0.098	1.057
Medium cited	0.317	0.035	0.000	1.374
Highly cited	0.610	0.036	0.000	1.841
References	0.002	0.000	0.000	1.003
Usage count	−0.026	0.002	0.000	0.974
Immu versus Econ	1.513	0.027	0.000	4.539
Constant	−2.382	0.039	0.000	0.092
Nagelkerke R Square	0.243			

OR odds ratio = Exp(B)

Fig. 2 Mean predicted probability for OA by FA Types and Coll Types
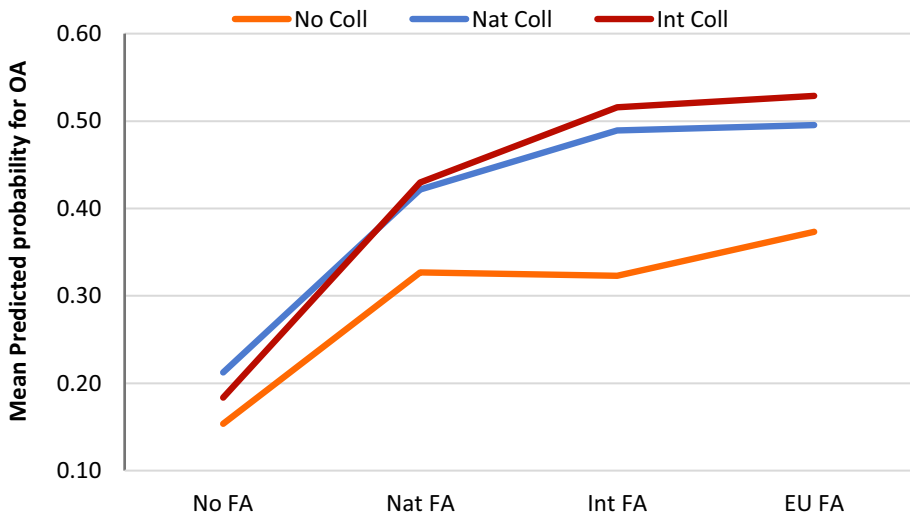
of finding an OA publication increases with the international collaboration in *Immu* (see "Appendix").

Considering that funding seems decisive to OA publishing, an additional analysis is performed with the dependent variable of the FA presence/absence, which represents 65% versus 35% of the articles (Table 1). Among other things, its relation with the different OA

Fig. 3 Mean predicted probability for OA by FA Types and No cited/Cited
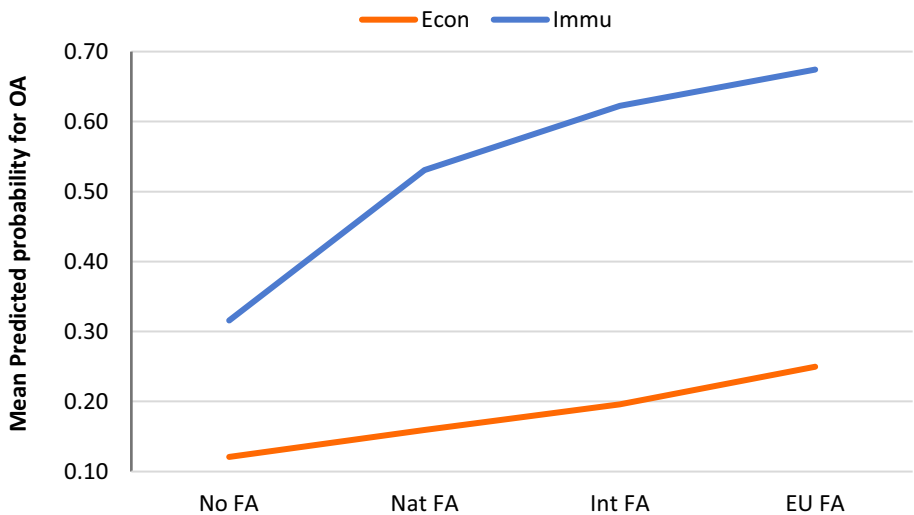
Fig. 4 Mean predicted probability for OA by FA Types and Field

types is studied. The results show that the overall probability of finding FA in publications (Table 4) increases especially in Green OA items (OR 2.65, $p < 0.001$), in those with international collaboration (OR 2.25, $p < 0.001$), with high citations (OR 1.60, $p < 0.001$) and in *Immu* field (OR 3.19, $p < 0.001$).

Besides, the likelihood of finding FA in publications rises with the interaction between different variables (see "Appendix"). On the one hand, Fig. 5 presents how some connections between OA types and collaboration types increases the mean predicted probability

Table 4 Logistic regression for the FA presence/absence

	LR for FA			
	B	S.E.	Sig.	OR
No OA versus				
Green OA	0.976	0.062	0.000	2.654
Bronze OA	0.769	0.042	0.000	2.157
Hybrid OA	0.776	0.056	0.000	2.172
Gold OA	0.489	0.038	0.000	1.631
No coll versus				
Nat coll	0.450	0.027	0.000	1.568
Int coll	0.812	0.029	0.000	2.252
No cited versus				
Low cited	0.223	0.030	0.000	1.250
Medium cited	0.428	0.033	0.000	1.534
Highly cited	0.471	0.033	0.000	1.601
References				
Usage count	0.013	0.001	0.000	1.013
Immu versus econ	1.160	0.025	0.000	3.191
Constant	− 0.987	0.028	0.000	0.373
Nagelkerke R square	0.206			

