Mapping open science at Spanish universities. Analysis of higher education systems

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Abstract

This study analyzes the implementation of open science in Spanish universities considering four perspectives: (i) regulations, policies, and strategies; (ii) knowledge production; (iii) research results; and (iv) perception by different academic actors. A qualitative and quantitative methodology is applied, drawing information from university websites, institutional reports, European project databases (*Cordis*), the *Web of Science* database, surveys of teaching and research staff, and surveys of vice-rectors and library directors. The information is grouped into regional university systems, according to the autonomous community to which each university belongs, and is analyzed on that basis. The results of the quantitative study show increasing interest in open-science activities, expressed as a growing number of publications, and an increase in participation, leadership, and funding in European projects. Institutional policies and regulations on open science, on the other hand, are few and focus almost exclusively on open access. The development of institutional repositories is one of the great achievements of the Spanish university system, and open-access publishing (mainly green open access) has grown considerably in the last decade. Teaching and research staff are not knowledgeable about open science, although in general they take a positive view toward it, while university policymakers report that most actions to promote open science are still in the process of being implemented. The results reveal heterogeneity among the various institutions' practices and implementation. As a regional system, the Catalonian university system stands out above the rest for its degree of open-science policy development and implementation and for its intense research activity in the field of open science.

Keywords

Open science; Universities; Regional university systems; Teaching and research staff; Researchers; University policymakers; Open access; University repositories; Institutional repositories; European projects; *Cordis*; Publications; *Web of Science*; Spain.

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1. Introduction

For two decades now, the open-science movement has been having considerable impact on different realms of the scientific and academic world. The process of opening up scientific knowledge kicked off with open-access initiatives in 2002, culminating when publicly funded scientific literature began to become open (**Méndez**, 2021). Technological progress, mass production of data, scientific social networks, citizen science, educational resources, and open code are shaping a different kind of science, modifying not only the way knowledge is produced but also the way it is shared.

Both the concept of open science and its many names (e-science, interconnected science, science 2.0) have evolved since the early days, and, as **Abadal** and **Anglada** (2020) explain, the names have changed more than the concept itself. While discrepancies over the constituent elements of open science can be found in the scientific literature, there is widespread agreement about two of its ingredients, open access (OA) and open data (*European Commission*, 2016; **Vicente-Sáez**; **Martínez-Fuentes**, 2018; *Foster*, 2018; **Tennant** *et al*., 2019).

The diversity of terms notwithstanding, because of open science's characteristic values of openness, transparency, effectiveness, reproducibility, collective benefit, and improvement of the social impact of research (**Anglada**; **Abadal**, 2018; **Abadal**, 2021, *Unesco*, 2021), this paradigm shift in research is having a huge repercussion in the scientific community and therefore in the realm of higher education.

However, as indicated by **González-Teruel** *et al*. (2022), the existence of a political framework and adequate funding are critical factors for successfully transitioning scientific practices toward the open-science model. The *European Commission*'s initiatives have been fundamental to the transition in Europe, as has the interest of many member countries in aligning themselves with the proposed goals. The interested countries include Finland, Slovenia, the Netherlands, France, and Portugal (**Abadal**; **Anglada**, 2021). In Spain, as shown by previous studies (**De-Filippo**; **Mañana-Rodríguez**, 2022), the legislative panorama is highly dynamic, with a wide range of directives written into laws and regulations. The highest-ranking Spanish legislation on open access is the *2011 Science, Technology and Innovation Act*, which was amended in 2022 by *Act 17/2022 of September 5*.

1.1. Universities as promoters of open science

As social agents, universities have a strong influence and a big social, economic and cultural impact. They mobilize a vast amount of human and financial resources, and they have the infrastructure to turn out high-impact scientific and technological developments. Institutions of higher education form the main knowledge-producing sector in most countries (**Sanz-Casado** *et al*., 2019). Furthermore, universities gather a large-enough critical mass to generate and roll out policies on many topics, including open science.

The prominent role of universities in the implementation of open-science strategies was underlined by the *European Commission* in its report *Open Science, Open to the World. A Vision for Europe* (*European Commission*, 2016). Another important proposal was that of the *Open Science Policy Platform* (*European Commission*, 2018), which gave rise to a series of recommendations for the introduction of open science in the European context on the basis of eight pillars (rewards and incentives, next-generation metrics, the future of scholarly publishing, the *European Open Science Cloud* (*EOSC*), FAIR data, research integrity, education and skills and citizen science) (**Ayris** *et al*., 2018).

The *General Conference* of the *United Nations Educational, Scientific and Cultural Organization* (*Unesco*) held in Paris in 2021 also proposed a series of recommendations for universities (e.g., in the design of rules and regulations), because it sees universities as important entities for promoting the practice of open science in coordination with national and international organizations (*Unesco*, 2021).

At the institutional level, too, some international networks of universities have taken up the challenge of implementing open science, as shown in the declaration of the *European University Association* (*EUA*, 2017) and the roadmaps of associations like the *League of European Research Universities* (*LERU*, 2018) and the *Young European Research Universities Network* (*Yerun*, 2018). The report from the *European Commission*'s *Open Science Policy Platform* (**Méndez** *et al*., 2020), which reviews the progress made thus far in applying the platform's recommendations on the eight pillars of open science, speaks of a general consensus in the future of scholarly communication with more-open practices, practices in which universities' participation is of core importance.

In the Spanish context, support for open science is clearly stated not only in the *Organic Act on the University System* (*Ley Orgánica del Sistema Universitario*), but also in the *Commitment of Spanish Universities to Introduce Open Science*, an undertaking passed in 2019 by the *Conference of Spanish University Rectors* (*Conferencia de Rectores de las Universidades Españolas*, or *CRUE*), which is aligned with international proposals.

> Since 2010, numerous initiatives focusing on open science have been launched to promote and implement open science in Spanish universities

The Spanish university system's biggest strides in open science have to do with open access. The leading entities in terms of open-access implementation and proposals include the *Spanish Foundation for Science and Technology* (*Fundación Española para la Ciencia y la Tecnología*, or *Fecyt*) and the *CRUE*'s *University Library Network* (*Red de Bibliotecas Universitarias*, or *Rebiun*), which have fostered the creation and development of repositories according to the mandates of green open access (*Fecyt*, 2016; 2017; 2018; *CRUE*; *Rebiun*, 2018; 2020; *CRUE*, 2019). In this framework, several universities, primarily public universities, have adopted open-access mandates and created repositories of their own.

Although it has been found that the main impulse for repository creation and open-access policies dates primarily to 2010, some studies do mention earlier pioneering actions in some regional university systems. One such action was the creation in 2001 of *Tesis Doctorals en Xarxa*, a repository of doctoral dissertations assembled by a consortium of 11 Catalonian universities, which established a model that other universities have since followed. The first institutional university repository was created in 2004 at the *Complutense University of Madrid*. Since then, repositories have gradually spread through Spanish universities (**Abadal** *et al*., 2013; **Serrano-Vicente**; **Melero**; **Abadal**, 2018), and now, as the results of our research show, all public universities have a repository of their own. Shared university repositories have even been developed in some autonomous communities (political and administrative regions of Spain). For example, the *RACO* repository of open-access Catalonian journals, a project of the *Consortium of University Services of Catalonia* (*Consorci de Serveis Universitaris de Catalunya*, or *CSUC*) and the *Library of Catalonia*, holds all the journals of Catalonian universities (**Pons-Serra**, 2016). Other major shared repositories are the *Madroño Consortium* (*Consorcio Madroño*) of Madrid universities, which is very actively involved in actions related with open science (*Consorcio Madroño*, 2017), the *Consortium of University Libraries of Andalusia* (*Consorcio de Bibliotecas Universitarias de Andalucía*, or *CBUA*) and the newly organized *Consortium of Valencian University Libraries* (*Consorcio de Bibliotecas Universitarias Valencianas*, or *Buval*), created in 2021.

Recent progress has also been made in the shape of proposed changes in the system that institutions use for assessing scientific output and academic careers, following criteria aligned with the components of open science. An agreement in this sense was signed in 2022 in the framework of *CoARA* (the *Coalition for Advancing Research Assessment*) among over 300 entities from 40 countries, including 52 Spanish institutions, 30 of which are universities (*CoARA*, 2023). The agreement made it clear that institutions of higher education are interested in the further implementation of actions related with open science.

1.2. The Spanish university system

In the 2022-2023 school year, the *Spanish University System* (*SUS*) contained 84 institutions, 50 public universities and 34 private universities (*Ministerio de Universidades*, 2022). The public universities are funded by the state, which establishes their general organizational outlines, while the private universities are financed by private and, in some cases, public funds and are generally operated for a profit. There are also some Catholic universities that confer official degrees whose validity is on a par with that of the degrees earned at public and private institutions; Catholic universities are essentially funded by tuition. Under Spanish legislation, the purpose of universities, whether public or private, is to render the public service of providing higher education.

