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Studying the research funding structure of countries through the analysis of funding acknowledgments¹

Belén Álvarez-Bornstein¹, María Bordons¹, Rodrigo Costas^{2,3} and Clara Calero-Medina²

¹ belen.alvarez@cchs.csic.es ; maria.bordons@cchs.csic.es

IFS, Centre for Humanities and Social Sciences (CCHS), Spanish National Research Council (CSIC), Albasanz 26-28, 28037 Madrid (Spain)

² clara@cwts.leidenuniv.nl ; rcostas@cwts.leidenuniv.nl

Centre for Science and Technology Studies (CWTS), Leiden University, Leiden (The Netherlands);

³Centre for Research on Evaluation, Science and Technology (CREST), Stellenbosch University, Stellenbosch (South Africa)

Introduction

Measuring the returns of research is of increasing importance for funding bodies, which have to demonstrate the benefits derived from their investment, such as knowledge creation and research output. In this context, the study of the funding acknowledgements (henceforth referred to as FAs) included in publications emerges as a relevant approach to track the research supported by different funding agencies, funding schemes or to analyse the synergies among them (Rigby, 2011).

Countries differ in their research funding systems in aspects such as R&D intensity, allocation mechanisms (project funding vs. institutional funding), organizational characteristics of funding bodies or level of involvement of public and private sectors (Reale, 2017; Auranen & Nieminen, 2010). Some of these factors might have a reflection on the FAs recorded in publications and in the subsequent analyses derived from them. Accordingly, cross-country analyses may provide interesting information for policy makers concerning issues such as the rate of funded research, the contribution of public and private support to research and the main funding sources.

Former studies in the literature have analysed FAs to compare countries regarding overall output (Wang et al. 2012) or specific disciplines (Zhao, 2010) with the aim of identifying research funding rates and main funding agencies (Gok, Rigby & Shapira, 2016) as well as the effects of funding on the impact of research (Wang & Shapira, 2015). In this paper the funding structure of a selection of countries and two biomedical disciplines is presented, studying their funding rates, national/foreign support, and main types of funding sources. The two biomedical disciplines are Cardiac & Cardiovascular Systems (CARD) and Virology (VIROL) (Álvarez-Bornstein, Díaz-Faes & Bordons, 2017), and seven countries that differ in their level of economic development, geo-political links, and R&D intensity are selected (Brazil, Germany, The Netherlands, South Africa, South Korea, Spain and Sweden).

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Objectives

The main objectives of this research are the following:

- To provide a general overview of the research funding structure of seven countries in two biomedical disciplines through the analysis of FAs recorded in publications.
- To characterize and explore what countries benefit more from international funding support, to what extent this support is associated to international collaboration and whether there are cross-country differences in the trend of countries to lead internationally funded research.

Methodology

Scientific publications were selected from the Web of Science (WoS) in the period 2010-2014. Only articles and reviews written in English were considered, since FAs from non-English papers are not indexed in WoS (Álvarez-Bornstein, Morillo & Bordons, 2017; Paul-Hus, Desrochers & Costas, 2016).

In the selection of countries different criteria were considered: (a) geographical location (four European countries and three non-European); (b) rate of R&D investment (%GDP): low (less than 1%) (South Africa), intermediate (between 1% and 2%) (Spain, The Netherlands and Brazil); high (between 2% and 3%) (Germany) and very high (more than 3%) (Sweden and South Korea); and (c) level of economic development and industrialization: Germany, Spain, Sweden and the Netherlands are high-income economies (World Bank), while South Africa, Brazil and South Korea have been described as “emerging economies” due to their rapid economic growth.

A general overview of the scientific production by country and discipline through activity, collaboration and impact indicators is provided; with special attention to the number of articles, collaboration rates (national and international) and citation-based indicators following the CWTS methodology (Waltman & Noyons, 2018): Mean Normalized Citation Score (MNCS), proportion of papers among the 10% most cited (PP top 10%) and Mean Normalized Journal Score (MNJS) (Van Raan et al., 2010). A variable citation window up to the third quarter of 2017 including self-citations was considered.

For the analysis of funding data, the information available in the WoS FAs fields, specifically in the funding agency field (FO), was used. Major funders were identified and classified in different institutional types: Research Organization, Funding Organization (e.g., Wellcome Trust, Deutsche Forschungsgemeinschaft), Governmental institution, Hospitals and Funding Channels (e.g. Cancer Center Support Grants, Horizon 2020), (Van Honk, Calero-Medina & Costas, 2016). Special attention was paid to the country, in order to identify the geographical origin of funding (national or foreign funders). The funding rate and the percentage distribution of agencies per geographical origin and type of funding organization were calculated. Differences between funded and non-funded papers were studied regarding scientific collaboration patterns.