OR odds ratio = Exp(B)
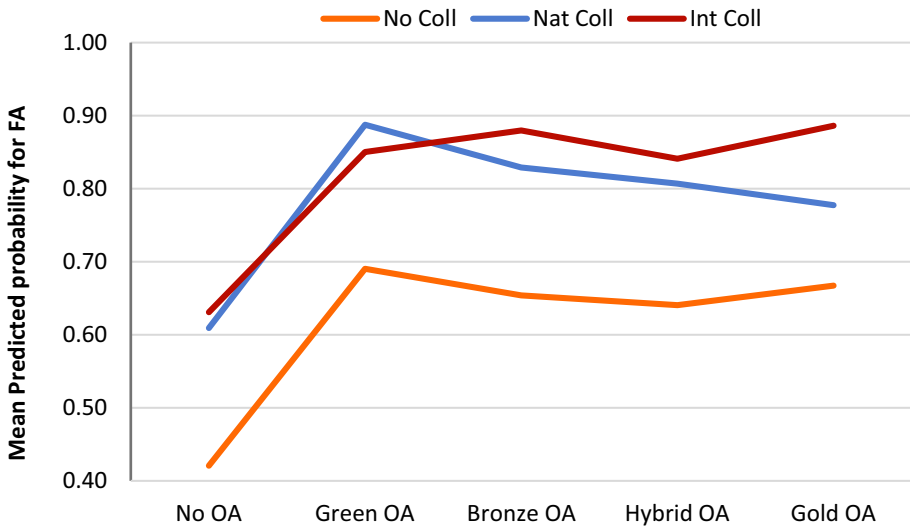
Fig. 5 Mean predicted probability for FA by OA Types and Coll Types

for FA, being significant those between Green OA publications and only national collaboration (OR 1.73, $p < 0.001$), between Gold OA and international collaboration (OR 1.48, $p < 0.001$), and between Bronze OA and international collaboration (OR 1.42, $p < 0.005$). On the other hand, there are also interactions between OA types and citations, particularly with the Green OA publications (OR 1.55, $p < 0.005$) and with the exception of the Hybrid
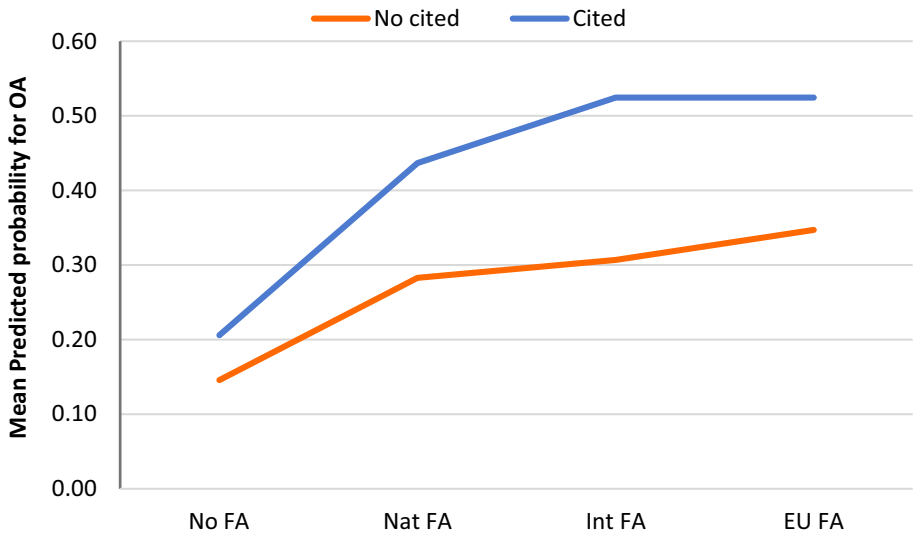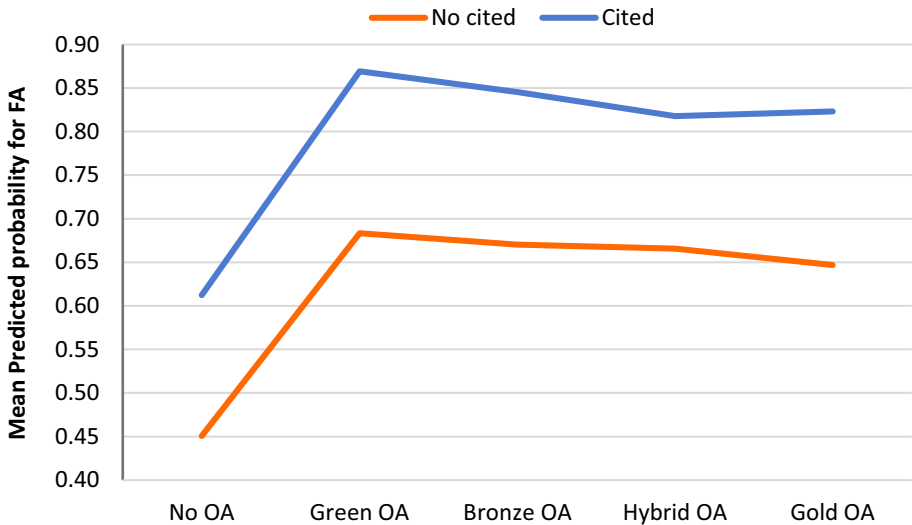
Fig. 6 Mean predicted probability for FA by OA Types and No cited/Cited
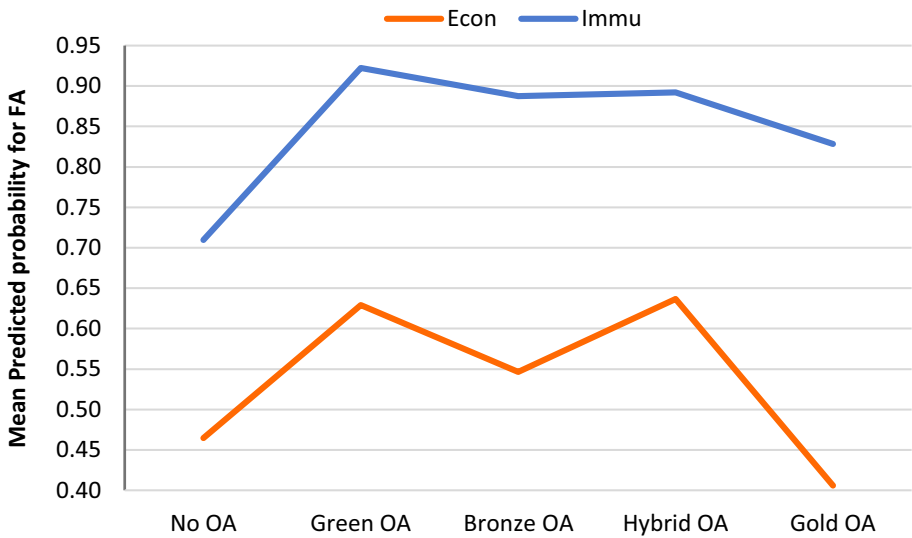
Fig. 7 Mean predicted probability for FA by OA Types and Field