In addition to classifying universities as public or private, the Spanish university system is decentralized into autonomous communities by the *1983 Organic Act on University Reform* (*Ley Orgánica de Reforma Universitaria*), which modernized university governance and emphasized the role of research (**De-la-Torre**; **Pérez-Esparrells**, 2019). Accordingly, each autonomous community has its own model for funding and evaluating its universities.

The number of public universities in each autonomous community has to do with that region's history, number of inhabitants and component provinces. There is no homogeneous nationwide structure. Some systems span a territory containing a large number of public universities (Andalusia, Catalonia, Madrid and Valencia). There is also a group of autonomous communities that have only one public university apiece, known as the "G-9" university group (Aragon, Asturias, the Balearic Islands, Cantabria, Castile-La Mancha, Extremadura, Navarre, the Basque Country and La Rioja). Furthermore, each system handles a very different volume of students and a very different volume of teachers and researchers. Madrid, Andalusia, Catalonia and Valencia are the autonomous communities with the greatest numbers of potential researchers in terms of scientific output.

This diversity of structure, size and organization among the universities of each autonomous community is of course a decisive element for university activities, so the regional university systems are the focal point of the analysis presented in this paper.

2. Objectives

Bearing in mind universities' role in the development of open science, this study looks into the Spanish university context to answer the following question: do regional university systems have different activity profiles in connection with the implementation of open science?

To find an answer, the following objectives are posed:

- analyze the development of regulations about open science,
- assess the degree of implementation and development of various activities related with open science (especially activities related with research projects and scientific publications),
- ascertain how different actors perceive Spanish universities' open-science activities,
- learn if activity profiles differ, using regional university systems as the unit of analysis.

3. Sources and methodology

To deal with the diversity and breadth of the activities related with open science, four dimensions of analysis are defined:

- regulations, policies and strategies about open science;
- knowledge production;
- research results; and
- perception of open science. Graph 1 shows these dimensions and the studies performed to characterize them.

The sources used and the methodology followed to study each of these dimensions are explained below. The study is structurally organized into these same four realms of analysis.

3.1. Regulations, policies and strategies

The main sources used to trace the extent of the "official" implementation of open-science policies are the websites of Spanish public universities. Public universities were chosen because they are all subject to the common regulations dictated by the ministry in charge of universities, yet each university may well have pursued a strategy of its own in its endeavors to implement open science.

First of all, search criteria were defined and their validity was checked. The search criteria were then applied to the set of public universities in the Spanish university system. The information was searched for and collected from each university's website from October to December, 2022. Terms associated with open-science activities were used to retrieve information about the following points:

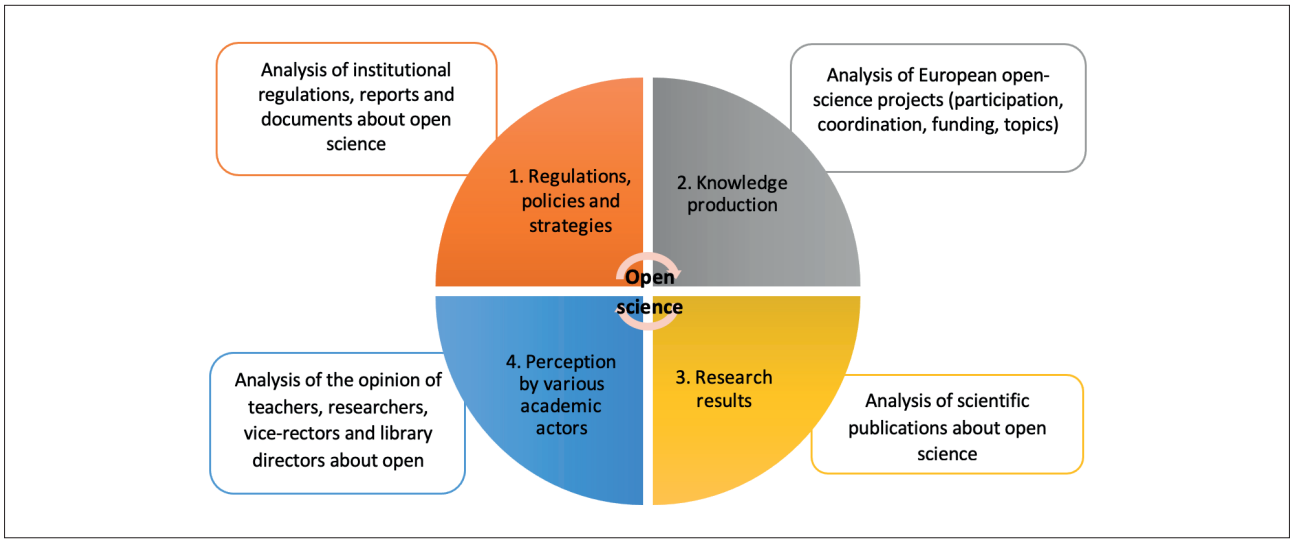
- existence of an institutional repository and the year it was created,
- institutional declaration of an open-access policy and year of approval by the university's board of governors,
- declaration of specific open-science policies,
- location where information on open science can be found (general university pages or university library's page),
- identification of the institutional officer responsible for open science (vice-rector, officer named by the rector),
- specific web page devoted to matters of open science or citizen science.

Although the results were found individually for each university, the information is presented on an aggregate basis by autonomous communities.

3.2. Knowledge production

Information about projects related with open science was obtained from the *Cordis* database *https://cordis.europa.eu*

This source reports the projects run under the various calls of the European framework programmes, which are some of Spanish universities' main funding channels (*Observatorio IUNE*, 2022). *Cordis* also furnishes precise, wide-ranging infor-



Graph 1. Dimensions for analyzing open science in the Spanish university system

mation on numerous variables associated with Spanish institutions' participation, leadership, funding and collaboration. Although the validity of other sources of information about participation in nationwide calls was initially explored, it was ultimately decided to use the European database only, because the alternatives offered little information and made it difficult to identify open-science projects (with the resulting underrepresentation of data) (**De-Filippo**; **Lascurain-Sánchez**, 2023).

Cordis afforded access to information about the European projects in the *Seventh Framework Programme* (*FP7*) and *Horizon 2020* (*H2020*). The projects led or participated in by persons from Spanish universities within the window from 2010 to 2021 (both years included) were selected from this pool. The keyword-based search strategy shown below was then used to identify the projects about open science. This strategy was based on previous studies on the topic and was reviewed and validated by experts in the area.

("open access" OR "open data" OR "open research" OR "citizen science" OR "citizen* scienc*" OR "open science" OR "communit* science*" OR "participator* research*" OR "participator* action* research*" OR "communit*-based research*" OR "citizen* research*" OR "science* shop*" OR "citizen* scient*" OR "public-participation" OR "open innovation" OR "community engagement" OR "citizen awareness" OR "community perception" OR "community-based environmental change intervention" OR "community-based environm*" OR "community-based environmental protest" OR "community based environmental movements" OR "community-based environmental health" OR "community-based environmental education" OR "crowd* science" OR "civic technoscience" OR "community based auditing" OR "community environmental policing" OR "citizen observatories" OR "participatory science" OR "volunteer monitoring" OR "volunteered geographic information" OR "volun* GIS" OR "neogeography" OR "participatory GIS" OR "street science" OR "locally based monitoring" OR "volunteer based monitoring" OR "public participation in scientific research" OR "popular epidemiology" OR "public engagement" OR "participatory monitoring" OR "participatory sensing" OR "open peer review" OR "open reproducibility" OR "open education resources" OR "open hardware for science" OR "citizen observatory", "community engagement research", "biodiversity monitoring", "civic science", "eBird", "locally-based monitoring", "community-based monitor*" OR "science 2.0" OR "interconnected science" OR "e-science")

The strategy was applied to project titles and abstracts (**De-Filippo**; **Lascurain-Sánchez**, 2023).

The resulting information was downloaded in CSV format and was cleaned and processed to find the following indicators:

- number of open-science projects obtained per university in each call,
- number of open-science projects led in each call,
- funding obtained (in euros),
- number of projects obtained by each university as a percentage of the set of projects obtained by the entire Spanish university system.

The results at the institutional level were aggregated by autonomous communities, and duplicated data due to cooperation between two or more universities in the same autonomous community were eliminated.

3.3. Research findings

An international database of scientific publications, the *Web of Science* (*WoS*), was consulted to find the amount of Spanish output about open science.