Finally, the research impact and presence of foreign funding depending on which country is leading the research (i.e. the first country in the affiliation list) was also studied.

Results

Scientific output by country

In the period 2010-2014, a total of 28577 papers were published by the selected countries in CARD and VIROL (21150 and 7427, respectively). Germany was the most productive country in terms of number of publications in both disciplines, while South Africa was the least productive country in CARD and Sweden in VIROL (Table 1).

Table 1. Indicators of activity, collaboration and impact for CARD and VIROL by country

	BRAZIL		GERMANY		NETHERLANDS		SOUTH AFRICA		SOUTH KOREA		SPAIN		SWEDEN	
	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL
N. Articles	1853	797	8213	2757	5329	1118	404	783	2830	772	2851	1254	2084	568
Impact indicators														
MNCS	0.80	0.82	1.58	1.30	1.63	1.49	1.56	1.08	0.86	0.73	1.55	1.11	1.78	1.15
MNJS	0.78	0.81	1.34	1.23	1.42	1.19	1.09	0.86	0.94	0.83	1.26	1.04	1.44	1.08
PP top 10%	7.5	8.8	20.5	19.3	21.0	22.6	19.1	15.4	7.9	6.3	18.7	13.8	21.6	14.3
Collaboration indicators														
N countries/paper	2.18	2.73	2.22	2.65	2.28	2.44	2.54	2.56	2.43	2.46	1.99	2.59	2.59	2.29
N org/ papers	3.73	5.11	3.93	5.02	4.12	4.38	4.17	4.63	4.36	4.46	3.36	4.68	4.89	4.17
N authors/paper	8.22	9.83	8.61	9.56	8.89	9.33	8.89	9.54	9.00	9.12	7.97	9.47	9.73	8.48
% Collaboration	65.9	83.2	72.6	80.0	79.3	83.4	77.7	88.0	58.0	68.9	78.7	82.1	85.7	88.7
% Nat. collab.	32.0	40.4	22.4	20.1	22.1	16.6	17.3	13.1	34.0	41.8	29.4	32.8	24.0	13.6
% Int. collab.	33.9	42.8	50.1	59.9	57.2	66.7	60.4	71.0	24.0	27.1	49.3	49.4	61.7	75.2
Impact by internat. collab.														
MNCS int.collab.	1.54	1.25	2.15	1.43	2.05	1.609	2.26	1.28	1.73	1.14	2.33	1.43	2.28	1.24
MNJS int.collab.	1.29	1.023	1.67	1.31	1.66	1.259	1.49	0.99	1.44	1.11	1.61	1.14	1.30	1.03

Regarding impact indicators, Swedish and Dutch CARD papers received the highest number of citations and were published in highly impact journals (MNCS and MNJS>1). On the contrary, Brazil and South Korea show impact scores below world average in the two disciplines (MNCS and MNJS below 1). Moreover, Germany and The Netherlands show the highest percentage of highly cited papers in both disciplines (around 20%) while Brazil and South Korea present the lowest shares (<9%).

Concerning collaboration, research in VIROL seems to be more collaborative than in CARD measured through the percentage of papers in collaboration and the number of authors and institutions per paper. Anyway, almost all countries show relatively high collaboration rates in the two disciplines. Only South Korea and Brazil—in CARD— show collaboration rates below 70%. In addition, these two countries had the highest national collaboration rates and, especially South Korea, the lowest international collaboration rate (around 25% in both disciplines). Sweden and South Africa also present a low percentage of papers with national collaboration while European countries and South Africa show high levels of internationalization.

Impact of internationally co-authored papers and influence of the country leading the research

Internationally co-authored papers show an impact above world average in the two disciplines and for all the countries analysed. Specifically, the gain in impact associated to international

collaboration was higher in CARD than in VIROL, and particularly in Brazil and South Korea (table 1).

To analyse the leadership role of countries in international collaboration, the share of papers in which they appear as first affiliation country was considered. As it is shown in table 2, South Korea presents the highest percentage of leading papers—around 50% of its papers in international collaboration—, while the percentage for the rest of the countries was between 30-45% (table 2). Anyway, no clear relationship between R&D intensity of countries and their tendency to lead internationally co-authored papers was observed.

