Compliance with open access mandates and its effects on research visibility: the case of the Spanish National Plan of R&D

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Abstract

This paper evaluates the Spanish open access (OA hereafter) mandate and its effects on Spanish research from 2014 to 2019. First, the degree of compliance with the mandate is studied. Then, classification trees and regression models are applied to determine the factors correlated with publishing in OA and the implications of OA types regarding the impact and visibility of academic articles. Results show that the compliance rate increased by 9% during the studied period, with a prevalence of gold and green OA routes. Moreover, the classification tree points towards the institutions' nature and the research areas as the variables that better explain OA publishing. We argue that the institutions' commitment to OA and the different availability of OA journals within research fields influence the decision to publish in OA. Last, we study how these practices affect research's visibility and impact. We found that, in general, publishing in OA is beneficial for researchers, especially if they choose the green route. Further research at the faculty or departmental level might help discern the best strategies to encourage open-access publishing.

Keywords

Open Access Mandates; Open Science; Spain; gold OA; green OA

1. Introduction

Open access mandates are policies that encourage the free distribution of research outputs, making them accessible to everyone. Several studies tested the effects of OA mandates on

research publishing behavior (Larivière & Sugimoto, 2018; Xia et al., 2012). In Spain, the mandate was implemented in 2013 for publicly funded investigations. Scholarly articles studying its implications were carried out very shortly after the mandate was implemented (Borrego et al., 2016; Melero et al., 2018), so effects in the medium and long term are still unknown. Therefore, this article studies compliance with the mandate in the medium term (2014-2019). We focus on the results published as a result of the two main national calls for basic funding: *Challenges of Society* (oriented research toward pre-existing goals) and *Generation of Knowledge* (non-oriented research) under the Spanish National Plan for the Generation of Knowledge and Scientific and Technological Strengthening of the R&D&I, which holds a specific OA mandate. In addition, we study the variables that influence the decision to publish in OA to understand better the factors that could improve OA practices in the future. Lastly, we analyze the effect these practices have on the impact and visibility of research.

The article is organized as follows: Section 1 includes a brief literature review of OA studies, the particular situation of Spain concerning OA initiatives and, more specifically, OA mandates, and the paper's main objectives and research questions. Section 2 and Section 3 detail the data and the statistical methods used in the analysis. The main results are provided in Section 4, which is divided into subsections that intend to answer the three research questions. Lastly, Section 5 discusses the results and concludes.

1.1 Literature review

1.1.1 Open access: definition and implementation

Open Science (OS) has been conceptualized in multiple ways, and it is often related to the practices associated with creating transparent, accessible, shared, and collaborative knowledge (Vicente & Martínez, 2018). Other definitions have emphasized the social role of science, defining OS as an 'open and collaborative science with and for society' (Anglada & Abadall, 2018). Within these definitions, the public and free availability of the research results has become a central element of the OS Paradigm, which has quickly crystallized in the emergence of the OA routes (De Filippo & Mañana-Rodriguez, 2020).

Emerging as a result of the growth of online subscription journals and the so-called serial crisis of the 1990s (Laakso et al., 2011), OA became a structured reality fostered by several declarations such as the Budapest Open Access Initiative (2002) or the Berlin Declaration (2003). Given that OA is usually understood as an element of Open Science, developments on

OS also affect OA –for instance, the European Open Science Cloud (EOSC, European Commission, 2016) or the Open Science Monitor (European Commission, 2023) as well as the Open Science Policy Platform, which advised the commission concerning the future development and application of OA policies. Europe's commitment to the publication of research results in OA sets a precedent with the pilot project developed in the Seventh Framework Program (FP7) for the publication of research results in OA, which becomes a mandate for Horizon 2020 (European Commission, 2016) and with the creation of OpenAIRE[1], a digital infrastructure that harvests published results which received funding from the European Commission.

In addition and within the initiatives that directly affect OA, Plan S[2] is particularly relevant. Plan S is a scheme conducted by the cOAlition S platform that establishes a ten-point roadmap tackling issues such as copyright management, criteria for assessing OA journals, the coverage of OA fees, and other relevant questions to foster the materialization of generalized OA publication of research results. The new cOAlition S proposal (Stern et al., 2023) recognizes the advances since the publication of the Plan S principles while proposing a new vision and set of principles reaffirming all actors' responsibility towards open science.

One of the first but still relevant arguments for OA is that research funded with public funds should be publicly available so the monetary investment is returned to society through scientific knowledge (Kirspop, 2008). This idea, along with the successive declarations made by the European Commission and other institutions, was a turning point in the evolution of OA and grounds for the so-called OA mandates. OA mandates are regulations developed by R&D institutions that offer guidelines for making publicly funded research freely available. To do so, mandates set goals in terms of the desired volume of OA publications (see ROARMAP[3], a database extensively covering such regulations and norms; Dawson, 2013). As a unified framework does not exist, the specific requirements of each mandate vary depending on the institution and country. One of the main differences among mandates is their degree of strictness and the consequences of non-compliance. The development of infrastructures to support the practical implementation of OA mandates is also a phenomenon of growing importance. One of its most relevant exponents is Open Research Europe (European Commission, 2022), a publication platform created and maintained by the European

[1] https://www.openaire.eu/
[2] https://www.coalition-s.org/plan_s_principles/
[3] https://roarmap.eprints.org/

Commission for research funded by the H2020 program. It enables the immediate OA publication of results and allows the open peer review of the published articles.

1.1.2 The study of Open Access in the academic literature

In the past years, scholars have studied the effects and implications of Open Access from multiple angles. In this sense, academic research has addressed the distribution of OA publications by type of OA, fields of knowledge and funding agencies (Larivière & Sugimoto, 2018), OA's relationship with citations (Pinowar et al., 2018; Science Metrix, 2018; Gumpenberger et al., 2013; Suber, 2012; Bautista-Puig et al., 2020 or Torres-Salinas et al., 2018), the different levels of access to OA (Elbaek, 2014; Bosman & Kramer, 2018) or the implications of OA policies (European Commission, 2016; FECYT, 2016). Gold OA has been an especially recurring research object within the OA academic literature. This type of OA has important economic and ethical implications as it often implies the existence of Article Processing Charges paid by the author to publish an article in OA in a subscription journal (Crawford, 2019; Pinowar et al., 2019; Robinson-Carcía et al., 2020). These studies also highlight the growth of gold OA compared with other OA types (Khoo, 2019).

Academic literature studying compliance with OA mandates has also risen, including new perspectives and analyses. Works on OA mandates include topics such as the case of university networks (De Filippo & Mañana-Rodriguez, 2022), specific funding programs like the European Commission FP7 (De-Castro & Franck, 2018), the role of public policies increasing citations to OA publications in PubMed (De Groote et al., 2015). Other studies also study the factors that might prevent scholars from publishing in OA, which is essential to understanding how and why OA mandates work or do not work. Crawford (2019) shows how the number of journals that charge Article Processing Charges (APCs) over the total number of journals varies across disciplines, representing 70% of journals in Biomedicine and STEM areas and 22% in Humanities and Social Sciences. APCs are an important factor for publishing in OA, as researchers have limited funds. In a recent study, Mañana-Rodriguez & Guns (2022) evidence the significant differences between areas in the availability of OA journals, thus punishing authors that might be willing to share their research in open access. Walters and Linvill (2011) researched 663 OA journals across six subject areas and found that 90% of journals with Impact Factors (IF) belonged to biology or medicine. As research evaluation agencies require researchers to publish in high IF journals, the non-availability of OA journals in some research areas might punish authors publishing in Open Access.