The search strategy defined in the previous phase was applied again to identify the Spanish publications in the *Web of Science Core Collection* (*SCI*, *SSCI*, *A&HCI*). The search for these terms in the "Topics" (TS) field returned a high percentage of publications that were not relevant, so the search was applied to the "Author Keyword" (AK), "Keyword Plus" (KP) and "Title" (TI) fields. Publications in all document types and all languages indexed by the database for 2010-2021 were retrieved. The publications signed by at least one Spanish institution (CU=SPAIN) were downloaded and entered in a relational database with information about all the document's fields. Data about open access were included as well, considering all the routes covered by the *Web of Science* (gold, green, bronze). Because *WoS* documents include the "Funding" field, it was also possible to identify the output from funded projects. The codes of the *Cordis* projects analyzed in the previous phase were used to identify the funded publications, which were also entered in the database. The information was later processed to eliminate duplicated data. The following bibliometric indicators were found for each university:

- number of publications produced about open science,
- contribution to the *SUS*'s total number of documents about open science, as a percentage,
- number of open-access publications about open science,
- contribution to the *SUS*'s total number of open-access documents about open science, as a percentage,
- number of OA publications about open science, as a percentage of that same university's total number of documents about open science.

Although the information was found on a university-by-university basis (including public and private universities alike), the results are presented on an aggregate basis by autonomous communities, eliminating duplicated data caused by cooperation between two or more universities belonging to the same autonomous community.

3.4. Perception by different academic actors

To place the quantitative information in context, opinions and assessments about how well open science has been introduced at universities were gathered from three relevant interest groups in the university community (teachers and researchers, vice-rectors whose portfolio includes open science and library directors). These opinions were, of course, not indicative of the opinion of the university community as a whole, but they did provide additional information useful for supplementing and interpreting the data obtained from other sources, and thus they helped gain a fuller view of the implementation of open science at universities.

After the groups from which it was considered interesting to glean information were defined, the instruments for gathering the desired information were designed and constructed. Three questionnaires were ultimately prepared, tailored to the characteristics of the three interest groups. The questionnaires for the vice-rectors and library directors share some questions seeking opinions about subjects that both groups deal with. The subjects addressed in the questionnaires were chosen with a view to collecting information about the implementation of open science, using the reference framework of the *Open Science Policy Platform*'s eight pillars (rewards and incentives, next-generation metrics, the future of scholarly publishing, the *European Open Science Cloud*, FAIR data, research integrity, education and skills, citizen science) (**Ayris** *et al*., 2018). This same outline was used to analyze the information obtained from the questionnaires. The questionnaires are available at
https://zenodo.org/record/6509944

where further information about the procedure is given (**Sánchez**; **De-Filippo**, 2022).

The information about teaching and research staff's perceptions of open science was provided by 251 teachers and researchers who answered the questionnaire constructed specifically for their group. The participants were contacted individually in October 2021 through a research panel. The persons available to participate voluntarily in this research were screened to yield a sample including at least 50% women, different positions (chaired professors, full professors), different contract types and employees of universities from all 17 autonomous communities, to ensure adequate regional representation.

The procedure for putting together the vice-rector group was to contact the secretaries of the rectors of all public universities by individual e-mail between May and June, 2022, asking for the person tasked with open-science responsibilities. When the key informant was identified, an e-mail message was sent asking him or her to participate either by answering the questionnaire specifically designed for the vice-rector group or by granting an interview. Eighteen vice-rectors responded by sending in the filled-out questionnaire.

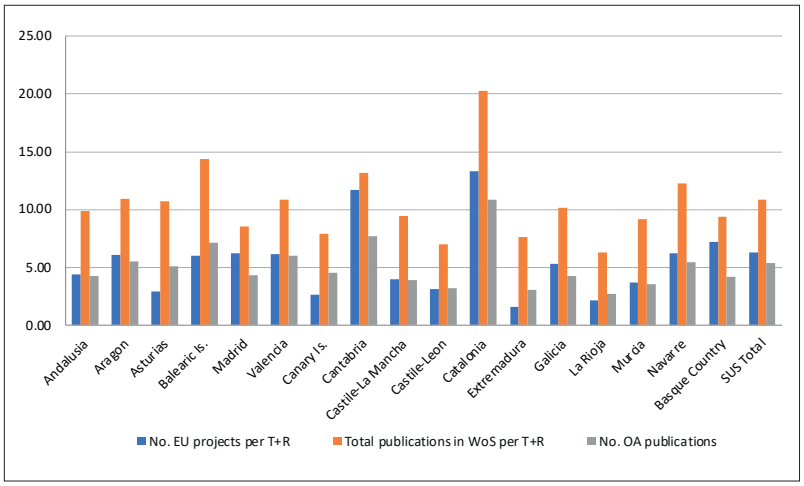
To contact library directors, an e-mail message was sent sometime between May and June, 2022, to the institutional address of the library director at each public university. Forty directors or acting directors responded to the request to participate in the project by sending in the filled-out questionnaire.

4. Results

To furnish an overall view of the situation of the Spanish university system and provide some context for the results of our analysis of the four dimensions, let us first examine the general indicators. Table 1 gives indicators associated with the size and activity of each autonomous community. The number of higher-education institutions in each autonomous community is shown. Next, the total number of permanent teachers and researchers (T+R) active in the last decade is presented. The total number of European projects granted in competitive calls, the total number of scientific publications indexed in the *Web of Science* database and the number of open-access publications are also shown.

The university systems with the highest activity volume belong to the autonomous communities of Catalonia and Madrid, followed by Andalusia and Valencia (table 1).

To put these figures into perspective, scientific activity is calculated according to the number of permanent professors in each autonomous community. In Graph 2, Catalonia leads in all indicators (with 20 publications per 100 teachers, 13 European projects per teacher or researcher and 11 publications per teacher or researcher in a decade). Catalonia is followed by Cantabria and the Balearic Islands; whose high figures are far above the *SUS* mean.



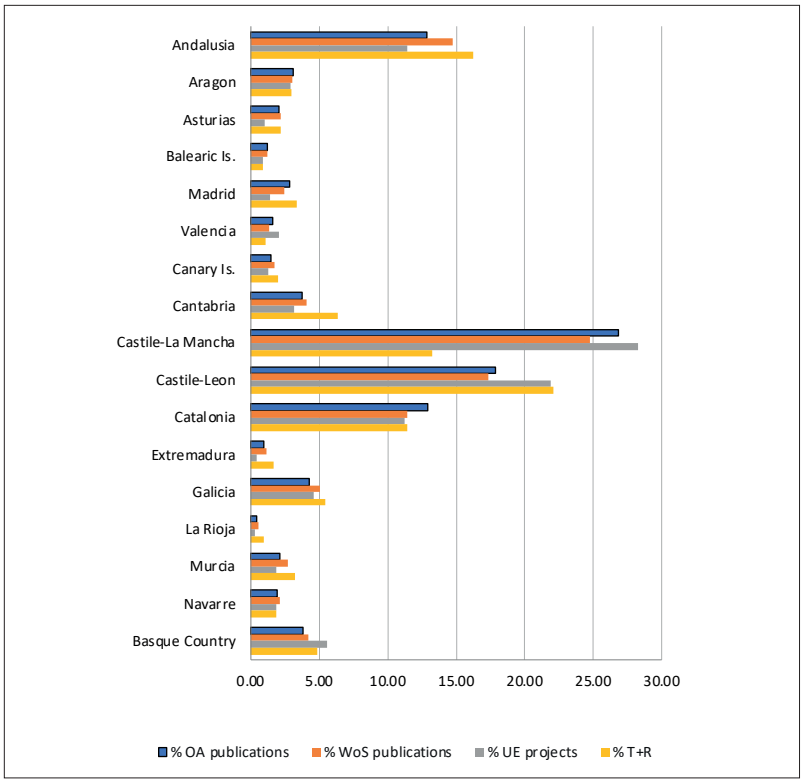
Graph 2. Scientific activity indicators in relationship to the number of teachers in each autonomous community

Table 1. Indicators of scientific activity in regional university systems.