Table 2. Scientific output in international collaboration: number of publications by leading country (first country of affiliation)

	BRAZIL		GERMANY		NETHERLANDS		SOUTH AFRICA		SOUTH KOREA		SPAIN		SWEDEN	
	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL
P int collab	629	341	4119	1651	3047	746	244	556	680	209	1406	619	1286	427
% Int collab	34.00	42.80	50.20	59.90	57.20	66.80	60.40	71.00	24.00	27.10	49.30	49.40	61.70	75.20
P national first	221	142	1544	711	1250	305	85	199	314	105	403	259	368	178
P foreign first	408	199	2575	940	1797	441	159	357	366	104	1003	360	918	249
% P national first	35.14	41.64	37.48	43.06	41.02	40.88	34.84	35.79	46.18	50.24	28.66	41.84	28.62	41.69

Regarding impact indicators, the highest MNCS and MNJS values were obtained in the set of papers led by a foreign partner for all countries, the effect being stronger for emerging countries (Brazil, South Africa and South Korea) and Spain, especially in CARD papers (figures 1 and 2). Researchers from the US were the most frequent foreign partners leading the research for all countries. The second most frequent foreign leading country was the UK, for Germany, South Africa, South Korea, Spain and Sweden; Canada for Brazil and Germany for The Netherlands.

Figure 1. Mean Normalized Citation Score in papers in international collaboration by leading country in CARD (left) and VIROL (right)

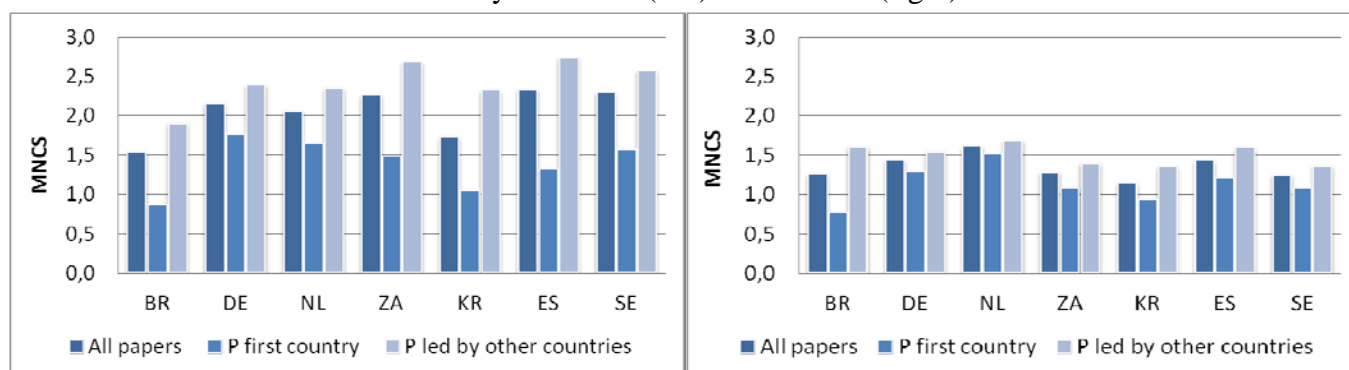
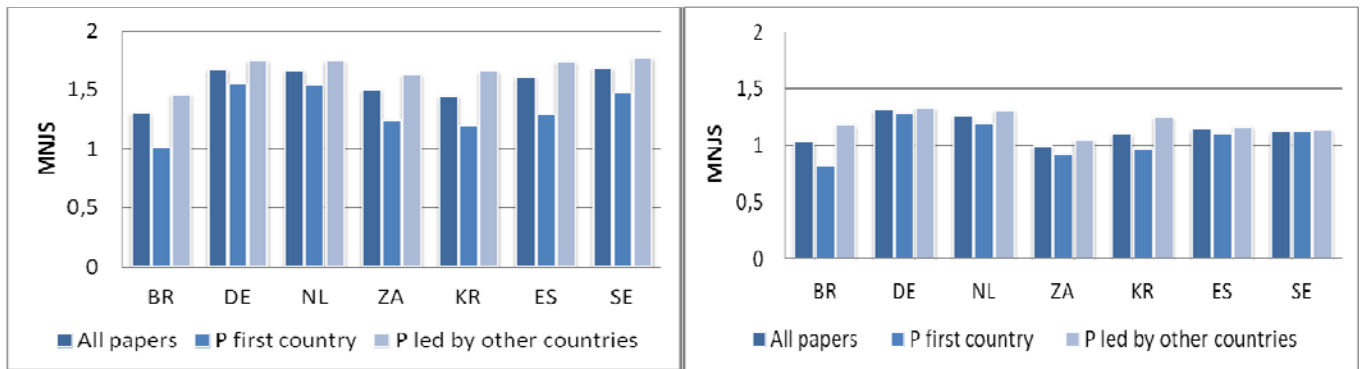