1.1.3 The case of Spain

Spanish Open Access regulation

Europe's commitment to open science has been taken up at the national level by different countries through the development of specific strategic plans to move towards more open science models, as in the case of Finland, the Netherlands, Portugal, France or Greece (De Filippo & Sastrón-Toledo, 2023). Likewise, Spain recently published its *Open Science National Strategy 2023-2027*. This strategy aims to bring together the OS measures and commitments that Spain has adopted to coordinate a strategy for their proper implementation. The document makes a diagnosis of the main strengths and weaknesses of the Spanish R&D system in the inclusion of open science practices and proposes four strategic objectives around which to work: *"*(1) guarantee the existence of digital infrastructures, (2) promote the proper management of research data, (3) implement free and open access by default to publications and scientific results financed directly or indirectly with public funds for all citizens, and (4) establish new mechanisms for evaluating research and a system of incentives and recognition aimed at promoting open science practices" (Ministry of Science and Innovation, 2023). However, as this work analyses the period between 2013 and 2019, evaluating the actions proposed by the strategy is outside the scope of the work.

Back to 2011, the Spanish Law of Science, Technology, and Innovation (Law 14/2011) already dedicated an article (number 37) to the dissemination of open access results, which includes a specific mandate stating that "researchers whose research activity is mainly financed with funds from the General State Budget shall make public a digital version of the final version of the contents accepted for publication in serial or periodical research publications, as soon as possible, but no later than twelve months after the official date of publication" (España, 2011). The recent modification of the law (Law 17/2022) extends the previous coverage to include "research data, code and methodologies" and requires publication on repositories to be "simultaneous with the official date of publication in other sources" (España, 2022). The new University System Law (Law 2/2023) also refers to Open Science and goes a step beyond by defining scientific knowledge as a "common good" (España, 2023). While previous Laws only recommended it, the 2/2023 Law also requires regional institutions to include the open publication of research results in the evaluation processes of researchers. The new mandate also overcomes the previous exceptions to the mandate, which included the possible agreements between authors and third parties regarding intellectual property rights, which are

now excluded from the regulation. Again, as this work analyses the period between 2013 and 2019, it will only consider the requirements of Law 14/2011, where exceptions were still considered. These exceptions included the transference of industrial and intellectual rights to third parties as a request of the authors and when research results have to be protected (España, 2011). In practical terms, the exception allows the authors to skip the OA mandate if they publish in a journal whose license prevents them from openly publishing the results. Furthermore, there are no consequences for non-compliance with Spanish regulations.

Apart from legislation, multiple national institutions have developed declarations and long-term strategies, although these are mere objectives and recommendations not enforced by law (FECYT, 2022; CRUE, 2019). Individual universities have also developed OA regulations, although at very different times. For instance, the Universitat Oberta de Catalunya (UOC) and the Universidad Politécnica de Madrid (UPM) developed their regulations in 2010, before the 14/2011 Law was launched, while others just did it ten years later (Universidad Rey Juan Carlos in 2020). For a deeper analysis of OA implementation in Spanish universities, refer to De Filippo and Mañana-Rodríguez (2022). Spanish universities have also joined international networks such as YERUN, YUFE, and YUFERING, where Open Science pilots were developed and implemented.

In order to facilitate OA publication, Spanish institutions, like other institutions internationally, have signed some kind of transformative agreements with academic publishers. Transformative agreements refer to contractual arrangements between publishers and institutions. In these agreements, institutions pay a specified sum to cover the costs associated with publishing a limited number of articles in open access (OA). Additionally, these agreements may encompass subscription expenses or, in certain instances, provide unrestricted access to publications within the journals specified in the contract (Borrego et al., 2020). For example, the Spanish National Research Council (CSIC) developed an 'Open Access Publishing Support Programme,' providing financial aid to cover article processing charges (APCs). Baquero-Arribas et al. (2019) calculated that for OA articles 'published between 2008 and 2018 by CSIC's authors, the Open Access Publishing Support Programme granted a discount to 10% of them'.

Previous research has analyzed the compliance of Spanish research institutions with OA mandates and regulations focusing on universities (Melero et al., 2018), regional research centers (Rovira et al., 2019), the National Research Council (Baquero-Arribas et al., 2019) or regional health services (Rodríguez Otero, 2022). As each institution has different research

practices and policies[4], its behavior regarding OA publishing highly varies. For instance, Melero found that OA rates in universities ranged from 1% to 63% of the publications between 2012 and 2014. In their study of Catalonian CERCAS, Rovira and colleagues found that 75% of the articles published between 2011 and 2015 were openly available. Besides these institution-specific studies, R&D projects' general compliance with the national OA mandate has yet to be evaluated.

The Spanish National Plan

The historical development of the Spanish R&D system has placed the funding of competitive projects as the primary implementation mechanism of R&D policy (Sanz Menéndez, 1997). Competitive projects constitute the main funding source for researchers and precious merit for academic promotion (Molas-Gallart, 2012). Since many competencies (higher education, health research institutes, and agricultural research centers) related to science and technology are administered by the different regions that constitute the country (Sanz Menéndez & Cruz Castro, 2005), national and regional funding instruments coexist. We focus on funding instruments under the Spanish National Plan for the Generation of Knowledge and Scientific and Technological Strengthening of the R&D&I, Spain's main R&D implementation plan[5]. The Spanish Research State Agency (AEI) manages the actions behind this plan. The two main AEI's calls for basic research funding are *Challenges of Society* (oriented research toward pre-existing goals) and *Generation of Knowledge* (non-oriented research). Both calls are aimed at research groups. Proposals are subject to an *ex-ante* evaluation consisting of a peer review process and a subsequent expert panel. The project's duration is three years, with the possibility of an extension of one year. In addition, the proposals that obtain the best evaluation include obtaining a 4-year predoctoral contract to carry out the project. Funding covers costs related to conferences, purchasing of material and equipment, article processing charges, intellectual or industrial property costs, and the possibility of recruiting a new person for the research group (it is not allowed to cover the costs of staff already associated with the research group) which in most of the cases is not possible due to the size of budgets.

[4] Within the term 'policy,' we consider a different sect of actions in favor of promoting OA. This includes recommendations, mandates, and requirements (i.e., promotion criteria).

[5] Since regions have different R&D strategies and priorities, regional competitive funding projects remain out of the scope of this work. However, it could be interesting to study OA mandates compliance differences within regions in future works.