Autonomous community	No. universities	No. T+R	% T+R	Total EU proj.'s	% EU proj.'s	No. *WoS* pub.'s	% *WoS* pub.'s	No. OA pub.'s	% OA pub.'s	OA/ Total *WoS*
Andalusia	11 (10 public)	10,525	16.26	462	11.40	103,659	14.73	44,552	12.88	42.98
Aragon	2 (1 public)	1,939	3.00	117	2.89	21,170	3.01	10,640	3.08	50.26
Asturias	1 (public)	1,421	2.20	41	1.01	15,249	2.17	7,233	2.09	47.43
Balearic Islands	1 (public)	585	0.90	35	0.86	8,405	1.19	4,165	1.20	49.55
Canary Islands	6 (2 public)	2,195	3.39	57	1.41	17,300	2.46	9,839	2.84	56.87
Cantabria	2 (1 public)	710	1.10	83	2.05	9,338	1.33	5,455	1.58	58.42
Castile-La Mancha	1 (public)	1,296	2.00	51	1.26	12,215	1.74	5,058	1.46	41.41
Castile- Leon	9 (4 public)	4,105	6.34	129	3.18	28,699	4.08	12,977	3.75	45.22
Catalonia	12 (7 public)	8,589	13.27	1145	28.25	174,077	24.73	92,903	26.86	53.37
Madrid	16 (7 public)	14,309	22.11	886	21.86	121,842	17.31	61,831	17.88	50.75
Valencia	8 (5 public)	7,408	11.44	454	11.20	80,448	11.43	44,579	12.89	55.41
Extremadura	1 (public)	1,084	1.67	17	0.42	8,273	1.18	3,282	0.95	39.67
Galicia	3 (public)	3,513	5.43	186	4.59	35,754	5.08	14,780	4.27	41.34
La Rioja	2 (1 public)	605	0.93	13	0.32	3,801	0.54	1,610	0.47	42.36
Murcia	3 (2 public)	2,085	3.22	76	1.88	19,168	2.72	7,303	2.11	38.10
Navarre	2 (1 public)	1,210	1.87	75	1.85	14,841	2.11	6,605	1.91	44.51
Basque Country	3 (1 public)	3,156	4.87	226	5.58	29,574	4.20	13,084	3.78	44.24
Total	**82**	**64,733**	**100.00**	**4,053**	**100.00**	**703,813**	**100.00**	**345,896**	**100.00**	**49.15**

Source: Based on *IUNE* (*https://www.iune.es*)

Account is also taken of each regional system's contribution to the Spanish university system's total. Teacher/researcher proportions can be used to detect those indicators that lie above or below the expected figure for each autonomous community. As can be seen in table 1, column 4, the region of Madrid accounts for 22% of the teaching and research staff, but its contributions in other indicators range between 17% and 21.8%, slightly below the expected level. Catalonia, on the contrary, with 13% of the Spanish university system's teachers and researchers, has figures that range between 24% and 28% of the *SUS* total, making it the leading autonomous community. Valencia also displays figures somewhat higher than expected considering its volume of teachers and researchers, while the rest of the autonomous communities have lower figures than expected (Graph 3).



Graph 3. Regional university systems' contribution to the Spanish university system

This initial information provides the context for examining the results of open-science activity, enabling an exploration of the scope of open-science activity in the university system of each autonomous community in the dimensions addressed in Graph 1. Annex 1 lists the universities assigned to each autonomous community (only the institutions where activity about open science was detected are included).

4.1. Open-science regulations, policies and strategies

The analysis of university websites was used to define a number of indicators tracing the introduction of open science in the Spanish university system. Table 2 shows the main results, grouped by autonomous community. Information in greater detail can be found in **Sánchez** and **De-Filippo** (2022).

All Spanish public universities in all autonomous communities have institutional repositories that are assigned a specific name. In 15 of the 17 autonomous communities (88%), there is at least one university whose website contains a document containing an open-access policy approved by the university's board of governors. Madrid (*Polytechnic University of Madrid*) and Murcia (*Polytechnic University of Cartagena*) were the first autonomous communities to post such documents (in 2010). In all autonomous communities, universities have a web page devoted to open access, but there are differences in web page location and access. In most cases the page is on the library's web space. At 19 universities in 10 autonomous communities, an institutional officer for open science either has already been appointed or is in the process of being appointed. At only one university (*Autonomous University of Barcelona*) is there an open-science committee; this is roughly the equivalent of the library committee at other universities, chaired by a vice-rector and made up of representatives of the university community. In 10 autonomous communities, at least one university has a specific web page devoted to open science or citizen science.

Table 2. Open-science regulations and policies in regional university systems.

Autonomous community (No. universities analyzed)	Repository	OA policies since...	OS on library website	OS on general university website	Open-science officer	Open-science/ citizen-science website
Andalusia (10)	100%	2013	100%	0%	20%	30%
Aragon (1)	100%	2013	100%	0%	100%	–
Asturias (1)	100%	2013	100%	0%	–	100%
Balearic Islands (1)	100%	2014	100%	0%	–	100%
Canary Islands (2)	100%	–	50%	50%	–	–
Cantabria (1)	100%	2012	100%	0%	100%	–
Castile-La Mancha (1)	100%	–	100%	0%	–	–
Castile-Leon (4)	100%	2014	75%	25%	25%	50%
Catalonia (7)	100%	2011	57%	43%	71%	71%
Madrid (6)	100%	2010	100%	0%	67%	17%
Valencia (5)	100%	2011	100%	0%	40%	40%
Extremadura (1)	100%	2013	100%	–	–	100%
Galicia (3)	100%	2013	100%	–	25%	–
La Rioja (1)	100%	2022	100%	–	100%	–
Murcia (2)	100%	2010	50%	50%	50%	50%
Navarre (1)	100%	2019	–	100%	–	100%
Basque Country (1)	100%	2016	100%	0%	–	–

Note: "--" means no information was found on this variable at the time of the study

4.2. Knowledge production

The search strategy identified 134 European projects about open science in which Spanish institutions were participants. Fifty-five were funded under the *Seventh Framework Programme*, and 79 were funded under *Horizon 2020*. Spanish universities participated in 52% percent of the 134 projects. The other Spanish institutions involved were the *Spanish National Research Council* (*Consejo Superior de Investigaciones Científicas*), RD&I foundations, private industry, professional associations, the health industry and technological centers. Universities led around one third of the *FP7* projects in which they participated and one fourth of the *H2020* projects in which they participated.

As can be seen in Table 3, the universities of Madrid are the leaders in terms of participation volume, while the Catalonian universities are first in terms of leadership and funding. Madrid has the highest *FP7* project participation figures, while Andalusia also displays good participation figures. Institution by institution, the foremost universities are *Madrid Polytechnic* (13 European projects) and *Catalonia Polytechnic* (12 projects); these are also the institutions that have secured the most funding.

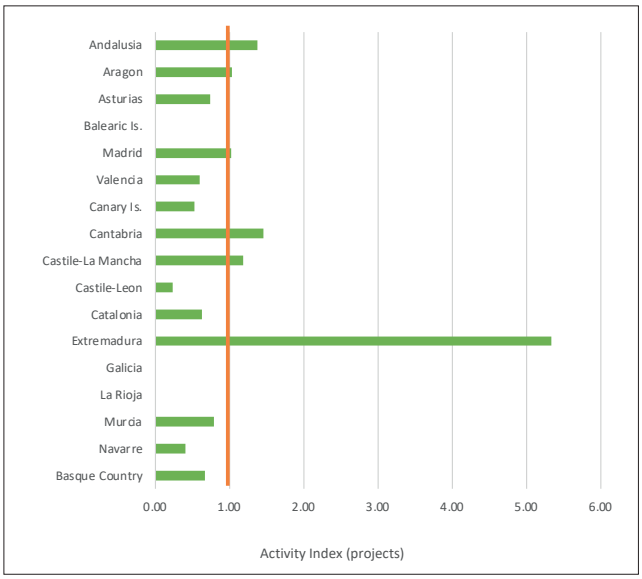
To ascertain whether activities about open science follow the same trend as overall activity in terms of project uptake, the percentages representing each autonomous community's contribution to the *SUS* total (table 1) were compared to the results for open-science projects. It was found that Madrid, with 22% of the *SUS* projects, is also responsible for 22% of the projects about open science. The trend runs the other way in Catalonia, however, where the figures for projects about open science (19.9% of the *SUS*) are lower than expected (Catalonia accounts for 28% of the *SUS*'s EU projects).

Table 3. European open-science projects in regional university systems (*Seventh Framework Programme* and *Horizon 2020*)

	Seventh Framework Programme			*Horizon 2020*				
Autonomous community	**No. projects**	**No. projects led**	**Funding (€)**	**No. projects**	**No. projects led**	**Funding (€)**	**Total No. projects**	**% of all *SUS* projects**
Andalusia	11	0	60,935.00	10	0	692,909.11	21	15.67
Aragon	1	1	173,394.00	3	0	1,228,215.97	4	2.99
Asturias	1	0	5,749.10	0	0	0.00	1	0.75
Balearic Islands	0	0	0.00	0	0	0.00	0	0.00
Madrid	20	2	2,570,501.28	10	2	3,731,083.00	30	22.39
Valencia	6	1	878,532.20	3	0	568,143.75	9	6.72
Canary Islands	1	0	5,749.10	0	0	0.00	1	0.75
Cantabria	3	0	232,069.10	1	0	30,625.00	4	2.99
Castile-La Mancha	0	0	0.00	2	0	994,342.03	2	1.49
Castile-Leon	0	0	0.00	1	0	303,625.00	1	0.75
Catalonia	12	7	4,574,942.74	12	4	5,057,330.26	24	17.91
Extremadura	2	0	5,749.10	1	0	423,152.50	3	2.24
Galicia	0	0	0.00	0	0	0.00	0	0.00
La Rioja	0	0	0.00	0	0	0.00	0	0.00
Murcia	2	0	22,851.30	0	0	0.00	2	1.49
Navarre	1	0	219,600.00	0	0	0.00	1	0.75
Basque Country	0	0	0.00	5	1	2,654,942.50	5	3.73
Total Spain	**55**	**30**	**8,750,072.92**	**79**	**26**	**15,684,369.12**	**134**	100.00

Note: The total number of projects is less than the sum of the projects, because there are some projects in which universities from more than one autonomous community participated.