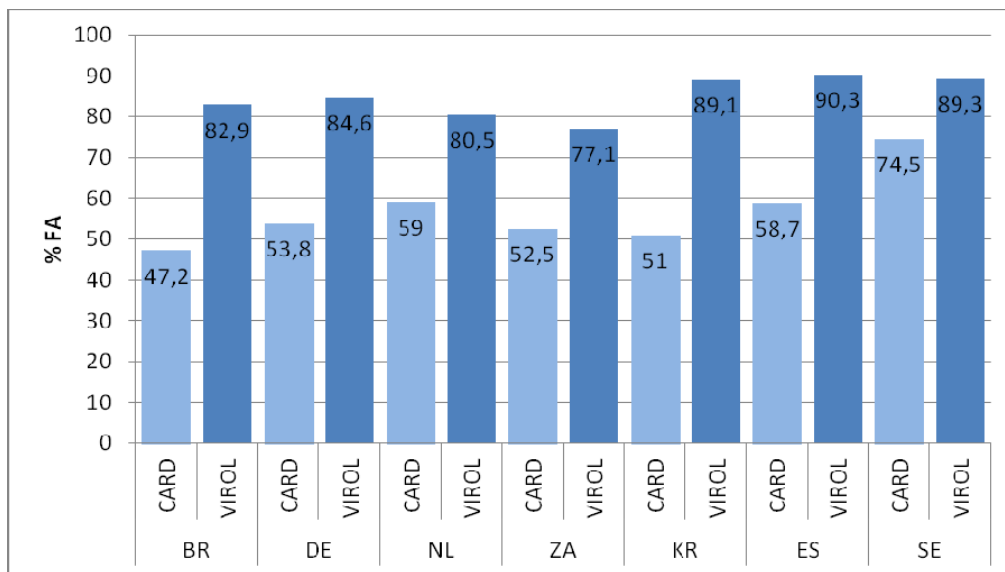
Figure 2. Mean Normalized Journal Score in papers in international collaboration by leading country in CARD (left) and VIROL (right)



Funding information

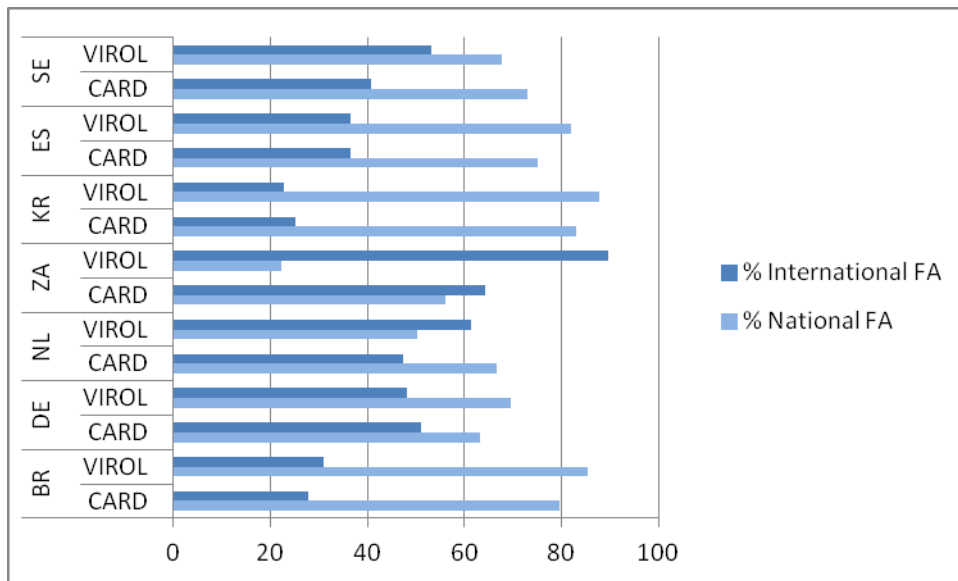
Funding was more frequently acknowledged in VIROL than in CARD in all countries. In VIROL, it ranged from 77%, in South Africa, to 90%, in Spain. Concerning CARD, Swedish papers reported the highest funding rate, in 74% of the papers, while the rest of countries acknowledged external funding in 50%-60% of the papers (Figure 3).

Figure 3. Funding rate by country and discipline



Regarding geographical origin of funding, national funding predominates in almost all countries and disciplines. The only exception is South Africa, where a high rate of funding from international agencies was reported (90% in VIROL and 64% in CARD). South Korea and Brazil acknowledged national financial support in more than 70% of papers and show the lowest percentages of international support (below 35%). (Figure 4).

Figure 4. Percentage of papers with national and/or international funding by country and discipline*



*The sum can be greater than 100 because some papers may include national and international FA

Additionally, funding from funding organizations and governmental institutions was more frequently acknowledged in Sweden, South Korea, Germany and Brazil, while research organizations support higher percentages of papers in Spain, South Africa and The Netherlands. Funding from hospitals and health system institutions was acknowledged in less than 10% of the papers in all countries (Figures 5 and 6).