Regarding open access, the call states that the research outputs of funded projects have to be published in a public repository between 6 and 12 months after publication, according to the 14/2011 law. It also requires that the projects' proposals must specify their OA plans. However, projects are not evaluated *ex-post*; thus, compliance with the mandate is unknown.

Research evaluation

A relevant issue in the case of Spain is that of individual evaluations rather than organizational ones (Cruz-Castro & Sanz-Menéndez, 2007). Tenured researchers are subject to two types of individual performance assessments at the national level: *habilitation* and *sexenios*. *Habilitation* is required to enter different positions at public research organizations and is managed by ANECA (the National Agency for Quality Evaluation and Accreditation). *Sexenios* review the scientific quality of researchers over six-year periods and are managed by CNEAI (the National Commission for the Evaluation of Research Activity). A positive evaluation implies a salary increase and a reduced teaching volume. In both evaluations, journal quartiles in WoS and Scopus are considered. Therefore, the likelihood of Spanish researchers publishing in OA might be influenced by whether they can fulfill these conditions. However, the effects of following the OA mandates for the researchers have not been studied.

1.2 Objectives and research questions

Despite *Challenges of Society* and *Generation of Knowledge* (hereafter CKG as Challenges and Knowledge Generation) calls being the main funding instruments in Spain, general compliance with its OA dispositions has yet to be discovered (see Borrego, 2016 work on R&D projects in 2011). This research has the main objective of analyzing CKG calls publication data to identify the degree of compliance of the publications with the national OA mandate. The article also explores the factors that might be related to the decision to publish in OA and the effect that publishing in OA might have on the publications. In particular, the article aims to answer the following research questions:

RQ1. What is the level of compliance with the national Spanish OA mandate of the publications funded by the CKG calls?

RQ2. Which are the factors influencing compliance with the Spanish OA mandate?

RQ3. Is compliance with the Spanish OA mandate beneficial for the researchers in terms of the impact and visibility of their publications?

2 Data

This study uses two datasets: a table with all the final resolutions of CKG calls from 2014 to 2019 and the articles the accepted projects indexed in the Web of Science produced.

2.1 Projects' data

The final resolutions CKG calls from 2014 to 2019 were extracted from the Spanish National Research Agency's website. All resolutions were downloaded in PDFs and then converted to tabular data using tabula-py 2.5.1, a Python library designed for reading the information in PDFs. We retrieved information on the 16.823 projects accepted from 2014 to 2019, as the ones accepted after 2019 did not have any publications by the download date (February 2, 2022). This dataset contains information such as the project's budget, the awarded institution, the research area, and the grant number.

After retrieving all the information, we manually grouped the different institutions according to the taxonomy of the Spanish Science, Technology, and Innovation Information System (SICTI)[6]. The different types of institutions considered are:

- Universities: Spain has 93 higher education institutions: 51 public and 42 private. As Melero et al. (2018) pointed out, there are huge differences within universities' OA policies; some hold mandates (with different requirements), while others just include recommendations. All public universities have repositories, while only some private universities have them.
- Public Research Organisations (PROs): Dependent on the General State Administration, these organisms are oriented towards scientific and technical research and technological services rendering activities. The main PROs are currently the Carlos III Institute of Health (ISCIII)[7], the Center for Energy, Environmental and Technological Research (CIEMAT), the Institute of Astrophysics of the Canary Islands (IAC), and the National Institute for Aerospace Technology (INTA). The Spanish National Research Council (CSIC) is also a PRO, but we have decided to differentiate it due to its autonomy, volume (number of researchers), and diversity (research areas).
- Spanish National Research Council (CSIC): Spain's most prominent public institution dedicated to research. It comprises 121 institutes and three national centers distributed

[6] https://www.ciencia.gob.es/Estrategias-y-Planes/Sistema-de-Informacion-sobre-Ciencia--Tecnologia-e-Innovacion--SICTI-/Red-Espanola-de-Centros-de-I-D-I--RECIDI-.html

[7] Apart from research activities, ISCIII also manages the different calls related to the Strategic Health Action funded by the Spanish Ministry of Science and Innovation.

across the Spanish regions. It has different OA policies such as research support services for OA publication (URICI Unit of Information Resources for Research), evaluation and promotion criteria that positively value OA publication, APC financial aids, and its own repository[8], among others (Baquero-Arribas et al., 2019).

- Regional R&D Centers: Research centers are dependent on the regional R&D administration. They have a high degree of autonomy (De Mendoza, 2021), meaning they sometimes develop their own OA strategies (see the case of IMDEA Nanoscience award[9] on promoting OS practices or the CERCA data management strategy[10]). They are highly visible (internationally) and competitive in national and international calls for projects. For example, CERCAs in Catalonia have been the eighth institution to receive more European funds since 2014 (Rovira et al., 2019), which makes them subject to the open science policies of the European Commission.
- Health Research Institutes: Hospitals with institutional accreditation for research with different research programs. Currently, 35 Health Research Institutes across 13 regions are accredited and coordinated by the ISCIII. The ISCIII has a strategy for promoting OA that provides recommendations to the different institutes[11]. It also has an institutional repository[12] where the different health research institutes can host preprints. On the other hand, there are institutes with their own strategies for promoting OA publication (see the case of the OS Commission at IIS-La Princesa[13] or the OS Strategy at IIS-Galicia Sur[14]).
- Innovation Hubs: Science and technology parks devoted to applied research. These institutions usually apply to innovation calls for projects. However, they also conduct basic research and, therefore, have some participation in the calls analyzed in this work. Their strategy regarding OA is subject to their own interest in fulfilling open science objectives. However, they are oftenly involved in European projects, which makes them dependent on the mandates of the European Commission.

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[8] https://digital.csic.es/

[9] https://nanociencia.imdea.org/home-en/news/item/the-imdea-nanoscience-open-science-project-receives-funding-from-fecyt-s-maria-de-guzman-call

[10] https://cerca.cat/wp-content/uploads/2022/08/OpenData-cat.pdf

[11] https://www.isciii.es/QueHacemos/Financiacion/IIS/PublishingImages/Paginas/Alianza-IIS/Informe_OA_Def_23%20nov.pdf

[12] https://repisalud.isciii.es/

[13] https://www.iis-princesa.org/publicaciones-open-science/

[14] https://www.iisgaliciasur.es/wp-co

- Private entities: Firms and foundations that conduct research. Private entities must comply with legal requirements but their internal regulations and strategies regarding OA might be completely different from one another.

2.2 Articles' data

The articles produced by the different projects were retrieved from Clarivate Analytics Web of Science (WoS) – 'Core Collection' and Science, Social Sciences and Arts & Humanities Citation Indexes (SCI, SSCI, AHCI, and ESCI) databases. The articles were identified through the funding acknowledgments field, which includes the funding agency and the grant number of the projects. A total of 80.243 articles were identified. All articles were published on or after 2014, as none of the projects had any publication in 2013. We stored all metadata provided by WoS.