OA type, which is not significant (Fig. 6). Finally, synergies can also be observed in Fig. 7, between the OA types and *Immu*, being especially intense with the Green OA publications (OR 2.62, $p < 0.001$).

On the other hand, the citation variable is also examined to see its relationship with the different OA types. Articles that have been cited represent 75% of all the analysed articles (Table 1). If the presence/absence of citations is considered as the dependent variable (Table 5), a greater probability is observed for OA publications, particularly

Table 5 Logistic regression for the presence/absence of citations

	LR for Cited			
	B	S.E.	Sig.	OR
No OA versus				
Green OA	0.488	0.067	0.000	1.629
Bronze OA	0.483	0.048	0.000	1.620
Hybrid OA	0.581	0.065	0.000	1.787
Gold OA	-0.040	0.041	0.338	0.961
No FA versus				
Nat FA	0.247	0.027	0.000	1.280
Int FA	0.546	0.053	0.000	1.727
EU FA	0.637	0.077	0.000	1.891
No coll versus				
Nat coll	0.220	0.031	0.000	1.246
Int coll	0.376	0.033	0.000	1.456
References	0.012	0.001	0.000	1.012
Usage count	0.078	0.002	0.000	1.081
Immu versus econ	1.282	0.029	0.000	3.604
Constant	−0.999	0.035	0.000	0.368
Nagelkerke R square	0.220			

OR odds ratio $=$ Exp(B)

for Hybrid OA items (OR 1.79, $p < 0.001$), with the exception of Gold OA, although this value is not significant. The likelihood of being cited increases also for funded publications, especially for EU FA (OR 1.89, $p < 0.001$), for those that include collaboration (especially international, OR 1.46, $p < 0.001$) and for those in *Immu* field (OR 3.60, $p < 0.001$).

Moreover, the probability of finding a cited publication also rises with the interactions between variables (see "Appendix"). For example, a couple of OA publication types increase the mean predicted probability for Cited thanks to funding (Fig. 8). The publications in Bronze OA are more likely to be cited when they include international funding (OR 1.81, $p < 0.005$), while for Green OA papers the probability increases with only national funding (OR 1.47, $p < 0.05$). Besides, it is interesting to mention that both the Bronze OA publications (OR 1.27, $p < 0.05$) and Gold OA items (OR 1.20, $p < 0.05$) benefit from collaboration in increasing their citation possibilities (Fig. 9), especially international collaboration for Gold OA articles (see "Appendix"). Finally, it should be also mentioned the great influence that specialisation has, along with some OA types, on the increase of the probability of being cited (Fig. 10). This increase is especially significant for Bronze OA when it is published in *Immu* (OR 1.66, $p < 0.001$), but also for Gold OA and *Immu* (OR 1.61, $p < 0.001$).