Figure 5. Distribution of papers by type of funding agency (VIROL)

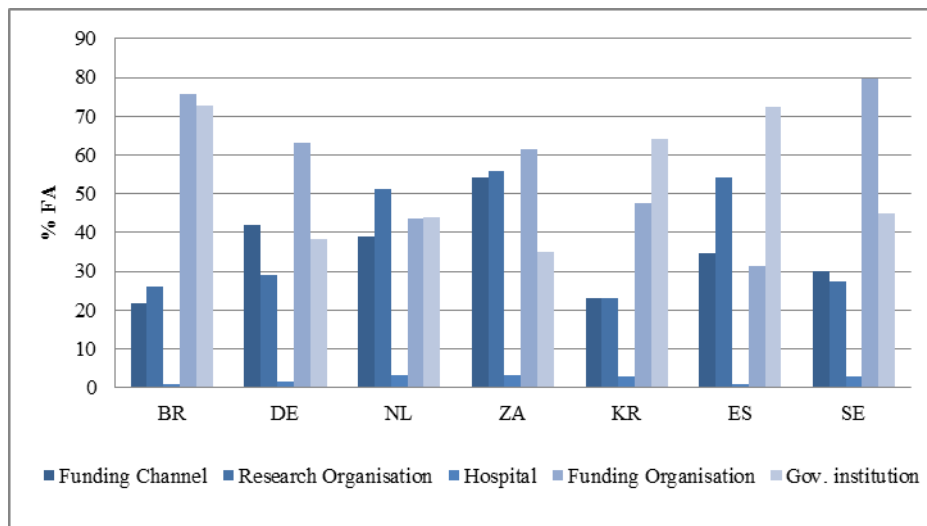
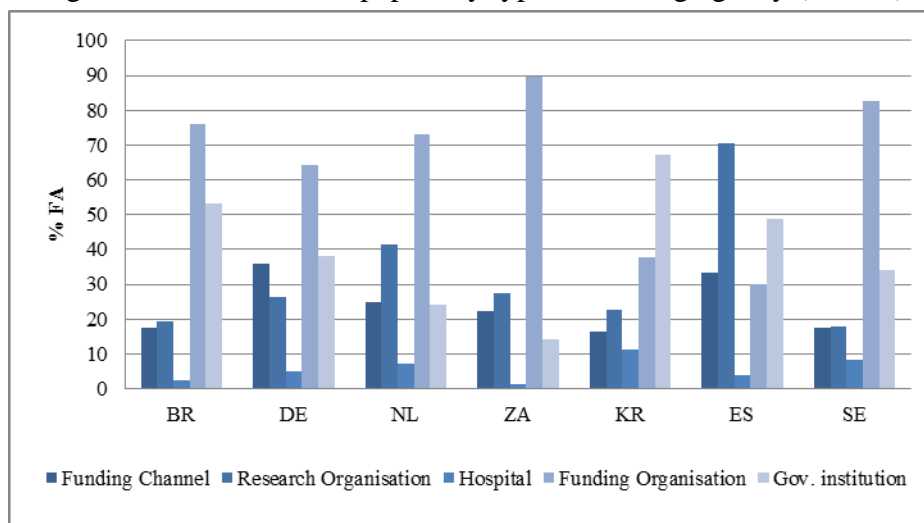


Figure 6. Distribution of papers by type of funding agency (CARD)