Some data fields were transformed or added to the WoS download. First, we simplified the WoS's classification for open access. WoS uses a classification that identifies whether an article has green (submitted, accepted, published), gold, hybrid, or bronze access. We reduced green open access to just one category and recorded all possible interactions between categories. This is, an article can be green and gold, green and hybrid, green and bronze and green and paywall if it is published both in a journal and a repository, or gold, hybrid, bronze, and paywall if it is only published in a journal. Considering all possibilities allowed us to address the effects of each route better.

Second, WoS's research fields were reduced to the five WoS areas to increase the operability of the data. Therefore, the final research areas were Arts and Humanities, Life Sciences and Biomedicine, Physical Sciences, Social Sciences, and Technology.

Journals with high impact factors (JIF) attract more attention, so the articles published there might benefit from the higher visibility and citation count. Some studies have defined the JIF as the most important factor for citation impact in most disciplines (Boyack & Klavans, 2005). As impact factors vary from one research area to another, this report uses the journals' quartiles to measure their impact factor as they consider the relative position of the journals in their reference areas. The quartile ranking was extracted from the Journal Citation Reports (JCR) and added to the table.

Collaboration in research has been considered a cause of better performance in terms of output and impact (Beaudry & Allaoui, 2012). Therefore, we added two variables to assess the effects

of collaboration: the number of authors and the presence of international co-authors as a dummy variable.

Finally, we added some control variables previously studied in the academic literature. The number of cited references and other size measures of the title, abstract, and the article itself might also be relevant for predicting the articles' impact (Didegah & Thelwall, 2013). Also, publications with more external references might be cited more (Haslam et al., 2008; Kostoff, 2007).

3 Methods

3.1 Descriptive statistics

Descriptive statistics were used to study the evolution of the different types of OA articles during the period under study. The visuals of this analysis (Figures 1 and 2) are displayed using Tableau 2021.3. Articles were classified regarding the 'Open Access Indicator' field in WoS. If an article has more than one type of OA acknowledged in the field, it is assigned to both types. Consequently, the total sum of the percentages shown in the charts might be over 100%. Additional descriptives further explore the variables the decision tree and regressions find significant (see 3.2 Statistical analysis).

3.2 Statistical analysis

Decision tree

To identify variables that might predict the classification of the documents as open access or not, a CRT (classification and regression) decision tree was conducted in SPSS 21. The choice of this algorithm instead of others, such as CHAID, is twofold: On the one hand, the algorithm groups independent variables in two groups per split, which allows a clearer understanding of the tree. On the other hand, the depth of the tree is greater than three, which is particularly useful for the independent variables included since they present many categories.

The dependent variable was OA, a dichotomous variable that takes the value 1 if the document is in OA (in any of its routes) and 0 if not. The independent variables included are those with the lowest degree of redundancy or co-linearity and a manageable number of categories. These are Research Area 5 (a grouping of the WoS categories into a 5-discipline scheme), ESI Highly Cited Paper, ESI Hot Paper (both dichotomous, 1 meaning 'yes' and 0 meaning 'no), Predoctoral contract, meaning if the project was awarded 0, 1 or 2 predoctoral contracts and Type of Center, which presents seven types of organizations recipients of the research grants.

With a maximum depth of 5, the minimum number of cases for the parent node was set to 5000, and the minimum number of cases for the child node was set to 2500 to limit the total volume of nodes given that the total N exceeds 80,000. The type of validation chosen was cross-validation.

Regression analysis

We use regression analysis to explore the relationships between variables further. We used negative binomial regression as our response is an overdispersed count variable (Ajiferuke & Famoye, 2015). We use citation count from WoS as our response variable to address the impact of academic articles. Open access type is used as the primary predictor. Two additional models add control variables. First, research area and publication year. The third model adds a dummy for being published in a Q1 journal, a dummy for international collaboration, the number of authors, and controls for article measures, such as the length of the article, the length of the title, the number of author keywords, and the reference count.

4 Results

4.1 RQ1: compliance with the Spanish OA mandate

The descriptive statistics below show the compliance of the CKG's calls publications with the OA mandate.

Table 1 presents the absolute numbers and percentages of articles published by CKG projects between 2014 and 2019 and their availability in OA. More than half of the production is available in open access (63,6%), and Green access is by far the preferred route to publish, followed by Gold access. Note that researchers may publish simultaneously within different routes, i.e., upload the preprint to an open repository (green) and publish the final version in an OA journal, paying an APC (gold).

Table 1. Articles distribution by type of OA, absolute numbers (WoS, 2014-2019)

Access	Type of OA	Number of articles*	Number of articles**
Open Access	Bronze	5,334	51,028 (63.6%)
	Gold	17,652	
	Green	47,348	
	Hybrid	4,175	

Paywall	-	29,215	29,215 (36.4%)

*Includes duplicates since articles may be in one or more OA categories

**Does not include duplicates; the numbers are unique articles

Figure 1 shows the publication rate of the different types of OA in relation to the total number of articles published by CKG projects between 2014 and 2019. The percentage of OA articles published increased by 7.3% during the period under study. The figure shows that 35% of the articles produced with public funds were non-OA in 2020. The evolution of the four OA access types shows that Bronze is the only category that has decreased its volume from 7.19% in 2014 to 5.35% in 2019. Green articles account for the largest share of OA articles; gold experienced the highest growth (13%).

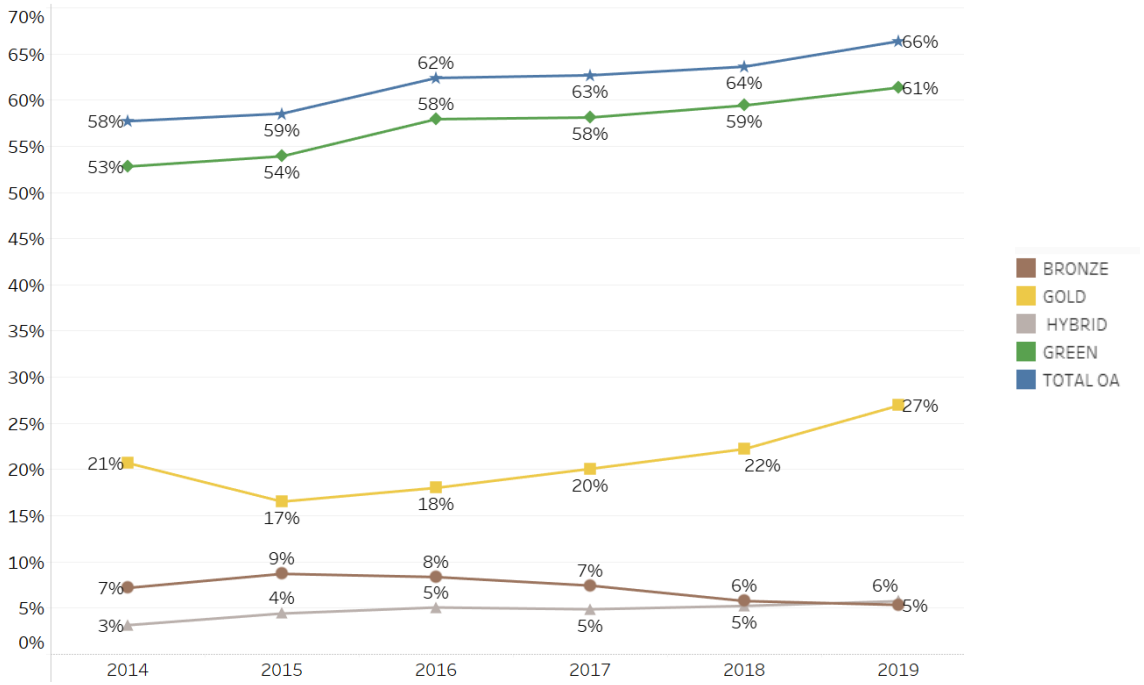

Figure 1. Percentage of articles published by open access type over the total number of articles (WoS, 2014-2019)

Figure 2 shows the share of each type of OA in relation to the total number of articles published in OA. Bronze articles decayed by 10% in the period studied, and Green articles constituted around 90% of all articles. Gold articles grew considerably in the period studied (15%).