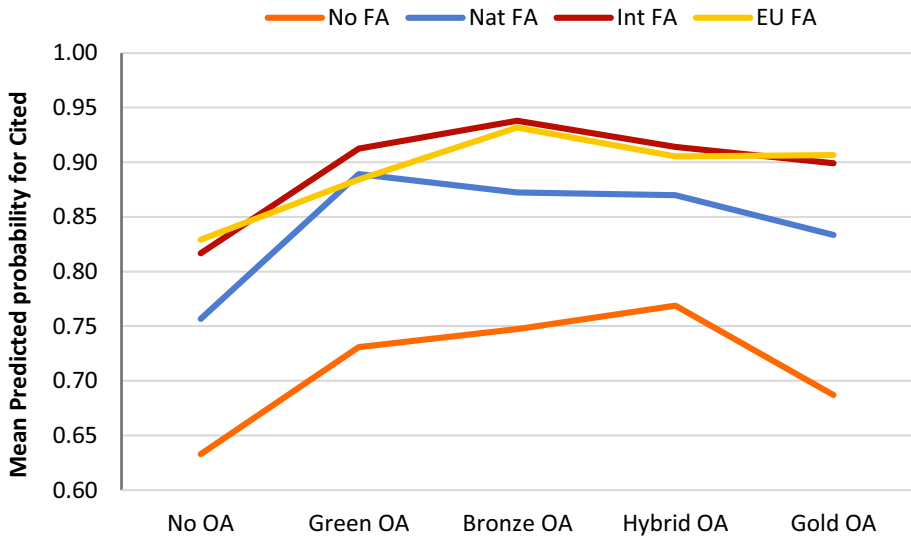**Fig. 8** Mean predicted probability for Cited by OA Types and FA Types
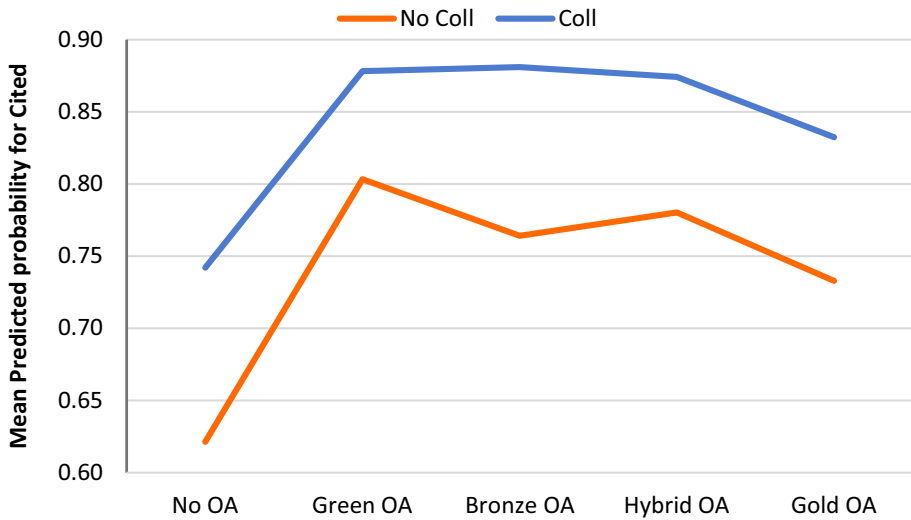

Fig. 9 Mean predicted probability for Cited by OA Types and No Coll/Coll
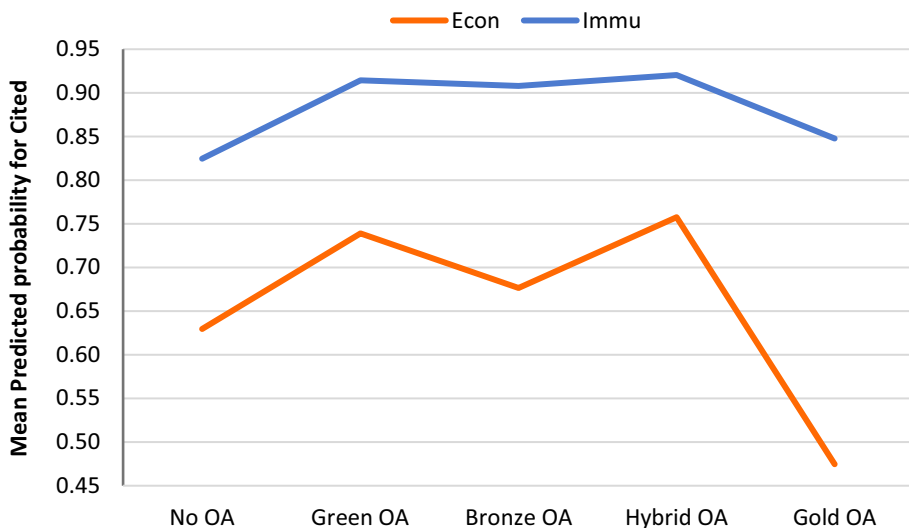
Fig. 10 Mean predicted probability for Cited by OA Types and Field

Discussion

Up to date, the OA publication is still quite scarce, representing around 35% of the articles written in English in the analysed WoS databases (SCIE and SSCI). Even so, in previous works, a rapid growth of this type of publications has been described, including the years of OA consolidation (e.g. Laakso et al. 2011). The results obtained show that the likelihood of finding an OA publication is related to the presence of FA (mainly from the EU sources, as anticipated in the first hypothesis), collaboration (chiefly international, as supposed in the second hypothesis) and to a greater number of citations (citation advantage), as expected in the third hypothesis. Further to this, the probability for OA rises in particular with some interactions. For instance, OA articles are more likely when there is collaboration and FA at the same time (especially if both are of international origin), when there are synergies between citations and international FA, or if there is an interaction between international FA and *Immu*. The last one is clearly influenced by the proportion of this type of funds in *Immu*. In any case, these connections highlight the importance of funding for OA publishing as predicted in the first hypothesis. This is consistent with the fact that funding agencies include specific requirements regarding the open publication of results sponsored by them and it is the reason why several authors have studied the fulfilment of these requirements (e.g. Larivière and Sugimoto 2018, Pinfield 2010, Wang et al. 2015a).