Collaboration patterns and impact of papers with/without FAs

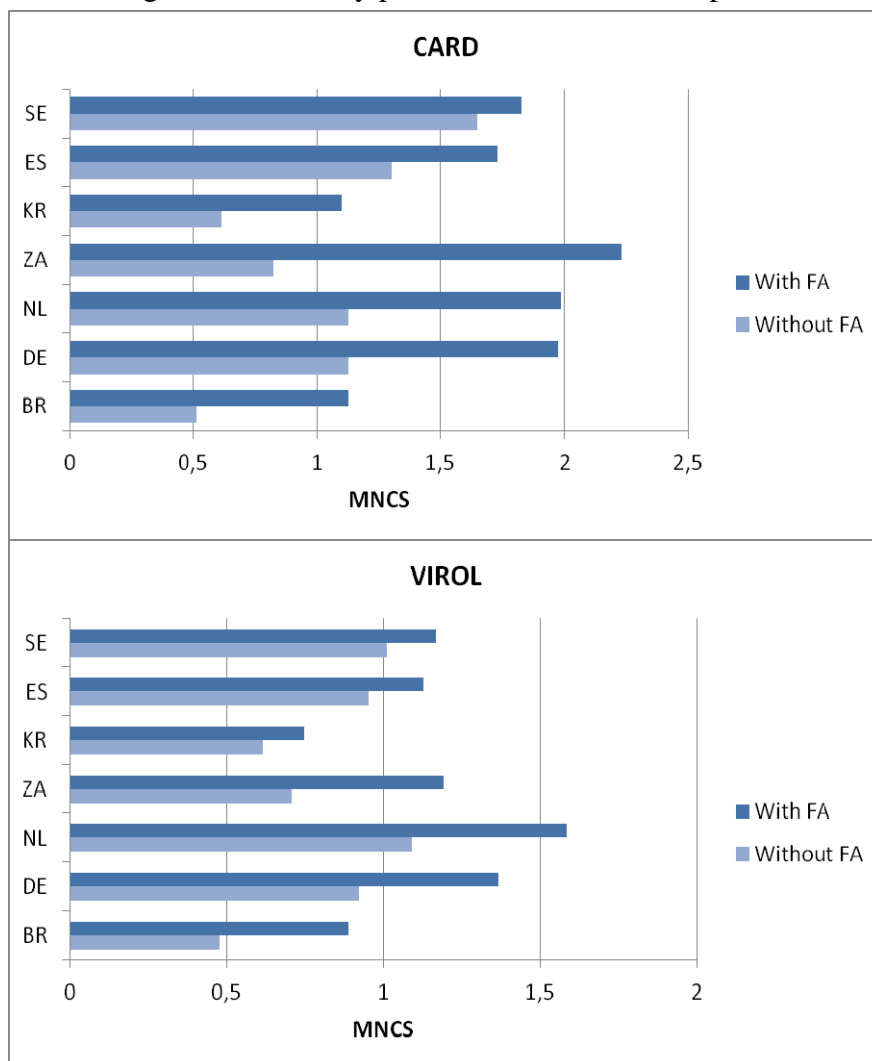
Collaboration patterns of papers with and without FAs are compared in table 3. Papers receiving external funding show higher collaboration rates and in particular higher international collaboration, which is twice as high as for papers not reporting funding and even higher in the case of South Africa.

Table 3. Collaboration patterns with/without FA by country and discipline

	BRAZIL		GERMANY		NETHERLANDS		SOUTH AFRICA		SOUTH KOREA		SPAIN		SWEDEN	
	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL
PAPERS WITHOUT FA														
% Collaboration	56.95	77.21	57.56	67.06	69.90	73.39	70.31	74.30	44.02	54.76	63.58	81.15	79.70	88.52
% National collab.	32.31	46.32	23.92	27.06	25.16	31.65	25.52	26.82	30.69	39.29	26.57	40.98	23.50	9.84
% Internat. collab.	24.64	30.88	33.67	40.00	44.74	41.74	44.79	47.49	13.33	15.48	37.01	40.16	56.20	78.69
PAPERS WITH FA														
% Collaboration	73.59	84.03	87.15	82.77	86.09	86.99	82.84	95.96	73.88	73.58	88.37	81.62	84.31	90.70
% National collab.	49.79	47.60	23.77	22.88	27.23	13.75	9.91	7.98	50.62	58.35	42.11	39.10	32.51	14.50
% Internat. collab.	50.21	52.40	76.23	77.12	72.77	86.25	90.09	92.02	49.38	41.65	57.89	60.90	67.49	85.50

Finally, it is interesting to note the higher citation impact of papers reporting funding in all countries and disciplines. The gain in impact of funded papers was higher in CARD than in VIROL, and particularly in Germany, the Netherlands and South Africa (Figure 7).

Figure 7. MNCS by presence of FAs and discipline



Geographical origin of funding in papers with international collaboration

Table 4 shows the number of internationally co-authored papers by country and discipline and the funding rate according to the presence of national or foreign funders. Firstly, we can mention that the total funding rate of papers with foreign partners is higher than that of the whole country for all countries and disciplines, and that research led by foreign partners predominates in most of the cases. Secondly, regarding the geographical origin of funding, papers with foreign funders are more common than those with national funders. Thirdly, foreign countries tend to lead the research in internationally funded papers, while local researchers tend to lead the research in papers with national funders. Finally, it is worth mentioning the high presence of foreign funders in South African papers, in particular in VIROL where less than 20% of the papers show national funders.