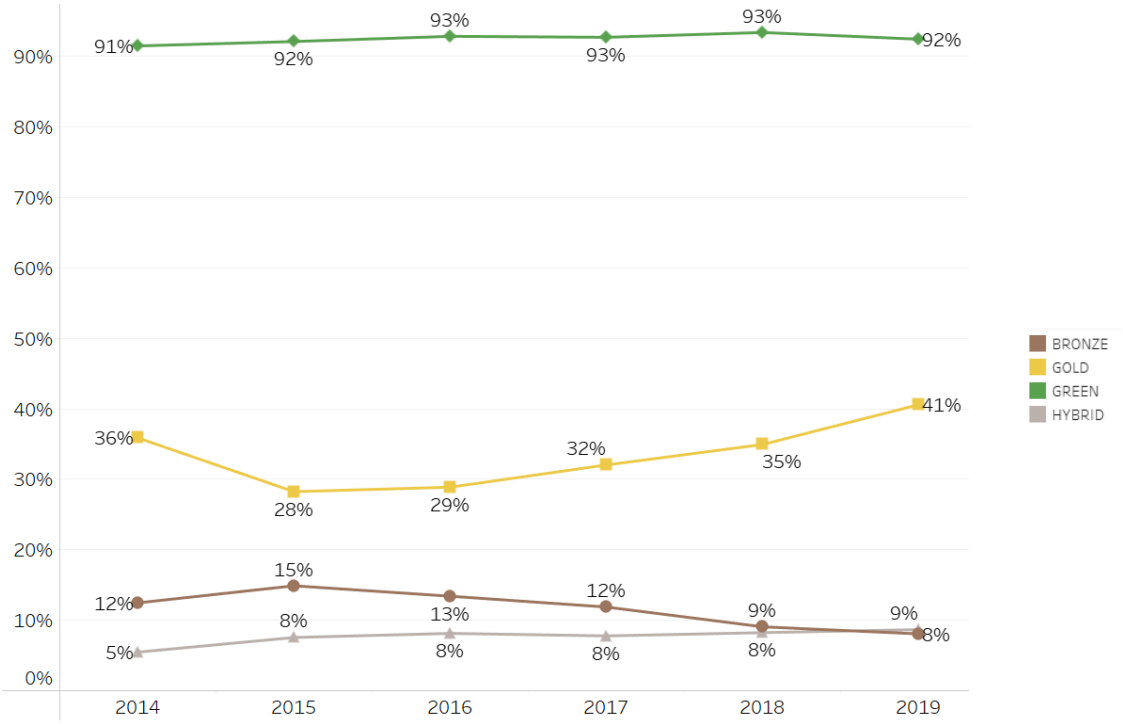

Figure 2. Percentage of articles published by open access type about the total number of OA articles (Web of Science, 2014-2019)

The results show a 9% growth rate in OA articles. Gold and Green access are the predominant OA types in the time series. As gold OA is experiencing steady growth (10% of the increase in sum), Bronze faces a sustained drop of 6%. Hybrid journals experienced a slight growth (about 3%) in the period studied.

4.2 RQ2: Factors influencing compliance with the Spanish OA mandate

A classification regression tree (CRT) is used to infer the factors influencing compliance with the OA mandate. Descriptive statistics analyze those factors in detail.

Figure 3 presents the results of the classification tree. The CRT yielded 15 nodes and 8 terminal nodes with a depth of 4, with a resubstitution and cross-validation risk estimation of 0.358. The overall correct classification was 64.2%, although the percentage for the non-OA cases was significantly lower than for the OA publications (12 and 94.2, respectively).

The main segmentation variable is the type of institutions. In this sense, universities and private entities present a lower frequency of OA when compared with the rest of the categories. For universities and private foundations, as well as for the rest of the categories, the following variable in the model is the research area. In this set of nodes, for all types of centers except universities and private entities, Arts & Humanities, Life Sciences & Biomedicine, and Social

Sciences are terminal nodes, which implies that no further variable can split the node with significant differences between the proportions of OA and non-OA publications. All terminal nodes are based on the same variable: the existence of a predoctoral contract, and, in all cases, the groups with 1 or 2 contracts present slightly higher proportions of OA publications, pointing out a non-spurious relationship between the two variables. A likely explanation for this variable's presence in the model is the extra funding awarded to projects with pre-doctoral contracts. Only proposals of the highest scientific quality and potential to qualify pre-doctoral researchers are awarded the additional funds required to pay the pre-doctoral contract. However, this is just a hypothetical explanation.

The dependent variables' order of relevance in the branching of OA publications is the type of center, research area, and predoctoral contracts. Also noteworthy is that the ESI highly cited paper and ESI hot paper are not included in the model. This implies that the variables mentioned above are better choices regarding the capacity to classify the publications as OA or non-OA.