Additionally, the probability of finding FA in documents increases with Green OA, and with the presence of international collaboration, high citations and research at *Immu*. Although the Green OA type is partially hidden by the order established in this study, its effect on FA is greater than that of other OA types, probably influenced by Green OA mandates, as stated by Björk et al. 2014. Besides, the occurrence of FA rises with the interaction between OA articles and collaboration, favouring especially Gold OA and Bronze OA items when it is international. This is surprising, considering that the Gold OA publication is the one with the least relation to funding. However, the case of the Gold OA type can be

explained by better access to funds through international cooperation, which can be dedicated to support the APC (as Valderrama-Zurián et al. 2019 point out). On the other hand, in the general distribution of documents, it can be seen how the combination between FA and collaboration benefits citation, as it was already detected in previous works, especially for international funds (e.g. Álvarez-Bornstein et al. 2019, Morillo 2019). Moreover, in this study, it has been found that OA publication improves the citation possibilities of this interaction. In fact, Gargouri et al. (2010) find that OA articles obtain higher citation rates regardless of the year, impact factor, number of authors, references, pages, discipline, type of article and country. Piwowar et al. (2018) point out a possible explanation, that greater access to published research may help to obtain a citation advantage, although causality is difficult to establish.

Furthermore, the impact is influenced by OA types. Thus, in the present work, citation likelihood is higher for Hybrid OA publications in line with Eysenbach (2006) and Cintra et al. (2018), since they observe a greater impact on Hybrid OA than on Green OA, although in both of them they find a citation advantage. Besides, the present work includes early citations, which benefit Hybrid OA publications, as they offer faster access. However, in the work by Piwowar et al. (2018) the citation is slightly higher in the Green OA type, followed closely by those of Hybrid OA. Even so, Green OA is somewhat hidden because the other OA types are also put first. For their part, Zhang and Watson (2017) observe that Green OA type is the most common and they do not find significant differences with the citation rates of Gold OA. Nonetheless, in their study, the latter also includes Hybrid OA which, when considered separately, does show higher citation rates. In fact, the last hypothesis of the present study expected that the Gold OA type had less chances of being cited. The results, although not significant, show a lower probability for this OA type, in line with Perianes-Rodríguez and Olmeda-Gómez (2019), who indicate that while the proportion of publications in Gold OA journals increases, the same is not observed for citations. On the other hand, Van Leeuwen et al. (2018) analyse the Gold OA output of three European countries, finding lower impact for the OA results and also a scarce presence of this type of publications (10% at best), although this trend is changing over the years. Similarly, the study by Piwowar et al. (2018) find that Gold OA has a growing presence, although the impact is low and seems to show a decrease, at least in the short term. Notwithstanding, the citation possibilities of certain OA types can experiment an increment with the presence of some interactions. For instance, international collaboration in Gold OA articles shows a higher proportion of citations. This relationship is in line with Breugelmans et al. (2018), because these authors find that OA and international collaboration are important in increasing the impact of publications. Nevertheless, they also find a few exceptions, because cooperation with European countries is not the same as cooperation between sub-Saharan African countries, as the latter not only does not increase the citation rate, but also decreases it.

Apart from that, important differences between disciplines can be observed. Thus, for example, in 2017, the discipline of *Econ* barely publishes 15% in OA, while *Immu* publishes more than 50% of its articles. These differences between disciplines have also been described previously. For instance, Piwowar et al. (2018) find that biomedical research publishes almost 60% in OA, especially in the Bronze OA type, although they also observe a high representation for articles published in Gold OA. In the case of the Social Sciences, these authors find a scarce publication in OA (just over 25%), being the Green OA type the one that obtains the maximum representation. In the present study, and according to the prevalence established in the methodology, the Gold OA type has the greatest presence in

Immu, since it accounts for more than 40% of its publications in OA, although Bronze OA is the second option. In the case of *Econ*, the latter is the one that reaches the maximum representation of the OA, although Hybrid OA and Green OA follow closely. Besides, collaboration is field dependent, because *Econ* presents less cooperation than *Immu*, although with higher proportion of international cooperation. Nonetheless, the probability of finding an OA publication increases with international collaboration in *Immu*, perhaps because of its greater presence of OA and Gold OA (related to international cooperation as explained above). Another difference between both disciplines is found in the usage count, since *Econ* shows higher values than *Immu*. This could be explained by its lower rates of OA publishing, as the usage count seems to be inversely related to open research, possibly because these publications can be accessed from multiple data sources. It should not be forgotten that the usage count is a tool of the WoS database and is limited to the information collected there. Nevertheless, this indicator is directly related to the presence of funding and to the presence of citations, as Chi et al. 2019 already observed.