Comparing each autonomous community's contributions to the total number of open-science projects with that same region's contribution to the total number of the *SUS*'s European projects yields the activity index (% open-science projects per autonomous community/% European projects per autonomous community). As shown in Graph 4, some regions are very engaged in open-science research activity. Their activity index is greater than 1, i.e., their contribution to the number of open-science projects granted is greater than expected. This is the case of Extremadura, which shows low activity in absolute terms but has a high activity index (since it furnishes 2.24% of the *SUS*'s open-science projects but just 0.42% of the *SUS*'s European projects). The other autonomous communities performing above average are Cantabria, Andalusia and Castile-La Mancha.



Graph 4. Regional university systems' contribution to projects about open science

4.3. Research results

A total of 1491 publications about open science were found in the target period. Although the number of documents in the *Web of Science* has been increasing, publications on open science do not make up more than 1% of any university's *WoS*-indexed publications. In absolute terms, the large regional systems, led by Catalonia, have higher numbers of documents about open science (table 4). At the institutional level, the highest production comes from the *University of Barcelona*, the *Polytechnic University of Madrid*, the *Autonomous University of Barcelona* and the *Complutensian University of Madrid*.

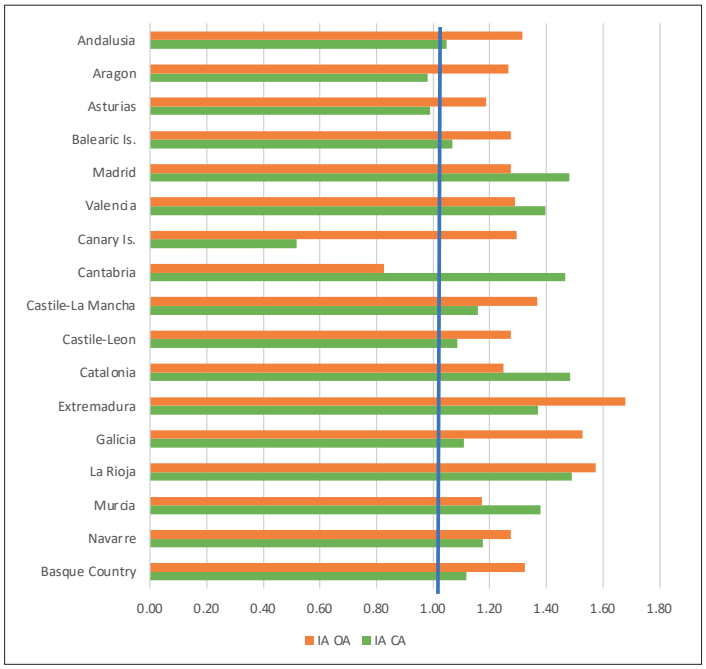
The Catalonian universities also have the majority of the open-access documents about open science (documents accessible via one of the routes considered here) in absolute figures (41.9% of the *SUS*'s open-science publications), followed by Madrid (28%). The leaders in terms of the number of OA publications about open science as a proportion of the total number of publications on open science in each autonomous community are the Canary Islands and Valencia, with over 70% (much higher than the *SUS*'s average of 58%) (table 4).

Table 4. Scientific publications about open science in the regional university systems (*Web of Science* 2010-2021)

Autonomous community	No. publications about OS	% publications OS	No. OA publications about OS	% OA publications OS	% OA
Andalusia	230	15.43	130	14.98	56.52
Aragon	44	2.95	28	3.23	63.64
Asturias	32	2.15	18	2.07	56.25
Balearic Islands	19	1.27	12	1.38	63.16
Madrid	382	25.62	247	28.46	64.66
Valencia	238	15.96	170	19.59	71.43
Canary Islands	19	1.27	14	1.61	73.68
Cantabria	29	1.95	14	1.61	48.28
Castile-La Mancha	30	2.01	17	1.96	56.67
Castile-Leon	66	4.43	38	4.38	57.58
Catalonia	547	36.69	364	41.94	66.54
Extremadura	24	1.61	16	1.84	66.67
Galicia	84	5.63	53	6.11	63.10
La Rioja	12	0.80	8	0.92	66.67
Murcia	56	3.76	25	2.88	44.64
Navarre	37	2.48	21	2.42	56.76
Basque Country	70	4.69	41	4.72	58.57
Total	1,491	100.00	868	100.00	58.22

Each autonomous community's contribution may also be seen in relationship to the total number of publications in *WoS*. In general, the production of publications about open science is intensive: with the exception of the Canary Islands, all autonomous communities have an activity index (AI) of 1 or more. As can be seen in Graph 5, the leaders are La Rioja (AI=1.49), Catalonia (AI=1.48), Madrid (AI=1.48), Cantabria (AI=1.46) and Valencia (AI=1.40). This means these autonomous communities display specialization in the subject.

The activity index (contribution to open-access publications about open science) of all regional university systems except the Canary Islands is more than 1 (Graph 5). This means the proportion of open-access publications about open science is higher than the proportion of open-access publications indexed in *WoS* as a whole.

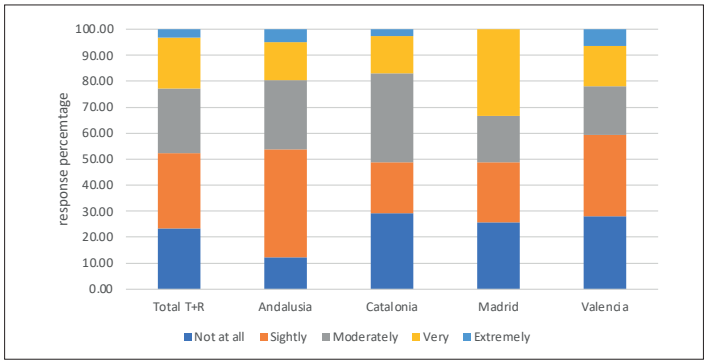


Graph 5. Regional university systems' contribution to publications about open science

4.4. Perception by academic actors

4.4.1. Information about open science

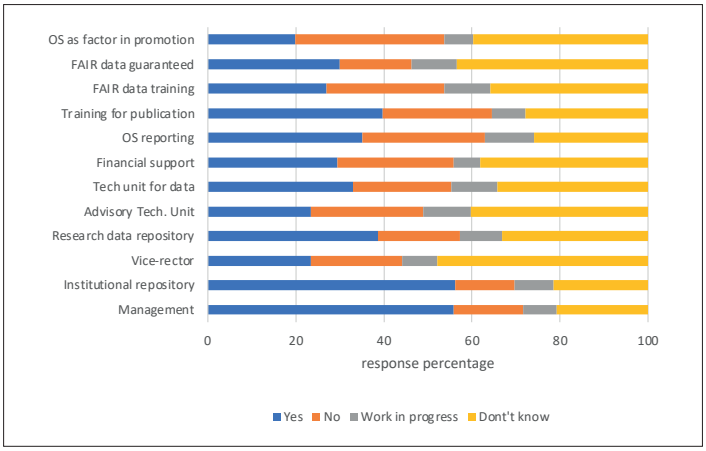
The teachers and researchers who participated in this research were asked how well-informed they considered themselves about open science. The answers on a five-point scale (1=not at all, 5=extremely) show that the participants consider themselves "moderately well-informed about open science" (mean=2.56, SD=1.18). As can be seen in Graph 6, 51% of the participants classify themselves as between "slightly" and "moderately" well-informed. The answers are similar in the four autonomous communities best represented in the sample (Graph 6).



