

A ranking of universities should account for differences in their disciplinary specialization

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Abstract A bibliometric analysis of the 50 most frequently publishing Spanish universities shows large differences in the publication activity and citation impact among research disciplines *within* an institution. Gini Index is a useful measure of an institution's disciplinary specialization and can roughly categorize universities in terms of general versus specialized. A study of the Spanish academic system reveals that assessment of a university's research performance must take into account the disciplinary breadth of its publication activity and citation impact. It proposes the use of graphs showing not only a university's article production and citation impact, but also its disciplinary specialization. Such graphs constitute both a warning and a remedy against one-dimensional approaches to the assessment of institutional research performance.

Keywords University rankings · Disciplinary specialization · Academic systems · Spanish academic system · Institutional research performance · Bibliometrics

Introduction

As research performance is nowadays widely considered as a crucial factor in moving towards a global and knowledge-based economy, a proper assessment of academic research has become a major policy concern for a wide range of stakeholders, among which (supra-) national governments, academic organizations, higher education governance and management, academic organizations, industry, researchers and students, and public opinion.

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When Nian Cai Liu and his colleagues at Shanghai Jiao Tong university published their first Academic Rankings of World Universities (Liu and Cheng 2005, 2008; SJTU 2007), they introduced a research topic that would develop into a discipline, with its own principles (CEPES 2006), organization of experts (IREG, the International Ranking Experts Group), Observatory (IREG 2009), international conferences and workshops, and numerous research papers (e.g., van Raan 2005; Aguillo et al. 2008; Calero-Medina et al. 2008) and books (Salmi 2009).

University rankings have gained a strong interest both from managers, researchers and the general public, and are used as tools in policy and planning, strategic positioning, research strategy development, value-for-money assessments, quality assurance, assessments of the quality, sustainability, relevance and impact of research activity, benchmarking against peer institutions, improve an institution's attraction capacity, and to identify research partners and career opportunities. A complete overview is presented in the report AUBR (2009).

Apart from the above mentioned *Academic Ranking of World Universities* published by Shanghai Jiao Tong University (SJTU 2007), important rankings are: *Times QS World University Rankings* (Times 2009), *SCImago Institutions Rankings* (SCImago 2010) published by the SCImago Research Group, located at the CSIC in Madrid and several Spanish Universities, *Leiden World Ranking*, published by the Centre for Science and Technology Studies at Leiden University (CWTS 2009), *Performance Ranking of Scientific Papers for World Universities* published by the Higher Education Evaluation and Accreditation Council of Taiwan (HEEACT 2009), and *Ranking Web of World Universities* from the Cybermetrics Lab at the CSIC in Madrid (CL-CSIC 2009).

These rankings combine an institution's research activities from all departments and research disciplines covered by a university, and calculate a score for a university as a whole. But as will be illustrated below, universities specialize hence the volume of an institution's research activity may be unevenly distributed among its departments. Moreover, a university may obtain a top position in one discipline, but perform only moderately in another.

The aim of the paper is threefold:

- Analyze and quantify for the 50 most publishing Spanish universities the degree of variability in publication activity and citation impact among research disciplines *within* an institution.
- Explore two-dimensional data presentations revealing both a university's score on a particular indicator as well as the variability of this score across disciplines.
- Examine how this complementary information is indispensable to obtain a valid and useful image of a national academic system and the role of individual universities therein.

For each institution a measure of disciplinary specialization is calculated called Gini Index and it is shown how Gini values are distributed among universities.

The Gini measure of inequality is commonly used for the measurement of income inequalities and has intensively been used in scientometric research for the measurement of increasing (or decreasing) (in)equality. Rousseau (1992a) and Burrell (1991) described its mathematical properties in great detail. Persson and Melin (1996) applied it in their study on equalization, growth and integration in science, and Moed et al. (1999) and Halfman and Leydesdorff (2010) in the measurement of inequality in national academic systems.

The section "[The Spanish academic system](#)" focuses on one particular national system: *Spain*. It needs emphasizing that the methodology presented in this section can also be applied to other countries or geographical world regions. It presents two-dimensional plots showing for the set of 50 main Spanish universities the overall publication activity or citation impact on the one hand, and the degree of their disciplinary specialization on the

other. In addition, Section “[The Spanish academic system](#)” gives for selected universities three-dimensional plots presenting the publication activity and citation impact in each discipline, showing the overall production in each discipline. These plots illustrate how the additional information on institutional specialization reveals policy relevant features of university research performance which tend to remain invisible if one focuses on statistics for a university as a whole.