Regarding impact, Sotudeh and Estakhr (2018) presuppose that citation advantage will not be the same for the different disciplines in the area of Social Sciences and Humanities. The results of the present study corroborate this, since *Econ* has less citation advantage than *Immu*, which is related to their different citation habits and to the fact that early citations are included. These differences in citation by discipline are also stated by Norris et al. (2008), as well as the dissimilar percentages of OA items and the various characteristics of each discipline that probably explain the disparities. Moreover, as revealed in the results, when published in *Immu*, Bronze OA and Gold OA increase the probability of being cited. This probability may be due to the greater weight of these types in *Immu* combined with the fact that they offer faster access, thus, there is a *knowledge translation advantage*, as Eysenbach (2006) states. That is, consumers and policy makers can acquire knowledge in a more accelerated manner. Notwithstanding, although there is some consensus on the OA citation advantage, there is no agreement on the underlying reasons. This is why Sotudeh (2019) decides to study whether citation is related to the topic. She concludes that while there are differences in citation according to the type of research topic, within each of them there is a citation advantage for OA publications, something also confirmed in the present work.

Limitations

Firstly, the results and conclusions derived from this paper should be framed within the studied research fields and period. Nevertheless, given that two disparate disciplines have been selected, it is possible to venture that the research published in OA will have equally beneficial results for other areas. This advantage of OA is understood in a broad sense, including all types of OA publications.

Secondly, this paper analyses OA articles as collected by the WoS databases, so not everything published in open is taken into account, especially in the cases of Green, Bronze or Hybrid publications. In addition, this study avoids duplication by choosing first the publishers OA types. Therefore, much of the Green OA type is hidden. This also happens in the work by Piwowar et al. (2018), who also indicate that information is lost from some institutional or thematic repositories and point that many authors carry out a retroactive self-archiving, which will increase access to the oldest literature in the future, but not in the present. This loss of Green OA publication is greater if a broader definition is used; covering any location other than that found in institutional repositories, such as departmental or personal web pages (Björk et al. 2014).

Thirdly, considering the data source of this study (scientific production collected in WoS), it is not possible to venture anything about the researchers' decisions regarding the publication of their articles. To analyse these decisions, it would be necessary to have supplementary information, which is beyond the scope of this work. What is analysed in this paper is the probability of finding a WoS article published in OA, based on certain characteristics of documents (especially the presence of funding, collaboration and impact).

Fourthly, a relatively recent year has been selected to obtain a greater proportion of OA articles, since in previous works it has been found that this increases over time (e.g. Piwowar et al. 2018). For this reason, as citations take time to occur, it must be considered that part of the ones studied here are very recent and that this negatively affects the research carried out in fields that use older literature. Nonetheless, it is interesting to examine to what extent the OA publication facilitates faster access to research results and their subsequent recognition through citations.

Finally, regarding the study of FA, limitations of the acknowledgements collected in publications must be taken into account, because they do not always include all the monetary support received and are only a partial result of the research carried out (as pointed out by Morillo and Álvarez-Bornstein 2018).

Conclusion

The findings obtained in the present study highlight the usefulness of OA publishing in accelerating access to quality research that serves to produce new knowledge. They also demonstrate that OA is related to greater funding, collaboration and impact of research. Although it is difficult to determine the cause-effect, greater funding and collaboration can encourage OA publishing and both can favour the citation advantage. However, other factors are expected to come into play once the OA becomes more represented. In any case, it is important to take into account the differences between research fields, both in OA publishing habits and in the support received to increase this access. In fact, in social sciences and humanities, the OA journals offer remains scarce and tends to have less impact. Funding bodies should be aware of these particularities when articulating their measures to stimulate the OA to new knowledge and encourage the creation of resources for the dissemination of information without compromising the quality of research.

Appendix

See Tables 6, 7, 8, 9 and 10.

Table 6 Logistic regression for the OA presence/absence with some interactions between variables

	Model 2: FA Types * Coll Types				Model 3: FA Types * Cited				Model 4: FA Types * Field			
	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR
No FA versus												
Nat FA	0.542	0.054	0.000	1.720	0.503	0.054	0.000	1.654	0.301	0.044	0.000	1.352
Int FA	0.398	0.136	0.003	1.489	0.528	0.107	0.000	1.696	0.408	0.079	0.000	1.504
EU FA	0.825	0.156	0.000	2.281	1.025	0.151	0.000	2.786	0.729	0.092	0.000	2.074
No coll versus			0.000									
Nat Coll	− 0.081	0.052	0.122	0.922	0.021	0.031	0.493	1.022	0.022	0.031	0.477	1.022
Int Coll	0.140	0.059	0.018	1.151	0.327	0.033	0.000	1.387	0.303	0.033	0.000	1.354
Cited					0.140	0.049	0.004	1.150				
No cited versus											0.000	
Low cited	0.057	0.034	0.090	1.059					0.056	0.034	0.097	1.058
Medium cited	0.318	0.035	0.000	1.374					0.312	0.035	0.000	1.366
Highly cited	0.611	0.036	0.000	1.842					0.612	0.036	0.000	1.845
References	0.003	0.000	0.000	1.003	0.003	0.000	0.000	1.003	0.002	0.000	0.000	1.002
Usage count	− 0.026	0.002	0.000	0.975	− 0.020	0.001	0.000	0.980	− 0.026	0.002	0.000	0.974
Immu versus Econ	1.512	0.027	0.000	4.535	1.489	0.027	0.000	4.432	1.117	0.044	0.000	3.055
FA types * coll types												
Nat FA by Nat Coll	0.125	0.066	0.057	1.133								
Nat FA by Int Coll	0.189	0.074	0.011	1.208								
Int FA by Nat Coll	0.407	0.156	0.009	1.502								
Int FA by Int Coll	0.534	0.148	0.000	1.706								
EU FA by nat coll	0.225	0.190	0.235	1.253								
EU FA by int coll	0.342	0.175	0.050	1.408								
FA types * cited												
Nat FA by cited					0.212	0.061	0.001	1.236				
Int FA by cited					0.400	0.115	0.000	1.492				