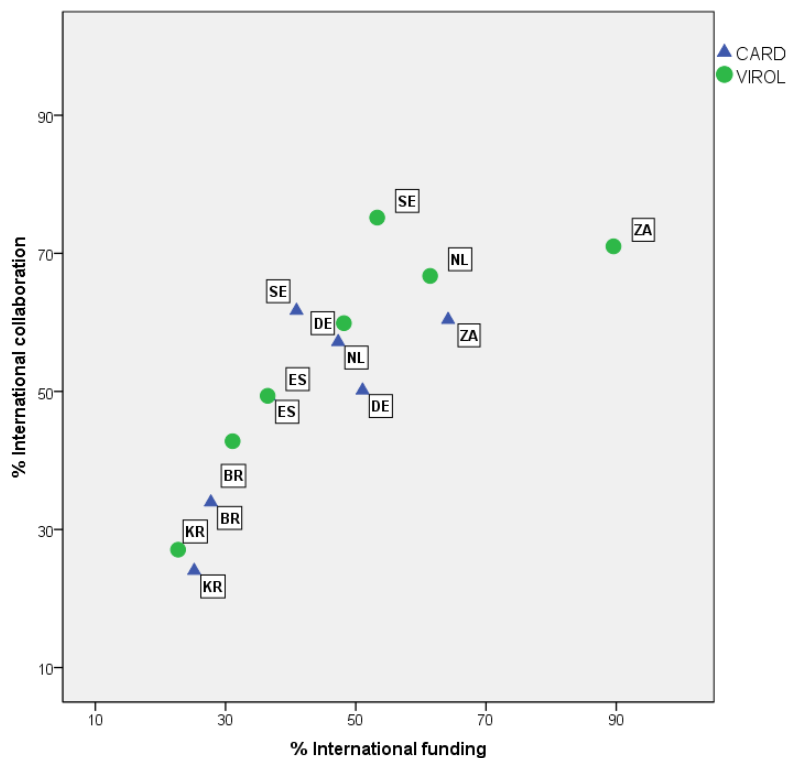
The US Government and the National Institutes of Health are the most prominent foreign funders for all countries, followed at a considerable distance by British, French or German funders, such as The Wellcome Trust in South Africa, the Leducq Foundation in Germany or the German Research Foundation (DFG) in Spain.

Table 4. Percentage of funded research in internationally co-authored papers by type of funders (national/foreign), leading country (national or foreign first country affiliation) and discipline

		BRAZIL		GERMANY		NETHERLANDS		SOUTH AFRICA		SOUTH KOREA		SPAIN		SWEDEN	
		CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL	CARD	VIROL
N. Art. with international collab. (AIC)		629	341	4119	1651	3047	746	244	556	680	209	1406	619	1286	427
% AIC with funders (all)	Total	61.69	87.68	69.00	89.70	67.90	87.80	64.75	84.71	72.79	93.78	68.99	92.08	76.75	88.76
	% foreign 1st	69	58	64	57	60	60	64	65	52	49	71	58	71	56
	%nat.1st	31	42	36	43	40	40	36	35	48	51	29	42	29	44
% AIC with national funders	Total	44.53	67.15	47.24	58.15	49.65	42.80	42.86	19.06	56.76	63.74	52.26	67.63	52.30	62.01
	% foreign 1st	26	38	33	33	32	28	29	31	20	23	35	38	38	30
	%nat.1st	74	62	67	67	68	72	71	69	80	77	65	62	63	70
% AIC with foreign funders	Total	74.49	67.88	76.07	74.86	73.35	83.90	80.95	93.88	61.27	67.84	71.43	70.10	71.20	69.91
	%foreign 1st	80	76	79	72	73	72	71	69	77	66	85	71	84	72
	%nat.1st	20	24	21	28	27	28	29	31	23	34	15	29	16	28