The section “[Discussion and conclusions](#)” presents a summary and discussion of the findings and draws conclusions. But first the dataset analyzed in this study is described in section “[Data and indicators](#)”. It is extracted from SCImago Institutions Rankings derived from Elsevier’s *Scopus*. This section also presents the indicators calculated in the study.

Data and indicators

Data

This paper presents a secondary analysis of bibliometric data on research institutions extracted from the SCImago Institutions Rankings Database (SCImago 2010), which is based on Elsevier’s *Scopus*. Scopus is a comprehensive, multi-disciplinary citation index published by Elsevier. It covers nearly 18,000 titles from more than 5,000 international publishers, including coverage of 16,500 peer-reviewed journals, and several hundreds of conference proceedings, trade publications and book series (Scopus 2010). On July 1, 2010, it contained about 40 million records, of which 20 million records going back to 1996 (Scopus 2010).

SCImago Institutions Rankings (SCImago 2010) contains bibliometric indicators of nearly 3,000 most productive research institutions across the globe in terms of number of published articles. It presents for each institution four indicators of research performance, measuring publication output, citation impact and scientific collaboration. Analyzed institutions are grouped into five research sectors: government, higher education, health, corporate and others.

A dataset was created with bibliometric indicators for the 50 Spanish universities with the highest number of research articles published during the time period 2003–2008. It contains for each of these universities and per discipline the number of published papers per year during 2003–2008, and the average number of cites per paper received up until 2008. This paper uses a journal subject classification system arranging all Scopus journals into 27 disciplines (Scopus 2010; see Appendix Table 2 for a full list).

Indicators

Table 1 summarizes the principal indicators calculated in this study.

Normalized publication activity index (PAI)

A university’s *publication activity index* in a particular discipline is defined as the share of a university’s papers in a specific discipline, divided by the world share of papers in that discipline. For instance, if 6% of papers from university U are published in physics and astronomy, and if the world’s institutions have jointly published 3% of their papers in this discipline, U’s PAI in that discipline amounts to $6/3$ or 2.0.

Table 1 Four bibliometric indicators calculated in this paper

Indicator	What it measures	Technical description
Article output	Size of scientific activity (number of active scientists) and article productivity (number of articles per active scientist)	The number of research articles published during 2003–2008 in journals and books processed for Scopus
Normalized Publication activity index in a discipline (PAI)	Focus of a university upon particular disciplines compared to the world distribution of papers across disciplines	Share of a university's papers in a discipline divided by the world share of papers in that discipline. A value above 1 means: a larger activity in the discipline than expected on the basis of the world distribution
Institutional disciplinary specialisation index (also denoted as disciplinary specialization)	The extent to which research papers are evenly distributed among disciplines (as in general universities) or are more concentrated in particular disciplines (as for instance in medical, agricultural or (poli-) technical universities)	<i>Gini</i> Index of the distribution of publication activity indices across disciplines obtains values between 0 and 1. A value of 0 indicates that the distribution of published papers across disciplines is equal to the world distribution. A value of (nearly) 1 indicates total concentration of papers in one single discipline
Discipline-normalised citation impact per paper (also denoted as overall citation impact)	Intellectual influence; prominence of research groups in their disciplines; their authoritativeness; their visibility at the international research front	Average number of citations per article, relative to the world citation average (see main text). A value above 1 means: above world average

Gini's index of concentration or specialization

For each institution a *disciplinary specialization index* calculated. It measures the extent to which a university's papers are evenly distributed across disciplines, taking into account the world distribution of papers across disciplines. It is defined as Gini's Index for a university's distribution of the *publication activity indices* (PAI) across disciplines. A value of zero is obtained for a university for which the distribution of published papers across disciplines is equal to the world distribution.

Figure 1 presents for three specific universities the cumulative publication activity index (PAI), expressed as a percentage relative to the sum of an institution's PAI values across all disciplines (on the vertical axis), against the cumulative percentage of disciplines ranked by descending PAI (horizontal axis). The figure illustrates what type of distributions corresponds with the various values of Gini's Index. For low Gini values, the curve is positioned near the diagonal, whereas for large values it tends towards a one-step staircase. More details can be found in Egghe and Rousseau (1990) and Rousseau (1992b).