Graph 6. Teacher and researcher information about open science

4.4.2. Information about university initiatives and strategies for fostering open science

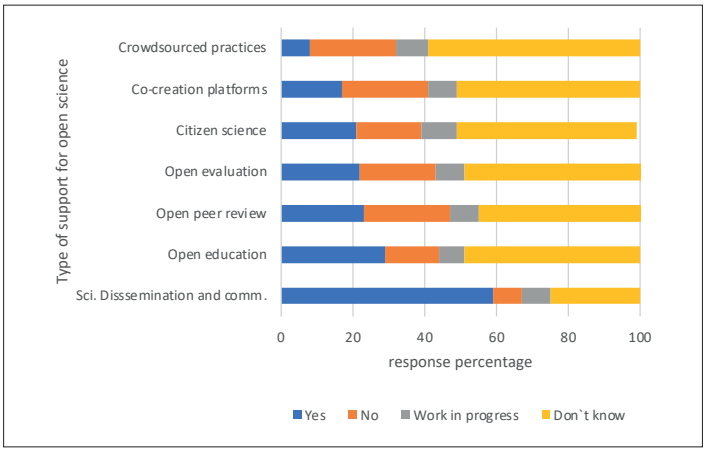
When teachers and researchers were asked to assess their university's initiatives to foster open science, the most frequent reply was "don't know," as shown in Graph 7. More than half (56.2%) of teachers and researchers know that their university has an institutional open-access repository, but 13.5% report that their university does not have a repository, 9% report that their university's repository is a work in progress, and 21.5% do not know if their university has an institutional open-access repository. These data are an indicator of teaching and research staff's ignorance about the subject, since, as said before (Table 2), each public university in the *SUS* does have an institutional open-access repository (*Menéndez Pelayo University* does not have one). Comparison of the universities in the four autonomous communities shows no differences as to the level of staff information on the subject.



Graph 7. Teacher and researcher knowledge of university strategies and actions to foster open science

4.4.3. University policies on open science (teachers and researchers)

The responses show that around half of the teachers and researchers do not know if their university has policies supporting researchers interested in doing open science, such as the policies in Graph 8. On almost all topics, "don't know" was the most frequent answer. Comparison of the four university systems does not reveal any significant differences.

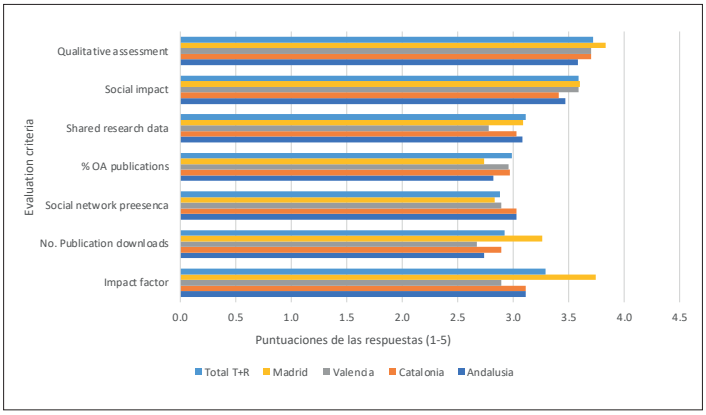


Graph 8. Teacher and researcher knowledge of university policies supporting open science

4.4.4. Criteria for assessing scientific output

Our inquiry into the best criteria for assessing the results of scientific activity in the framework of open science shows (Graph 9) that qualitative evaluation is the highest-scoring evaluation criterion (mean=3.72), followed by journal impact factor and number of citations received (3.29).

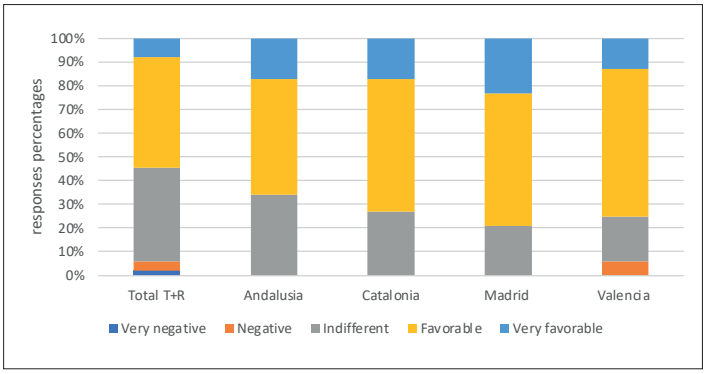
A comparison of autonomous communities reveals some differences in teachers' view of the importance of the impact factor; teaching staff in the Valencia region give this indicator its lowest score, 2.89, while teaching staff in Madrid give it its highest score, 3.74.



Graph 9. Criteria for evaluating scientific output. Assessment by teachers and researchers

4.4.5. Opinion about open science

Teachers and researchers generally voice a positive opinion of open science (3.85), and only 23% feel there are negative aspects associated with open science. No significant differences are found among the members of the university systems of the four autonomous communities (Graph 10).



Graph 10. Opinion about open science. Assessment by teachers and researchers

4.4.6. Open science from the standpoint of vice-rectors and library directors

As stated before, the information contributed to this study by university vice-rectors and library directors was analyzed qualitatively in connection with the *Open Science Policy Platform*'s eight priorities or pillars (**Ayris**, 2018).

In regard to pillar 1 (rewards and incentives), vice-rectors report that the lack of rewards for engaging in open-science activities in assessment and career advancement is the main barrier to transitioning to an open-science model in Spanish universities. Furthermore, over half the vice-rectors admit that their university has not yet evaluated and implemented any system of acknowledgement for engaging in open-science activities.

> "Spanish universities have become more and more involved in participating in and leading European projects on open science in the last decade"

In regard to pillar 2 (next-generation metrics), less than a fourth of the universities of the participating vice-rectors and library directors seem to have planned a policy for research activity recognition that includes open-science principles. The same percentage of universities include criteria concerning open publication in their annual research reports. Forty-four percent plan to prepare guidelines on good and bad practices in traditional bibliometrics and the development of new metrics. Fifty percent plan to train inexperienced researchers to accept the changes required by responsible metrics use.

When questioned about pillar 3 (the future of scholarly publishing), only 20% of the library directors report that open-science publication objectives are supervised. They claim that 90% of their universities track green open-access publication and 80% track gold open-access publication. The majority of the universities (73%) track the public cost of open publication.

When questioned about pillar 4 (the *European Open Science Cloud*, or *EOSC*), nearly half the library directors participating in the study report that their universities have not signed the *EOSC Declaration*. Only 10% have signed the agreement. Furthermore, there appears to be a serious lack of knowledge about this issue, because 35% do not respond.

In regard to pillar 5 (FAIR data), the majority of the library directors report that their university has not implemented a FAIR data policy, while 17.5% say their school is in the process of rolling out such a policy.

About pillar 6 (research integrity), 40% of vice-rectors report that their university has a code of good practice in research that includes the principles of open science. Furthermore, 44% of the vice-rectors assert that their university encourages researcher awareness of how open science can guarantee the highest standards of research. The rest report either that their school does not do so or that some progress has been made, but work remains to be done and there are challenges yet to be faced.

About pillar 7 (education and skills), most of the vice-rectors report that their university has established a specific plan for training teaching and research staff, doctoral candidates and administration and service staff in issues related with open science.

In pillar 8 (citizen science), no university has any procedure in place to encourage citizen participation in research projects. Only two universities foster citizen science using open labs or researchers' initiatives to foster citizen science. A little over a quarter of the universities collect information about their open-science research projects.

The results of the various phases of the study presented in this chapter are discussed below.

5. Discussion

Throughout this research, the goal was to map the development of open science in the Spanish university system based on an analysis of regulations, knowledge production, research results and the perceptions of various academic actors from the different autonomous communities of Spain. To this end, first of all information about the context was gathered, to learn about regional university systems' volume of activities.

The information obtained shows that the university systems of the autonomous communities of Madrid, Catalonia, Andalusia and Valencia are those that have the highest critical mass, in terms of both number of universities and number of students and teachers. These data match the data on distribution by number of inhabitants and GDP (*INE*, 2022), and they bear a direct influence on the volume of scientific activities done. An examination of, for example, scientific publications in the *Web of Science* shows the clear supremacy of Catalonia (25% of the Spanish total), followed by Madrid (17%), Andalusia (15%) and Valencia (10%). In the decade from 2000 to 2010, these four autonomous communities were already responsible for most of the country's output, although the figures were more evenly distributed (**Casani** *et al*., 2013). However, from 2010 to 2021, the universities of Catalonia increased their lead over the other autonomous communities, upping their contribution by two percentage points, while the other regions' output declined.

The findings of our work show that the autonomous communities with the greatest volume of scientific activity in terms of knowledge production (research projects) and research results (scientific publications) are those that have the most public universities. Previous studies of the Spanish university system's characteristics and performance have found this same relationship (**Casani** *et al*., 2014). The authors clearly identified the existence of public and private "subsystems" with very different activity patterns, where public universities were the leaders in terms of absolute numbers of institutions, teachers and students. However, volume is not the only thing that differentiates the public system from the private system. Public universities' research is more visible: their publication percentage in first-quartile journals is much higher. In addition, the public system is more active than the private system and competes more effectively for European pro-

ject funding, plus it has co-operation networks that are more internationally oriented. Public universities display greater activity in competitive drive (ability to secure funds for research in tenders) and knowledge transfer (number of patents and R&D agreements with business) (**Casani** *et al*., 2014).