Table 6 (continued)

	Model 2: FA Types * Coll Types				Model 3: FA Types * Cited				Model 4: FA Types * Field			
	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR
EU FA by cited					0.118	0.162	0.468	1.125				
FA types * field												
Nat FA by Immu									0.579	0.056	0.000	1.784
Int FA by Immu									0.659	0.092	0.000	1.933
EU FA by Immu									0.590	0.116	0.000	1.805
Constant	− 2.304	0.047	0.000	0.100	− 2.341	0.047	0.000	0.096	− 2.180	0.042	0.000	0.113
Nagelkerke R Square	0.243				0.235				0.246			

OR odds ratio = Exp(B)

	Model 4: Coll Types * Field			
	B	S.E.	Sig.	OR
No FA versus				
Nat FA	0.652	0.027	0.000	1.920
Int FA	0.808	0.043	0.000	2.243
EU FA	1.058	0.057	0.000	2.880
No coll versus			0.007	
Nat coll	0.012	0.053	0.819	1.012
Int coll	0.139	0.050	0.006	1.149
No cited versus				
Low cited	0.058	0.034	0.084	1.060
Medium cited	0.318	0.035	0.000	1.374
Highly cited	0.611	0.036	0.000	1.842
References	0.003	0.000	0.000	1.003
Usage count	−0.026	0.002	0.000	0.975
Immu versus Econ	1.396	0.052	0.000	4.041
Coll types * Field				
Nat Coll by Immu	0.036	0.065	0.584	1.036
Int Coll by Immu	0.267	0.065	0.000	1.306
Constant	−2.322	0.045	0.000	0.098
Nagelkerke R Square	0.243			

Table 7 Logistic regression for the OA presence/absence with interactions between Coll Types and Field

OR odds ratio = Exp(B)

Table 8 Logistic regression for the FA presence/absence with some interactions between variables

	Model 2: OA Types * Coll Types				Model 3: OA Types * Cited				Model 4: OA Types * Field			
	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR
No OA versus												
Green OA	0.721	0.131	0.000	2.057	0.654	0.132	0.000	1.923	0.496	0.088	0.000	1.642
Bronze OA	0.581	0.087	0.000	1.787	0.617	0.092	0.000	1.853	0.291	0.070	0.000	1.338
Hybrid OA	0.675	0.116	0.000	1.965	0.773	0.124	0.000	2.166	0.573	0.074	0.000	1.773
Gold OA	0.452	0.074	0.000	1.571	0.287	0.072	0.000	1.332	−0.043	0.093	0.644	0.958
No Coll versus			0.000				0.000				0.000	
Nat Coll	0.432	0.031	0.000	1.541	0.451	0.027	0.000	1.570	0.451	0.027	0.000	1.570
Int Coll	0.751	0.033	0.000	2.120	0.821	0.029	0.000	2.273	0.803	0.029	0.000	2.232
Cited					0.300	0.028	0.000	1.350				
No cited versus												
Low cited	0.223	0.030	0.000	1.250					0.220	0.030	0.000	1.246
Medium cited	0.425	0.033	0.000	1.529					0.417	0.033	0.000	1.517
Highly cited	0.470	0.033	0.000	1.599					0.456	0.033	0.000	1.577
Usage count	0.013	0.001	0.000	1.013	0.015	0.001	0.000	1.015	0.013	0.001	0.000	1.013
Immu vs. Econ	1.152	0.025	0.000	3.165	1.159	0.025	0.000	3.187	1.007	0.027	0.000	2.736
OA Types * Coll Types												
Green OA by Nat Coll	0.549	0.167	0.001	1.731								
Green OA by Int Coll	0.124	0.162	0.442	1.133								
Bronze OA by Nat Coll	0.185	0.106	0.080	1.203								
Bronze OA by Int Coll	0.350	0.117	0.003	1.419								
Hybrid OA by Nat Coll	0.136	0.147	0.354	1.146								
Hybrid OA by Int Coll	0.139	0.146	0.341	1.149								
Gold OA by Nat Coll	−0.083	0.088	0.344	0.920								
Gold OA by Int Coll	0.392	0.109	0.000	1.479								

Table 8 (continued)

	Model 2: OA Types * Coll Types				Model 3: OA Types * Cited				Model 4: OA Types * Field			
	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR
OA Types * Cited												
Green OA by Cited					0.441	0.149	0.003	1.554				
Bronze OA by Cited					0.224	0.103	0.029	1.251				
Hybrid OA by Cited					0.051	0.139	0.711	1.053				
Gold OA by Cited					0.279	0.083	0.001	1.321				
OA Types * Field												
Green OA by Immu									0.965	0.129	0.000	2.624
Bronze OA by Immu									0.792	0.090	0.000	2.209
Hybrid OA by Immu									0.494	0.114	0.000	1.639
Gold OA by Immu									0.707	0.103	0.000	2.029
Constant	−0.959	0.030	0.000	0.383	−0.970	0.030	0.000	0.379	−0.923	0.029	0.000	0.397
Nagelkerke R Square	0.208				0.205				0.211			

OR odds ratio = Exp(B)