A university's normalized citation impact in a discipline

The base indicator is the average number of citations per paper published from a university in a particular discipline. And the normalized citation impact of a university in a discipline as its cites-per-paper ratio in this discipline divided by the discipline's world citation average.

‘Overall’ normalized citation impact of a whole university

This paper calculates a relative citation rate for an institution, by first calculating for each individual paper the ratio of its actual citation score and the average citation rate in the discipline the paper covers, and in a second step the mean value of this ratio over all papers published by an institution. This indicator is labeled in the SCImago Institutions Rankings as the Karolinska crown indicator and is denoted as an institution’s *overall* citation impact in this paper.

The Spanish academic system

Figure 2a, b, c show for each of the three universities included in Fig. 1 an overview of the publication activity and citation impact in each of the 26 disciplines, showing the total production in each discipline. As outlined in the section “Data and indicators”, data relate to the time period 2003–2008. A list with the developed names for the corresponding abbreviations of the disciplines is included in Appendix Table 2.

Figure 2a shows that the citation impact of the University of Barcelona is rather broad: it is in most disciplines above 1.0. In engineering, energy, chemical engineering, medicine computer science and veterinary sciences the citation impact is more than 50% above world average. This university has a profile of a general university as it shows a normalized

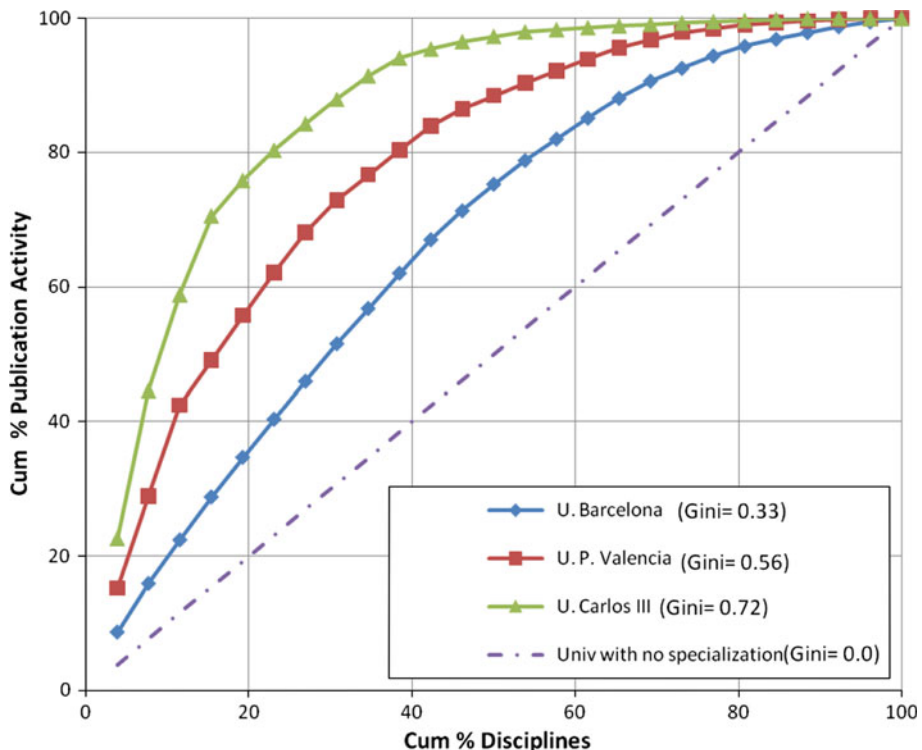


Fig. 1 Gini index of disciplinary specialization for three universities

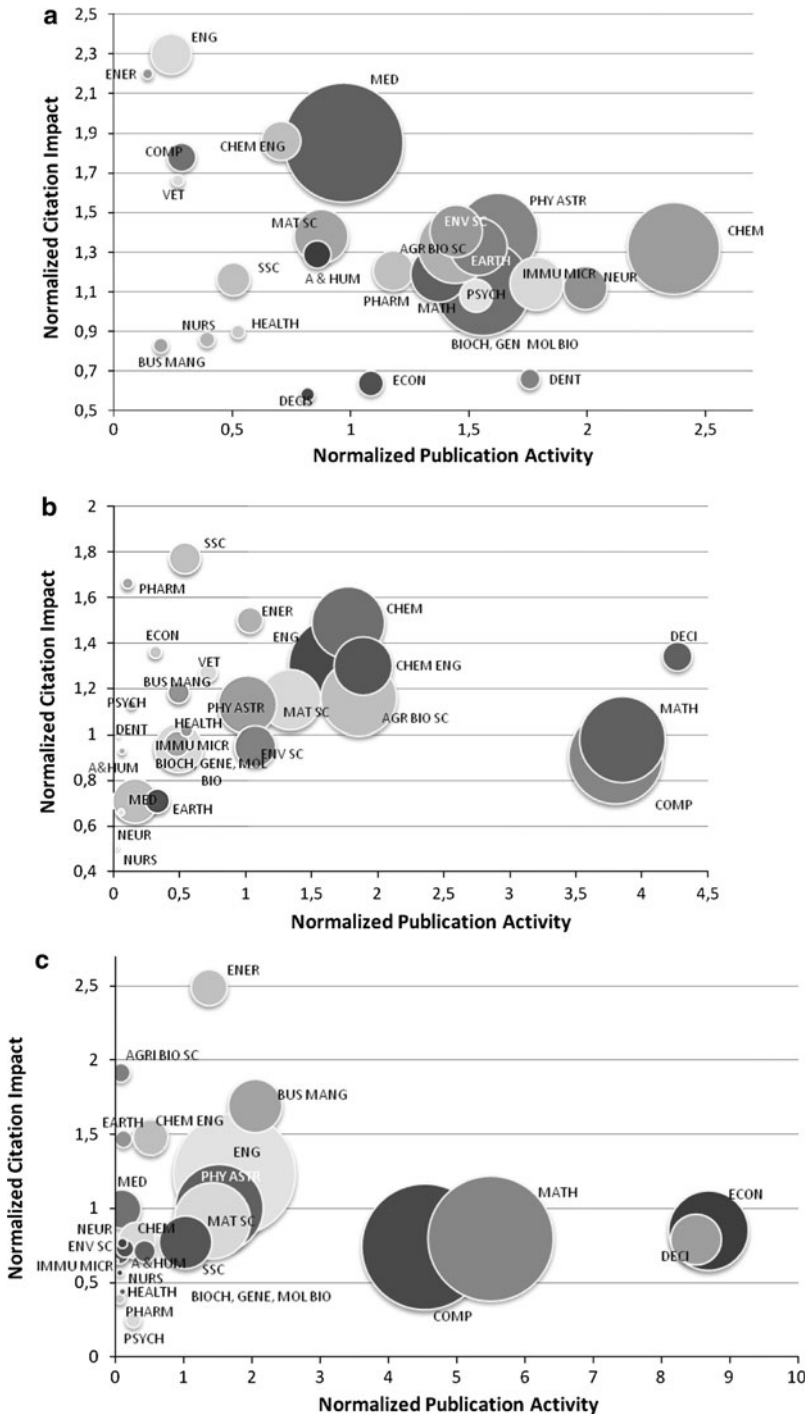


Fig. 2 **a** Citation impact versus publication activity per discipline for Univ Barcelona. **b**: Citation impact versus publication activity per discipline for Politechnic Univ Valencia. **c** Citation impact versus publication activity per discipline for Univ Carlos III

Figure 2b shows a profile that is typical for a (poly)technical university. It shows the highest publication activity indices in typical applied science and engineering disciplines: decision science, computer science and mathematics. Figure 2c reveals the profile of a highly specialized university. It has a disproportionally high publication activity in economics, econometrics and finance and decision sciences, and, to a lesser extent, but still with values above four in computer science and mathematics.

A second group of general universities (Gini index below 0.45), but with a smaller publication output (between 1,000 and 1,500 papers) includes the Universities of Granada, Sevilla, Santiago de Compostela, Pais Vasco and Zaragoza. The Polytechnic Universities of Valencia and Madrid published more than 1,000 papers per year, and have Gini, like the Polytechnic University of Catalunya, Gini specialization indices between 0.55 and 0.60. The most strongly specialized universities according to Fig. 3 are the Universities of Carlos III and Leon. The University Pompeu Fabra shows a Gini index similar to that of the big polytechnic universities.