After discussion of some points related with the general scientific activity of the various regional systems, emphasis was placed on the implementation of open science.

It was found that, as previous studies have observed, open access is the most well-developed open-science initiative in terms of regulations, policies and strategies (**De-Filippo**; **D'Onofrio**, 2019). Accordingly, it became important for us to consider open access in our study as well.

The findings obtained after analyzing university websites showed that the institutions of the various regional university systems have open-access policies approved by their boards of governors and that these policies have been especially keenly applied in the last ten years. In this sense, and in line with the kind of development taking place in the rest of the EU (**De-la-Torre** *et al.*, 2021), Spanish universities were found to be making an explicit effort to align their current open-access regulations and practices with those of Spain's peers. As **De-Filippo** and **Mañana-Rodríguez** (2022) report, how well open-access policies and regulations line up with the practical application of open access is the key to understanding the efficacy of policies and regulations and the real magnitude of application.

Although having open-access repositories and policies is an important step toward implementing open science for universities, the real use researchers put these repositories and policies to should be studied. Other researchers (**Nicholas** *et al*., 2017; **Rodríguez-Bravo**; **Nicholas**, 2019; 2020) have cautioned that repositories are not a very appealing publishing channel for either consolidated researchers (who are reluctant to change their ways, and many of whom still use decision-making criteria motivated by traditional incentives) or young researchers (who seek high-impact journals for reasons of competitiveness). In fact, young Spanish researchers' attitude toward self-archiving and self-archiving tools has hardly advanced at all since 2016 (**Rodríguez-Bravo**; **Nicholas**, 2021)

This situation might be assumed to pertain exclusively to the Spanish context if not for the fact that it has been found in other countries and world regions (**Blankstein**; **Wolff-Eisenberg**, 2019). The results presented in this paper, while not a reflection of the practices of all teachers and researchers, do show that researchers are more knowledgeable about the existence and function of repositories in the development of open science, although there is still room for improvement.

Website analysis also showed that, apart from open-access regulations, other actions related with open science do not yet appear to have been implemented very widely. At only 19 universities of 10 autonomous communities were universities identified that had named (10) or were in the process of naming an open-science officer, and only one open-science committee was identified (at the *University of Barcelon*a). The results show that the topic meets with unequal amounts of interest among the university policymakers of the various regional systems. Catalonian institutions show the greatest progress in this field. Catalonian centers of excellence, like the *Cerca* centers, promote open-science activities –particularly open-access activities– as part of the autonomous community's policies for the non-university realm (**Rovira**; **Urbano**; **Abadal**, 2019). *Cerca* centers frequently collaborate with universities, so they have delivered a major boost to the autonomous community's scientific activities.

This study also looked into projects and publications related with open science. It can be inferred from the results that interest in research into open science is quite recent, since most of the scientific publications and projects cluster in the last few years, coinciding with the roll-out (starting in 2011-2012) of various European and Iberian policies focusing on the promotion and consolidation of the open-science movement.

In the particular case of knowledge production, participation in European calls (one of the main sources of funding for Spanish universities) is observed to be on the rise (*Observatorio IUNE*, 2022). The universities of Madrid and Catalonia, especially the polytechnic universities, lead the pack in terms of the number of projects granted, leadership and funding. International projects tend to deal with subjects concerning computer science or engineering, the same big fields that other recent studies (**De-Filippo**; **Lascurain-Sánchez**, 2023) have detected. This clustering of interest is perhaps one of the reasons why the autonomous communities with polytechnic universities are so active.

When the percentage of open-science projects approved is compared to the percentage of total projects approved, the numbers are the same in both categories (22%) for the universities of Madrid. Catalonia's proportion of open-science projects is, however, much lower than its contribution to the set of European projects (19.9% open science *vs.* 28% European in all fields). In other autonomous communities, open-science research activity is much more intense, as in the case of Extremadura, followed by Cantabria, Castile-La Mancha (whose absolute figures are low, however) and Andalusia.

This interest in open-science research has also been seen in other studies examining participation in projects whose funding comes from sources other than the *European Commission*. For example, a great deal of participation in projects under the *Spanish National Plan* on

> Publications on open science are oriented toward open access, open data, and citizen science

topics related with citizen science and open access has been observed in recent years (**De-Filippo**; **Lascurain-Sánchez**, 2023). Furthermore, analysis of public university websites has identified projects on open science at 66% of institutions. These projects, most of which have to do with citizen science, are generally run by individual researchers under the aegis of entities like the proc citizen science *Ibercivis Foundation*, with no institutional participation by the researchers' university. Analysis based on project title and contents shows that these projects primarily have to do with the environment (**Sánchez**; **De-Filippo**, 2022).

Spain has considerable scientific open-science output, whether the pool examined is the publications covered by the *Web of Science* or the journals indexed in *Scopus*. These data are consistent with those found in previous studies. As a number of authors (**De-Filippo**; **Silva**; **Borges**, 2019) have observed, universities –especially public universities– are the institutions that produce the most documents about open science, particularly those universities that have implemented strategies to promote scientific openness through the creation of institutional repositories, projects about open science and participation in institutional networks for the application of open access. The larger institutions are the major producers, yet there are some other universities that are also highly active in open-science matters, although their output is just average for Spain as a whole. We refer to the polytechnic universities of Catalonia, Madrid and Valencia, which play an important role.

These results make it clear that open-science mandates, regulations and policies have their quantitative counterpart in research output. This is evident not only in the output about open science, but also in open-access publications, whose growth and percentage figures are higher than those of Spanish publications as a whole (*Analytics*, 2022).

Grouped geographically (by autonomous community), the big regional systems (led by Catalonia) are the systems that publish the most about open science in absolute terms. When the indicators about contributions to open-science activities are cast into a more-relative light, it can be seen that all the autonomous communities of Spain display intense activity, evidence of the importance that the topic of open science is acquiring in terms of the dissemination of research results.

Interestingly, a high percentage of publications about open science are open-access publications. The Catalonian universities top this list in absolute figures. Again, the percentage of OA publications about open science is considerable in the Canary Islands and Valencia, although these regions' output figures are more modest than Catalonia's. In the case of the Catalonian universities, the high numbers are not fortuitous; there is a regional open-access policy that includes actions like the "open-access observatory" (in place at all Catalonian universities), which examines the development of open access in Catalonia.

In addition to reporting quantitative results, this study includes information about the way people who can potentially perform activities related with open science see various aspects of open science. This has enabled us to provide a certain amount of context for the quantitative data and identify trends in the perceptions of stakeholders related with open science. One of our data-based conclusions is that the teaching and research staff who answered the questionnaire feel that they have limited information about open science. This academic group displays ignorance and/or only vague knowledge of the initiatives their university is running to encourage open science. They know even less about technical aspects and infrastructure (e.g., data management systems). Nevertheless, in general teachers and researchers think well of open science. Comparative analysis shows no significant differences among the answers given by the staff of the university systems of four selected autonomous communities, except in their opinion of the best criteria to consider when evaluating scientific output.

> "University teachers do not appear to be very knowledgeable about open-science initiatives in which their own institutions are involved"

The views of policymakers (vice-rectors in charge of open science and library directors) go a long way toward explaining teachers' and researchers' ignorance. The vast majority of policymakers feel that the progress made in introducing open science at universities has primarily involved initiatives related with open access to publications. In this sense, they report, strides have been made in universities' support for open-access publication (e.g., payment of open-access publication charges, legal guidance service for researchers interested in open publication). Most of the university policymakers consulted feel that open science is gaining momentum and in fact is formally included in universities' strategic plans, and that progress has also been made in a number of processes related with research data management and the possibility of sharing research data.

However, the data indicate that, at the practical level, most universities have not prepared specific policies on open science, nor have they set up representative committees to work on the subject. Only a fourth of the universities to which the participating vice-rectors and library directors belong have appointed someone to lead the roll-out of open science, one tenth have created units of technical staff in the area of research infrastructure for open science, and just a third have developed some program to raise awareness and provide information about the challenges and changes involved in the practice of open science.

> The development of university repositories is one of the Spanish university system's major achievements, as is the growing amount of open publication being done (especially green open publication)

According to the vice-rectors surveyed, the main barriers to the transition to an open-science model at universities has to do with the fact that employees who foster open-science activities earn no incentives and no acknowledgement in performance evaluations or career advancement. Over half the participants recognized that their university does not look at open-science activities as part of its hiring, performance evaluation or promotion policies. The second barrier in this group's eyes is the absence of nationwide and/or regional policies or directives about open science and the rise in costs (infrastructure, specialized staff, etc.). Library directors add that limited institutional knowledge about matters related with the benefits and limitations of open science is another barrier. Lastly, the surveyed policymakers perceive a certain resistance to change (especially reluctance to share research data) on the part of teaching and research staff.