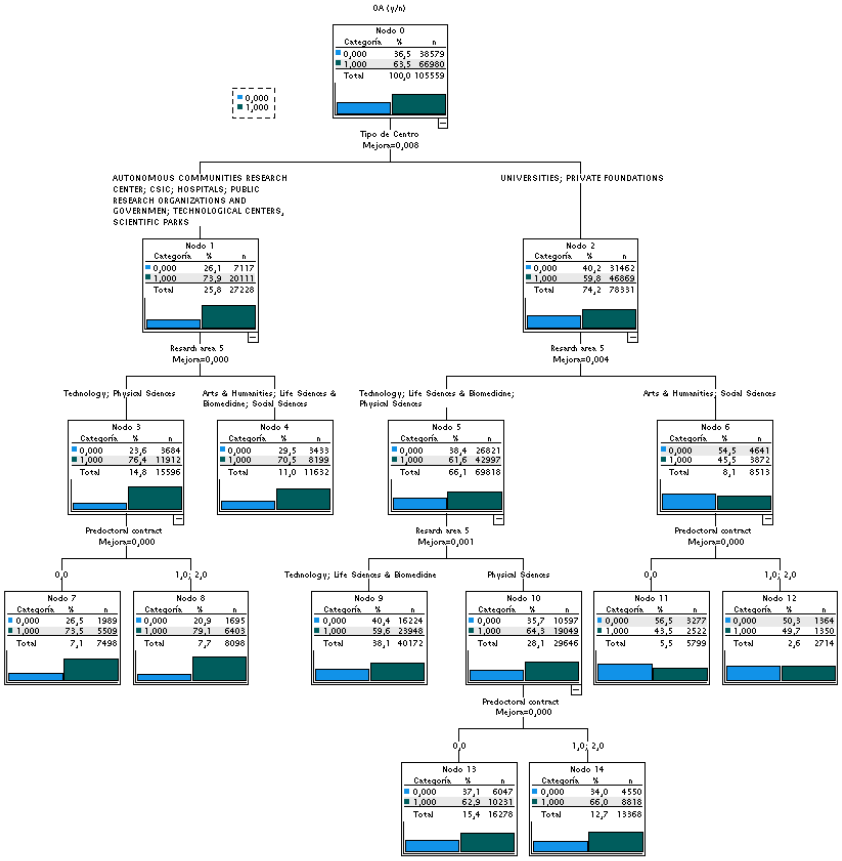

Fig. 3. Classification three with the main variables related to open access

The tables below show the descriptive statistics supporting the results of the classification tree. Table 1 shows the different patterns shown by R&D institutions in terms of productivity measured as the number of articles per project and OA publication. The Spanish National Research Council and Regional R+D centers show high productivity rates and similarly high rates of OA publications (five articles per project and 74% of articles in OA). Universities are equally productive, with an average of five articles per project, but they show one of the lowest rates of OA publication (60%). PROs and Health Research Institutes produce an average of 4 articles per project and present similar rates of OA publications (76% and 73%, respectively). Innovation Hubs have the highest OA rate and produce three articles per project on average. Finally, private entities produce an average of one article per project and publish a third of their outputs in open access.

Table 1. Productivity and open access articles by type of institution

Institution	Average number of articles per project	Total number of articles in OA	Total number of articles	Percentage articles in OA
Spanish National Research Council (CSIC)	5	13,465	18,187	74%
Regional R+D Centres	5	5,134	6,939	74%
Universities	5	48,799	80,820	60%
Public Research Organisations (PROs)	4	2,391	3,155	76%
Health Research Institutes	4	1,134	1,548	73%
Innovation Hubs	3	331	431	77%
Private entities	1	14	44	32%

Table 2 shows the percentage of open access per research area. Life Sciences & Biomedicine, Physical Sciences, and Technology show percentages of OA above 60%, whereas Arts & Humanities and Social Sciences publish less than half of their articles in open access.

Table 2. Percentage of open-access articles by research area

Research Area	Number of articles in OA	Total number of articles	Percentage articles in OA
Arts & Humanities	326	764	43%
Life Sciences & Biomedicine	18,426	29,153	63%
Physical Sciences	26,997	40,044	67%
Social Sciences	3,762	8,126	46%
Technology	17,469	27,470	64%

Last, the performance of institutions in terms of OA publication and research area describe similar relations. Table 3 shows that universities and private entities show the lowest percentages of OA articles in every area. Other public entities show higher values, especially in areas of their expertise (life sciences and STEM). For example, Health Research Institutes perform better in Life Sciences & Biomedicine (71%) and Technology (90%); Regional R&D Centres outstand in Life Sciences & Biomedicine (71%), Technology (77%) and Physical Sciences (75%) and PROs stand out in Physical Sciences (85%), Life Sciences & Biomedicine (66%), Technology (66%). On the other side, Arts & Humanities are mainly allocated in universities with low rates of open access (43%). CSIC and Regional R&D Centres also have some production in this area, 38% and 100% respectively (note that this last one is due to very few publications produced, just 3 in the period studied). Likewise, Social Sciences publications are mostly done in universities, with the lowest open access rate within public institutions (46%).

Table 3. Percentage and total of open-access articles by research area and institution

Research Area	Spanish National Research Council (CSIC)	Regional R&D Centres	Universities	Public Research Organisations (PROs)	Health Research Institutes	Innovation Hubs	Private entities
Arts & Humanities	38% (19)	100% (3)	43% (304)	-	-	-	-
Life Sciences & Biomedicine	72% (5,377)	71% (1,650)	59% (10,941)	66% (704)	71% (873)	61% (63)	-

Physical Sciences	75% (5,374)	75% (2,207)	65% (20,073)	85% (1,388)	76% (63)	64% (48)	-
Social Sciences	56% (92)	68% (89)	46% (3,565)	47% (8)	57% (17)	33% (3)	32% (14)
Technology	76% (2,603)	77% (1,185)	61% (13,916)	66% (291)	90% (181)	89% (217)	-

In sum, the CRT revealed that the type of institution is the variable that first explains the main differences in terms of OA publishing, with universities and private entities the institutions that most differ from the rest of organizations (with rates below 60% of articles in OA in contrast to the other institutions with rates above 70%). The following variable conditioning OA is the research area, showing considerable differences between Technology and Life and Physical Sciences (up to 60% of their articles in OA) and Social Sciences and Humanities (below 50% of their articles in OA). Moreover, the intersection between the type of institution and area reveals more precise results of these variables. Despite universities accounting for the most significant amount of scientific output, their OA behavior remains below the average of the other institutions. Private entities are seen as outliers as they focus on one area (Social Sciences) and handle the lowest OA rate.

4.3 RQ3: Effects of publishing in OA on the impact and visibility of CKG publications

Table 4 shows the regression analysis results in odd ratios. Model(1) presents the relationship between the type of OA and the citation count. Model(2) adds research area and publication year controls, and Model(3) includes additional explanatory variables such as the number of authors, the reference count, the number of pages, and dummies for whether or not the journal is entirely in OA, whether or not the journal is in the first quartile and whether or not the article is written in international collaboration.

All three models show that the types of OA are significant and have a positive relationship with the number of citations in an article. The only exceptions are the articles published in Gold Access, which show a significant but negative relationship with the citation count. The consistent positive relationship between all green articles and the citation count suggests the positive effects of depositing publications in open repositories. Further research should examine the specific impact of pre-prints, post-prints, and submitted versions.

Although OA is generally related positively to the number of cites, other factors need to be considered, and the case of gold OA needs to be further examined. The relationship between the explanatory variables and the visibility of the publications (measured as their presence in Q1 journals) is therefore addressed below (Table 4).

Including controls for research areas and publication, the year does not affect the relationship of OA types with their number of citations per article. Although the coefficients vary, their significance and the direction of the relationship are the same except for bronze access, which now shows a positive but non-significant relationship with the response variable. However, bronze is a relatively obscure category aggregating articles published under an unknown license. As expected, other variables, such as journals in the first quartile, international collaboration, and the number of authors, show a positive and significant relationship with citation count. Other controls consider the research area, publication year, and article measures that might influence the impact of the publication.

In all models, the inclusion of Green OA positively affects the relationship between other access types and citation count. For instance, in Model(1), the coefficient for green and Hybrid is 0.598, whereas gold's coefficient is 0.194. This effect is repeated in all models and all access types. In the case of gold, the inclusion of green changes the direction of the relationship. While gold seems negatively related to citation count, the relationship turns positive when articles are deposited into an open repository.