University	Nr papers per year (X)	Disciplinary Specialization Index (Y)
UCAR	500	0.72
ULE	250	0.62
UPCT	200	0.58
UPF	450	0.57
UPM	1050	0.57
UPVA	1150	0.55
UPC	1700	0.59
UPN	150	0.54
UPNA	250	0.52
UPG	300	0.51
UPD	350	0.50
UPJ	400	0.49
UPV	450	0.48
UPH	500	0.47
UPA	550	0.46
UPB	600	0.45
UPC	650	0.44
UPD	700	0.43
UPH	750	0.42
UPJ	800	0.41
UPK	850	0.40
UPL	900	0.39
UPM	950	0.38
UPN	1000	0.37
UPP	1050	0.36
UPQ	1100	0.35
UPR	1150	0.34
UPS	1200	0.33
UPU	1250	0.32
UPV	1300	0.31
UPW	1350	0.30
UPX	1400	0.29
UPY	1450	0.28
UPZ	1500	0.27
UPA	1550	0.26
UPB	1600	0.25
UPC	1650	0.24
UPD	1700	0.23
UPH	1750	0.22
UPI	1800	0.21
UPJ	1850	0.20
UPK	1900	0.19
UPL	1950	0.18
UPM	2000	0.17
UPN	2050	0.16
UPP	2100	0.15
UPQ	2150	0.14
UPR	2200	0.13
UPS	2250	0.12
UPU	2300	0.11
UPV	2350	0.10
UPW	2400	0.09
UPX	2450	0.08
UPY	2500	0.07
UPZ	2550	0.06
UPA	2600	0.05
UPB	2650	0.04
UPC	2700	0.03
UPD	2750	0.02
UPH	2800	0.01
UPI	2850	0.00
UPJ	2900	0.00
UPK	2950	0.00
UPL	3000	0.00

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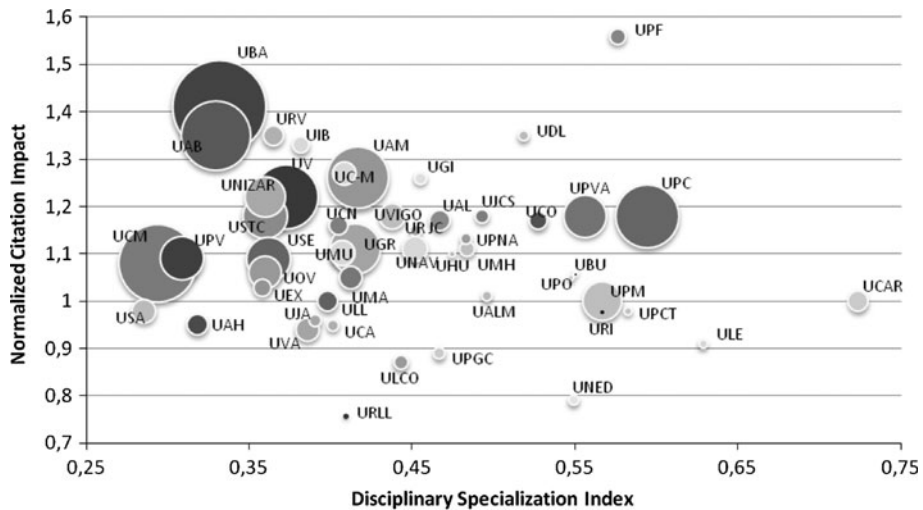


Fig. 4 Overall citation impact versus disciplinary specialization for the top 50 Spanish universities

the same citation impact may have completely different Gini disciplinary specialization indices. For instance, there are two universities of which the citation impact is above 1.4. But one of these is general—University of Barcelona—while the second, University Pompeu Fabra, is highly specialized.

A list with the developed names for the universities acronyms is given in Appendix Table 3.

Discussion and conclusions

First, three general comments must be made regarding the interpretation of the indicators presented in the previous section “[The Spanish academic system](#)”. Firstly, it must be noted that books play an important role in social sciences and especially in arts and humanities. Since Scopus does hardly index books in these disciplines, the results presented in this paper related to these disciplines may not be fully representative for a university’s total production and impact.

A second comment is that there is no one-to-one correspondence between a discipline name and a department name. For instance: not merely computer science departments publish in the discipline computer science. Hence, the outcomes presented in this paper cannot be used directly to assess particular research departments or faculties within a university.

Thirdly, if one is interested in obtaining a more detailed insight into the research performance of the various research groups, departments and faculties, a *bottom-up* approach is more adequate which starts with identifying the names of individual researchers and the research groups or departments in which they are active, in a next step compile a verified list of publications of each researcher involved, and finally calculates indicators per group of authors.