Analysis of the information furnished by the various groups representing the university academic community shows that open science is generally seen as positive. Teaching and research staff's friendly views on open science appear in other studies (**Rodríguez-Bravo**; **Nicholas**, 2020; 2021), which note that researchers, especially younger researchers, favor open science more in views than in deeds, i.e., actual open publication and research data sharing. This clash between attitude and conduct was also noted by the university policymakers who participated in the surveys, who referred to teachers' and researchers' reluctance to share their research data.

The data analyzed here, especially the data furnished by the survey participants, also show a slow but real movement from the planning stage to the implementation stage. This observation agrees with the results presented in the *Open Science Policy Platform*'s final report (**Méndez** *et al*., 2020).

Nevertheless, some challenges remain to be met. Some of them reflect differences in the way different stakeholders perceive and value the implementation of open access in the universities in the Spanish university system. There are different levels of knowledge and access to information about open science, and the cultural shift needed to get open science really going has not yet happened. **Abad-García** *et al.* (2022) conclude, on the basis of the findings of a 2021 survey of vice-rectors of Spanish universities, that Spanish institutions of higher education still have a long way to go before they consider an overall model that provides more to favor a greater implementation of open science than just planning and policy agenda buzzwords. The study by **González-Teruel** *et al.* (2022) finds a dynamic scientific ecosystem whose actors are becoming increasingly knowledgeable about different aspects of open science and are displaying more-positive attitudes toward it. Some constraints have been revealed, however, that limit the full implementation of open science, which will require institutions to provide the right structures and incentives.

While our study encompasses several dimensions in the attempt to gain a broad overview of the implementation of open science in Spanish universities, we are aware that our work has its limitations. One of its most important constraints is that it focuses on those practices related with open science that can be studied through formal documents like research projects and scientific publications. Learning about other practices, such as free-software development, open data, open-education initiatives and citizen-science actions, involves setting mechanisms in motion to explore the validity of new sources to retrieve reliable, comparable, standardized information. We have begun doing so as part of a research project in progress that will surely reveal new facts about the scope of open science. Another line of research we are currently working on has to do with the proposal of suitable metrics for analyzing open-science activities.

Furthermore, the inclusion of the perception of different academic actors in this study is not intended as a means of drawing conclusions explaining the feelings of the entire academic community. On the contrary, it is a qualitative dimension that was incorporated with the goal of complementing the information gleaned from the quantitative study and providing a rough approach to the opinion of certain key actors. In this sense, the information stakeholders provided was extremely useful for increasing the existing knowledge about the implementation of open science at universities.

6. Conclusions

The results of the quantitative and qualitative analysis bring us to a series of conclusions related with the implementation of open science at Spanish universities.

Open-science regulations, policies and strategies have begun to be implemented in the last 10 years, focusing mainly on open access. The creation of institutional repositories and the dissemination of output by the green route form one of the Spanish university system's major achievements. No great headway seems to have been made, however, in the institutional promotion of initiatives concerning subjects such as open-data management, free software, open evaluation, and citizen science.

While projects and publications about open science have increased in number in recent years, they do not appear to be related to institutional initiatives. Instead, they are the product of certain groups or researchers' individual interest in the subject. Open publication of research results is becoming consolidated as an increasingly frequent practice promoted by institutional and regional initiatives, as in the case of Catalonian universities.

Teaching and research staff are found to be unknowledgeable about open science, although they think well of it. The lack of information and initiatives from universities may explain educators' lack of knowledge about specifics. In view of these data, there is clearly a need to inform the university community about what action is being taken.

> "Open science at Spanish universities is still in the process of being implemented"

The information furnished by key informants who play a major role in university management helps elucidate the teaching and research staff's limited knowledge about open science. At all events, the comparison between the kinds of practices the open-science model espouses (open access to research data, open publication, citizen participation in research) and the way work continues to be done at universities shows that the required cultural shift has not yet happened. In the best of cases, it might be just getting under way, according to the reports of the policymakers who participated in this research.

Generally speaking, there is evidence that whether a university is public or private is a factor that influences the university's scientific performance. In the case of projects and publications, open science is no exception to the rule. Grouping universities into regional systems also reveals certain distinctive, differential characteristics in connection with open science. The Catalonian university system, for example, has more structures and resources available for doing open science. As a whole, Catalonian public universities have the most well-structured institutional repositories and the repositories that offer the fullest information; the Catalonian university system is one of the few that actually does function as a system. Other large autonomous communities, such as Madrid, Andalusia, and Valencia, account for a healthy share of open-science activities and present leading figures in some features, although in general their figures are due to the particular activity of a given university and are not part of a homogenous regional profile. In the autonomous communities that have only one university, the volume of activities related with open science remains low.

In generally, the development of open science in the Spanish university system can be regarded as having made modest progress, but there are major developments that have yet to be made. One of them is the fundamental shift from policy to practice: practice promoted by institutions themselves, in a regional legislative framework that will enable collaborative work and growth throughout the autonomous community's institutions. Training for teachers and researchers, the inclusion of policies rewarding open-science activities, the appointment of university policymakers and officers with powers in open science, and good communication of institutional strategies are some of the things that will be fundamental for moving forward in the consolidation of open science.

The data lead us, as other experts on the subject have (**Anglada**, 2022; **González-Teruel** *et al*., 2022), to conclude that open science has not yet "taken off" in Spanish universities, so the consolidation of open science will depend on what is done in the next few years.

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Annex 1. List of universities in which scientific activity on open science has been detected (by autonomous community)

CCAA	Universidad
Andalusia	*Universidad de Almería*
Andalusia	*Universidad de Cádiz*
Andalusia	*Universidad de Córdoba*
Andalusia	*Universidad de Granada*
Andalusia	*Universidad de Huelva*
Andalusia	*Universidad de Jaén*
Andalusia	*Universidad de Málaga*
Andalusia	*Universidad de Sevilla*
Andalusia	*Universidad Pablo de Olavide*
Aragon	*Universidad de Zaragoza*
Asturias	*Universidad de Oviedo*
Balearic Islands	*Universitat de Les Illes Balears*
Canary Islands	*Universidad de La Laguna*
Canary Islands	*Universidad de Las Palmas de Gran Canaria*
Cantabria	*Universidad de Cantabria*
Castile-La Mancha	*Universidad de Castilla - La Mancha*
Castile-Leon	*Universidad de Burgos*
Castile-Leon	*Universidad de León*
Castile-Leon	*Universidad de Salamanca*
Castile-Leon	*Universidad de Valladolid*
Catalonia	*Universitat Autònoma de Barcelona*
Catalonia	*Universitat de Barcelona*
Catalonia	*Universitat de Girona*
Catalonia	*Universitat de Lleida*

CCAA	Universidad
Catalonia	*Universitat de Vic*
Catalonia	*Universitat Internacional de Catalunya UIC*
Catalonia	*Universitat Oberta de Catalunya*
Catalonia	*Universitat Politècnica de Catalunya*
Catalonia	*Universitat Pompeu Fabra*
Catalonia	*Universitat Ramon Llull*
Catalonia	*Universitat Rovira i Virgili*
Madrid	*Universidad Antonio de Nebrija*
Madrid	*Universidad Autónoma de Madrid*
Madrid	*Universidad Carlos III de Madrid*
Madrid	*Universidad Complutense de Madrid*
Madrid	*Universidad de Alcalá*
Madrid	*Universidad Nacional de Educación a Distancia*
Madrid	*Universidad Politécnica de Madrid*
Madrid	*Universidad Rey Juan Carlos*
Valencia	*Universidad Católica de Valencia San Vicente Mártir*
Valencia	*Universidad CEU Cardenal Herrera*
Valencia	*Universidad de Alicante*
Valencia	*Universitat Jaume I*
Valencia	*Universidad Miguel Hernández de Elche*
Valencia	*Universitat Politècnica de València*
Valencia	*Universitat de València*
Extremadura	*Universidad de Extremadura*
Galicia	*Universidade de A Coruña*
Galicia	*Universidade de Santiago de Compostela*
Galicia	*Universidade de Vigo*
La Rioja	*Universidad de La Rioja*
La Rioja	*Universidad Internacional de La Rioja*
Murcia	*Universidad Católica de Murcia*
Murcia	*Universidad de Murcia*
Murcia	*Universidad Politécnica de Cartagena*
Navarre	*Universidad de Navarra*
Navarre	*Universidad Pública de Navarra*
Basque Country	*Universidad de La Iglesia de Deusto*
Basque Country	*Universidad del País Vasco*