Table 4. Regression models

	Dependent variable:		
	cites_count		
	(1)	(2)	(3)
OA type - green and gold	0.007	0.056***	0.099***
	(0.010)	(0.009)	(0.009)
OA type - green and hybrid	0.598***	0.650***	0.328***
	(0.018)	(0.017)	(0.015)
OA type - green and bronze	0.613***	0.541***	0.175***
	(0.020)	(0.018)	(0.016)
OA type - green and paywall	0.229***	0.215***	0.144***
	(0.009)	(0.009)	(0.008)

OA type - gold	-0.749***	-0.457***	-0.163***
	(0.026)	(0.025)	(0.023)
OA type - hybrid	0.194***	0.277***	0.259***
	(0.041)	(0.037)	(0.034)
OA type - bronze	0.268***	0.126***	0.026
	(0.027)	(0.025)	(0.023)
Journal in Q1 (dummy)			0.613***
			(0.006)
International collaboration (dummy)			0.167***
			(0.006)
Collaboration (number of authors)			0.009***
			(0.0001)
Research area control	No	Yes	Yes
Publication year control	No	Yes	Yes
Length measures control	No	No	Yes
Constant	2.453***	693.481***	786.306***
	(0.006)	(4.497)	(4.081)

Observations	105,559	105,206	105,094
Log Likelihood	-376,736.500	-364,609.200	-351,308.200
theta	0.712*** (0.003)	0.878*** (0.004)	1.140*** (0.006)
Akaike Inf. Crit.	753,489.100	729,244.400	702,656.300

Note:	*p **p ***p<0.01

To better understand the regression coefficients for gold OA and the relationships between publishing in gold and citation count, Table 5 shows the percentage of publications in each quartile for each OA type across different research fields. Quartile highly affects citation count, so having fewer journals in the first quartile can affect the relationship between gold access and publications' impact. This analysis confirms the difficulty of finding fully OA journals in the first quartile, which increases depending on the research area (Table 5). The lowest ratio of publications in the first quartile (although it is still a high ratio) refers to gold articles (44.7%). Another interesting fact is that the highest percentage of articles with non-JIF also refers to gold articles (8.6%). This refers to journal articles not indexed in the Journal Citation Report

(ESCI Collection). The table also shows differences between areas across quartiles, being Life Sciences & Biomedicine, Technology, and Physical Sciences the areas with a higher percentage of publications in all quartiles and types of access.

Table 5. Percentage of types of open access articles by Journal Impact Factor (JIF) quartiles and research area

JIF Cuartil	Research Area	% OA Gold	% OA Hybrid	% OA Bronze	% OA Closed
Q1	Arts & Humanities	0,00%	0,00%	0,10%	0,00%
	Life Sciences & Biomedicine	19,60%	20,90%	29,30%	9,80%
	Physical Sciences	10,40%	30,70%	30,20%	29,20%
	Social Sciences	0,50%	1,10%	1,30%	1,80%
	Technology	14,20%	9,90%	7,10%	14,70%
	Total	**44,70%**	**62,70%**	**68,00%**	**55,60%**
Q2	Arts & Humanities	0,10%	0,10%	0,00%	0,10%
	Life Sciences & Biomedicine	11,50%	7,00%	10,10%	3,80%
	Physical Sciences	12,40%	12,10%	3,80%	14,10%
	Social Sciences	1,90%	0,90%	0,80%	1,50%
	Technology	8,30%	4,80%	3,00%	8,40%
	Total	**34,10%**	**24,90%**	**17,70%**	**27,90%**
Q3	Arts & Humanities	0,00%	0,00%	0,00%	0,00%
	Life Sciences & Biomedicine	2,20%	1,70%	3,20%	1,60%
	Physical Sciences	3,40%	2,00%	2,70%	3,90%
	Social Sciences	0,40%	0,90%	0,90%	1,40%
	Technology	4,00%	1,40%	1,40%	2,80%
	Total	**10,00%**	**6,00%**	**8,30%**	**9,70%**
Q4	Arts & Humanities	0,00%	0,00%	0,00%	0,00%

	Life Sciences & Biomedicine	0,50%	0,40%	0,50%	0,40%
	Physical Sciences	0,60%	0,40%	1,00%	1,30%
	Social Sciences	0,60%	0,50%	0,50%	0,80%
	Technology	0,90%	0,70%	0,80%	1,00%
	Total	**2,60%**	**2,00%**	**2,90%**	**3,50%**
Non JIF	Arts & Humanities	0,60%	0,50%	0,20%	0,20%
	Life Sciences & Biomedicine	1,90%	1,50%	0,80%	0,50%
	Physical Sciences	2,30%	0,60%	0,70%	0,90%
	Social Sciences	1,90%	1,20%	0,70%	0,90%
	Technology	1,90%	0,70%	0,70%	0,80%
	Total	**8,60%**	**4,40%**	**3,10%**	**3,40%**

Publishing in OA has, therefore, mixed effects. Whereas publishing in green and hybrid OA has beneficial effects on the impact of an article, gold OA affects the impact negatively. This phenomenon might be influenced by the sparse presence of full OA journals in the first quartile, which is highly correlated with the volume of cites of an article.

5. Discussion and conclusion

Our results about the degree of compliance of CKG's projects (RQ1) are consistent with previous studies regarding open access mandates in Spain, particularly in R&D projects (Borrego, 2016). Borrego found that 58.4% of the articles result of publicly funded projects in 2011 were published in open access in the subsequent years, which aligns with our estimations. However, in 2013, the national OA mandate had been in force only for 2.5 years, so it was too soon to address its effects in the long term. Six years later, there has been a growth rate of 9% in OA articles. The growing number of gold publications shown in the results is also in line with previous studies on Spain (Torres-Salinas et al., 2016) and elsewhere (Robinson-García et al., 2020; Torres-Salinas et al., 2018) and evidences the shift to this model of OA in the last decade. However, it is important to highlight the limitations of our study regarding the project-related publication search strategy. This strategy depends on researchers' reliance to

acknowledge the project that enabled them to conduct their research in their submitted publications. In cases where researchers did not acknowledge funding despite having it, it was impossible to retrieve the publications. For cases where researchers misspelled the project ID, the data collection algorithm (based on the Jaccard distance) detected publications with similar project IDs. If there was sufficient evidence[15] to confirm that the publication came from the project, it was included in the dataset.

Nevertheless, researchers may also associate publications with specific projects for other reasons. We are aware that researchers usually enjoy many funding sources (Aagaard et al., 2021), and their final scientific output sometimes varies from the project proposals they enjoy. Even so, we believe it is a good strategy for studying compliance with the mandate because if researchers acknowledge the funder, they are *de facto* incurring the obligation to comply with the mandate. Moreover, it is important to be cautious about establishing causal relationships between the current regulation and the rise of OA publications since other factors might play a significant role (see Borrego, 2017).