The analyses of the 50 most frequently publishing Spanish universities presented in section “[The Spanish academic system](#)” have revealed large differences in the publication

activity and citation impact among research disciplines *within* an institution. Using this index, one can roughly categorize universities in terms of general versus specialized. This analysis has shown that a categorization of universities according to their disciplinary specialization into three categories—general, moderately specialized and highly specialized—is useful. This categorization enables one to identify the truly general universities covering most if not all scientific-scholarly disciplines, the institutions specializing on specific, rather broad disciplines, such as polytechnic or medical universities, and finally the highly specialized ones, focusing on a one or two relatively narrow disciplines.

The findings have illustrated that a university's overall score, based on the aggregate of publications in all covered disciplines, can be strongly dominated by the results for one or two disciplines only. One single impact measure for a university as a whole does not provide information on the disciplinary breadth of publication activity and citation impact.

The paper presented two types of graphs. A first gives for an individual university a breakdown of publication activity and citation impact by discipline. Such graphs reveal a third dimension as well: the total number of articles published by a university in a particular discipline. A second type presents for each institution in a particular set its publication activity or citation impact in relation to its disciplinary specialization. Also the later plot shows a third dimension: the total number of articles published by a university. Both types of graphs represent an important next step in the assessment of universities' research performance and provide relevant additional information in rankings of entire universities. In this way, they constitute both a warning and a remedy against one-dimensional approaches to the assessment of institutional research performance.

Appendix

See Tables 2 and 3.

Table 2

Disciplines

Agricultural and Biological Sciences	AGR BIO SC
Arts and Humanities	A&HUM
Biochemistry, Genetics and Molecular Biology	BIOCH, GENE, MOL BIO
Business, Management and Accounting	BUS MANG
Chemical Engineering	CHEM ENG
Chemistry	CHEM
Computer Science	COMP
Decision Sciences	DECI
Dentistry	DENT
Earth and Planetary Sciences	EARTH
Economics, Econometrics and Finance	ECON
Energy	ENER
Engineering	ENG
Environmental Science	ENV SC
Health Professions	HEALTH
Immunology and Microbiology	IMMU MICR

Table 2 continued

Disciplines	
Materials Science	MAT SC
Mathematics	MATH
Medicine	MED
Neuroscience	NEUR
Nursing	NURS
Pharmacology, Toxicology and Pharmaceutics	PHARM
Physics and Astronomy	PHY ASTR
Psychology	PSYCH
Social Sciences	SSC
Veterinary	VET

Table 3

Organization	
Universitat de Barcelona	UBA
Universidad Complutense de Madrid	UCM
Universitat Autònoma de Barcelona	UAB
Universitat de Valencia	UV
Universitat Politècnica de Catalunya	UPC
Universidad Autónoma de Madrid	UAM
Universidad de Granada	UGR
Universidade de Santiago de Compostela	USTC
Universidad de Sevilla	USE
Universidad del País Vasco	UPV
Universitat Politècnica de València	UPVA
Universidad de Zaragoza	UNIZAR
Universidad Politécnica de Madrid	UPM
Universidad de Oviedo	UOV
Universidade de Vigo	UVIGO
Universidad de Murcia	UMU
Universidad de Navarra	UNAV
Universidad de Salamanca	USA
Universidad de Castilla-La Mancha	UC-M
Universidad de Valladolid	UVA
Universidad de Málaga	UMA
Universidad de Alcalá de Henares	UAH
Universitat d'Alacant	UAL
Universidad Carlos III de Madrid	UCAR
Universidad de La Laguna	ULL
Universitat Rovira i Virgili	URV
Universidad de Cantabria	UCN

Table 3 continued

Organization	
Universidad de Córdoba	UCO
Universidad de Extremadura	UEX
Universidad de las Islas Baleares	UIB
Universitat Pompeu Fabra	UPF
Universidad Miguel Hernández	UMH
Universidade da Coruna	ULCO
Universitat Jaume I	UJCS
Universidad de Jaén	UJA
Universitat de Girona	UGI
Universidad de las Palmas de Gran Canaria	UPGC
Universidad Rey Juan Carlos	UR JC
Universidad de Cádiz	UCA
Universidad Pública de Navarra	UPNA
Universitat de Lleida	UDL
Universidad Nacional de Educación a Distancia	UNED
Universidad de Almería	UALM
Universidad de León	ULE
Universidad Politécnica de Cartagena	UPCT
Universidad de Huelva	UHU
Universidad Pablo de Olavide	UPO
Universidad de Burgos	UBU
Universidad de La Rioja	URI
Universitat Ramon Llull	URLL

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