Table 9 Logistic regression for the presence/absence of citations with some interactions between variables

	Model 2: OA Types * FA Types				Model 4: OA Types * Coll				Model 3: OA Types * Field			
	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR
No OA versus												
Green OA	0.257	0.129	0.046	1.293	0.373	0.156	0.017	1.452	0.309	0.100	0.002	1.362
Bronze OA	0.323	0.087	0.000	1.381	0.319	0.099	0.001	1.376	0.187	0.077	0.015	1.206
Hybrid OA	0.538	0.117	0.000	1.712	0.496	0.137	0.000	1.642	0.480	0.084	0.000	1.616
Gold OA	−0.111	0.070	0.115	0.895	−0.170	0.083	0.040	0.844	−0.390	0.094	0.000	0.677
FA					0.311	0.026	0.000	1.365				
No FA versus												
Nat FA	0.217	0.030	0.000	1.243					0.239	0.027	0.000	1.270
Int FA	0.451	0.064	0.000	1.570					0.533	0.054	0.000	1.705
EU FA	0.634	0.096	0.000	1.886					0.630	0.077	0.000	1.878
Coll					0.263	0.031	0.000	1.301				
No Coll versus												
Nat Coll	0.222	0.031	0.000	1.248					0.221	0.031	0.000	1.247
Int Coll	0.375	0.033	0.000	1.455					0.370	0.033	0.000	1.448
References	0.012	0.001	0.000	1.012	0.012	0.001	0.000	1.012	0.012	0.001	0.000	1.012
Usage count	0.078	0.002	0.000	1.082	0.079	0.002	0.000	1.082	0.078	0.002	0.000	1.081
Immu versus Econ	1.275	0.029	0.000	3.579	1.245	0.028	0.000	3.474	1.184	0.032	0.000	3.267
OA Types * FA Types			0.045									
Green OA by Nat FA	0.383	0.157	0.015	1.466								
Green OA by Int FA	0.275	0.237	0.246	1.316								
Green OA by EU FA	−0.227	0.318	0.477	0.797								
Bronze OA by Nat FA	0.175	0.107	0.101	1.191								
Bronze OA by Int FA	0.594	0.190	0.002	1.812								
Bronze OA by EU FA	0.340	0.287	0.236	1.404								
Hybrid OA by Nat FA	0.087	0.147	0.554	1.091								

Table 9 (continued)

	Model 2: OA Types * FA Types				Model 4: OA Types * Coll				Model 3: OA Types * Field			
	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR	B	S.E.	Sig.	OR
Hybrid OA by Int FA	0.119	0.239	0.619	1.126								
Hybrid OA by EU FA	−0.091	0.277	0.743	0.913								
Gold OA by Nat FA	0.096	0.086	0.267	1.100								
Gold OA by Int FA	0.263	0.161	0.102	1.301								
Gold OA by EU FA	0.156	0.235	0.507	1.169								
OA Types * Coll												
Green OA by Coll					0.184	0.172	0.285	1.202				
Bronze OA by Coll					0.239	0.112	0.032	1.271				
Hybrid OA by Coll					0.163	0.155	0.293	1.177				
Gold OA by Coll					0.182	0.092	0.049	1.199				
OA Types * Field												
Green OA by Immu									0.366	0.135	0.007	1.441
Bronze OA by Immu									0.505	0.099	0.000	1.657
Hybrid OA by Immu									0.268	0.132	0.042	1.308
Gold OA by Immu									0.478	0.105	0.000	1.613
Constant	−0.979	0.036	0.000	0.376	−1.301	0.048	0.000	0.272	−0.960	0.035	0.000	0.383
Nagelkerke R Square	0.221				0.217				0.222			

OR odds ratio = Exp(B)

Table 10 Logistic regression for the presence/absence of citations with interactions between OA Types and Coll Types

	Model 4a: OA Types * Coll Types			
	B	S.E.	Sig.	OR
No OA versus				
Green OA	0.373	0.156	0.017	1.453
Bronze OA	0.318	0.099	0.001	1.375
Hybrid OA	0.492	0.137	0.000	1.636
Gold OA	−0.177	0.083	0.032	0.838
No FA versus				
Nat FA	0.245	0.027	0.000	1.278
Int FA	0.539	0.054	0.000	1.714
EU FA	0.634	0.077	0.000	1.885
No Coll versus				
Nat Coll	0.183	0.034	0.000	1.201
Int Coll	0.340	0.037	0.000	1.404
References	0.012	0.001	0.000	1.012
Usage count	0.078	0.002	0.000	1.082
Immu versus Econ	1.279	0.029	0.000	3.591
OA Types * Coll Types				
Green OA by Nat Coll	0.328	0.190	0.085	1.388
Green OA by Int Coll	−0.022	0.186	0.906	0.978
Bronze OA by Nat Coll	0.213	0.120	0.077	1.237
Bronze OA by Int Coll	0.220	0.130	0.091	1.246
Hybrid OA by Nat Coll	0.118	0.172	0.493	1.125
Hybrid OA by Int Coll	0.118	0.171	0.490	1.125
Gold OA by Nat Coll	0.142	0.097	0.145	1.152
Gold OA by Int Coll	0.272	0.114	0.017	1.313
Constant	−0.972	0.036	0.000	0.378
Nagelkerke R Square	0.221			

OR odds ratio = Exp(B)

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