Regarding the factors influencing OA publication (RQ2), institution type appears to be the most influential. The result is in line with recent research that has highlighted the role of institutions on research output (Slowe, 2018), funding (Zacharewicz et al., 2019, and recent application on Luwel & Visser, 2022), and open access (Pontika et al., 2022). Although it is not possible to provide a complete description of the potential institutional factors affecting their approaches towards OA and compliance with mandates, we assume their goals, types of research, and funding sources might underline differences in the accomplishment of the mandates. We hypothesize that the limited strategic capacity of universities (a fact especially relevant in the case of Spanish universities as appointed by Cruz-Castro & Sanz-Menéndez (2007)) is one of the causes of their low publication of results in open access. Factors such as their limited capability of coordination and thus different strategies (for instance, recommendations versus promotion), their heterogeneous nature (in relation to the wide range of research fields that they cover, each of them with different OA habits), the different degree of awareness that each of them shows towards meeting the challenges of open science and their dual nature (balance between teaching and research duties), might be influencing the degree of compliance of OA mandates. Melero et al. (2018) evidenced how Spanish universities' policies to ensure OA mandates greatly vary. Still, more than half of their production is published in

[15] These cases were automatically detected and manually checked. In most cases the errors were minimal and visually detectable without giving rise to doubt i.e. researchers writing *ECO2014 57442 P* instead of *ECO2014-57442-P*.

OA and, in absolute values, accounts for the majority of the scientific production as a result of the SNP. Another potential factor contributing to that increase is the influence of transformative agreements, which facilitate the publication of OA in practice. Again, although the development of transformative agreements is becoming more common, there are differences between universities. However, in contrast to the above, universities account for the highest rates of publications within the different areas, placing them as crucial actors in the R&D system.

In contrast, in our analysis, the CSIC is one of the most prolific research bodies, even though it has been one of the latest Spanish institutions to adopt an OA mandate (De Filippo & Mañana-Rodríguez, 2022). Despite enjoying a high level of autonomy compared to other PROs (Cruz-Castro & Sanz-Menéndez, 2018), the degree of internal coordination at CSIC is higher than at universities. Although divided into research institutes, the CSIC has a well-defined institutional hierarchy: a unique Governing Board and a president appointed by the Spanish Council of Ministries. Regulations approved by the Presidency are directly applied to all CSIC institutes. Likewise, another crucial element of the CSIC's mandate is the institution's commitment to review the scientific staff's evaluation criteria, so publishing in open access is positively considered for evaluation purposes. Section d) of the OA mandate establishes the future review of the hiring and promotion criteria and the internal assessment of research output within the institution[16]. Although merely speculative, recognition and promotion have been proven to influence researchers' behavior in other contexts (European Research Council, 2017). Further research at the institutional or departmental level might be helpful to discern the best strategies to promote publication in open access and provide recommendations to institutions that want to improve their performance.

Likewise, PROs, Regional R&D Centres, Innovation Hubs, and Health Research Institutes also have high percentages of OA. The fact that approximately half of their funding comes from national and international project calls, which makes them subject to national and European OA policies, may explain their high rates of OA. Again, as commented in section 2.1. their research autonomy allows them to develop their own measures to favor the publication in OA. Another critical aspect when studying OA performance is that each research area has different behaviors regarding publishing in open access. As said earlier, the classification tree points to it as one of the main segmentation variables. This fact aligns with previous literature (Mañana-Rodriguez & Guns, 2022; Crawford, 2019), so future research might consider it. Although the

[16] https://digital.csic.es/bitstream/10261/179077/3/Mandato_Acceso_Abierto_CSIC_2019.pdf

ESCI database has been included to mitigate it, another limitation of this study is the biased coverage of the Web of Science's Arts & Humanities and Social Sciences collection (Mongeon & Paul-Hus, 2016). Additionally, other factors outside the scope of this study might influence these publication patterns: the availability of journals in OA and the availability of funds to charge APCs, among others.

Finally, individual attitudes might also be playing a role. The Open Science movement has influenced the policy sphere and individual researchers and groups that might have changed their publishing practices. Previous research on this question is still exploratory but highlights the importance of personal attitudes and social norms in OA publishing (Moksness & Ottar Olsen, 2017). A survey conducted by Segado-Boj, Martin-Quevedo, and Prieto-Gutiérrez (2018) found that Spanish researchers had very positive attitudes towards open access. However, the survey coverage was limited and biased towards social sciences researchers, so more evidence is needed to generalize its results. Moreover, the survey just measured very general attitudes towards open access, but no reference was made to the practice of publishing in OA. Therefore, further research is still needed to address the relationship between the Spanish OA mandate and the increasing proportion of open publications.

Regarding the benefits of publishing in OA for researchers (RQ3), the results show that gold OA is negatively related to citation count. However, this might be related to the relatively low percentage of gold journals in the first JIF quartile compared to other access types. The analysis is limited by our sample, which only includes publications funded by CKG's projects, usually skewed towards the highest quartiles. The nature of these calls highly influences this fact as grants are allocated to the most prestigious projects and highly consolidated researchers in Spain. The relationship between gold OA, citations, and JIF could have negative implications for researchers related to promotion and tenure. As researchers are asked to publish in journals with high IF, the relatively low percentage of gold journals in the first quartile might condition them to publish in other access types. This inequality might have a stronger effect in research areas with a low number of Gold journals and with lower funding to dedicate to APC charges.

Finally, it is worth highlighting the relevance of Green OA. In all cases, Green access positively affects the relationship between other types of access and citation count. This means that regardless of the access type, depositing a publication in an open repository positively affects the impact of that publication. We did not include the types of Green access in the analysis, but studying their effect might contribute to the growing literature field on the role of pre-prints and post-prints in publications' impact (Björk et al., 2014). These results suggest that to improve their impact, individual researchers should include their publications in open

repositories. Hence, future policies and institutions should encourage the deposit of preprints in institutional repositories. This decision will benefit the visibility of the researchers' work, and there is still room for improvement for researchers to use this route (Martín-Martín et al., 2018).

Evaluation agencies should also address these issues. There is an ongoing discussion on the harmful effects of metric evaluation and proposals for new evaluation frameworks (Wilsdon et al., 2017; Wouters, 2019). Some research evaluation agencies have included Open Research and Responsible Research & Innovation (RRI) criteria to reward publishing in OA (such is the case of the United Kingdom's Research Assessment Exercise). However, there is a long way to go to achieve evaluation systems recognizing RRI aspects (Pontika et al., 2022). As stated above, identifying high-performance institutions in terms of OA publication and analyzing their OA initiatives could help other research bodies improve their compliance with OA mandates. As in the case of the CSIC, fostering the use of institutional repositories, recognizing and rewarding OA publishing practices, and providing APC financing could encourage researchers to publish in OA.

Although this is not the primary concern of this article, another issue to be considered in further research is the legitimacy of using public funds to cover Article Processing Charges to publish publicly funded research in OA. The results obtained in this research could support a more detailed analysis of such a topic.

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Conflict of interest

The authors have no conflicts of interest to declare relevant to this article's content.

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