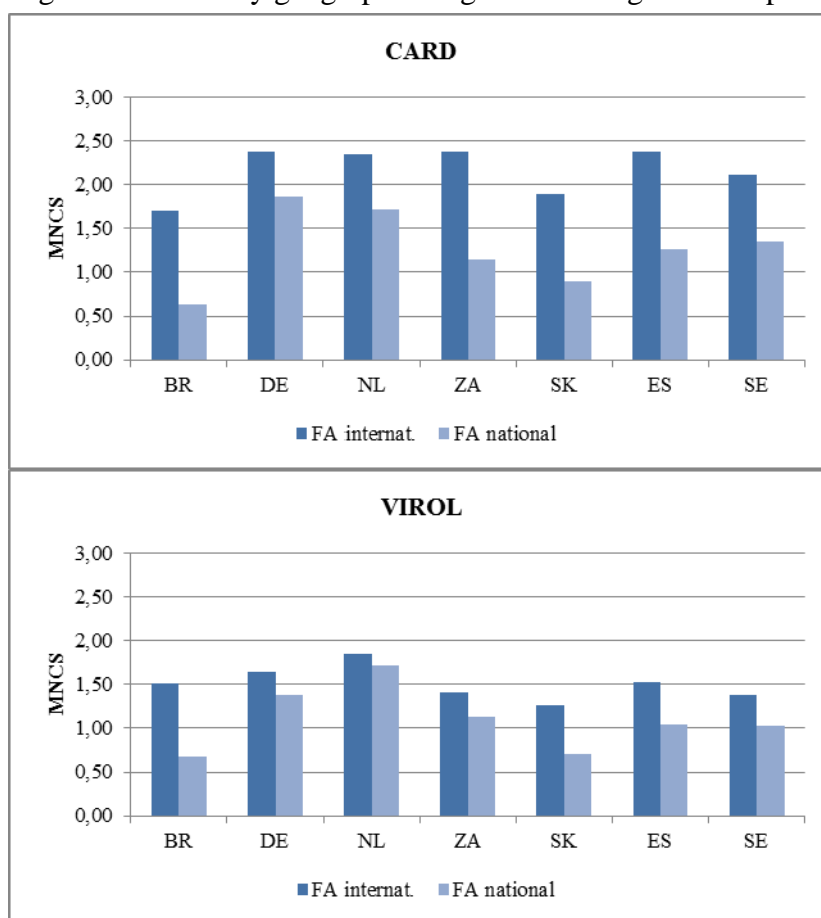
Figure 8 depicts the distribution of countries by international collaboration and international FA, and a positive relationship between both variables can be noticed. The case of South African VIROL papers is remarkable. These papers reached the highest percentage of foreign funding and, additionally, had one of the highest international collaboration rates. On the contrary, research from South Korea and Brazil, shows low internationalization in terms of both collaboration and financial support.

Figure 8. International collaboration rate and percentage of international FA by country and discipline



Finally, it is interesting to note that papers with foreign funding attain higher impact than those with national funders, in particular in CARD, and in Brazil and South Korea (figure 9).

Figure 9. MNCS by geographic origin of funding and discipline



Conclusions

Our study reveals differences between countries and disciplines in scientific activity and funding structure. Concerning scientific activity, European countries proved more active in terms of publications and attained more impact than emerging countries. Brazil and South Korea show the lowest average impact (below world average) and the lowest share of papers among the 10% most cited. These countries exhibit also the lowest percentage of papers in collaboration among two or more institutions and the lowest share of internationally co-authored papers. Conversely, a high level of internationalization is observed for European countries, in particular for Sweden and the Netherlands, but also for South Africa.

Internationally co-authored papers show higher impact as measured through the MNCS indicator, being this positive influence higher in CARD and in the emerging countries. Specifically, international collaboration boosted MNCS around three times in CARD and two times in VIROL papers from emerging countries. Interestingly, all countries obtain the highest impact in research led by foreign partners, and this is observed for emerging countries but also for the most scientifically advanced ones like Germany.

Additionally, the study of the funding rates reveals larger differences by discipline than by country, obtaining VIROL higher funding rates (77-90%) in all countries, probably due to its

more basic nature, since academics are more likely to be funded than clinicians in hospitals (Álvarez-Bornstein, Díaz-Faes & Bordons, 2017; Lewison, 2003). However, cross-country differences become apparent in the funding structure. National funding predominates in most of the countries and obtains the highest figures in Brazil and South Korea, where the lowest funding from foreign agencies is observed (below 30%). This is consistent with the low international collaboration rate found for these countries, since a clear relationship between international collaboration and foreign funding was described.

Results concerning South Africa deserve special attention. In spite of the low R&D intensity of this country, it manages to obtain an impact slightly above world average and relatively high share of papers among 10% most cited. The fact that it shows high international collaboration rate and high support from foreign agencies can be an important explaining factor. Research organizations and the higher education system in this country promote international collaboration through the mobility of students and researchers and it might contribute to enhance country recognition in the international research landscape (Sooryamoorthy, 2010). In the other end of the spectrum is located South Korea, with a high R&D intensity, but impact below world average. Its low international collaboration may hinder country accessibility to funding from foreign sources.

Papers in international collaboration are more likely to present funding support and, in particular, support from international sources. Moreover, international funding is more likely to occur in papers led by a foreign partner, probably because research is usually led by the country providing funding support. Scientific collaboration and internationalisation have become essential for the development of science in many fields since they may enhance scientific achievement and research impact, in particular for the peripheral countries (Goldfinch et al., 2003). In this context, research funding systems may play a strategic role pursuing this objective. On the one hand, national research funding systems try to foster international collaboration, and on the other hand, new opportunities are encountered by researchers to be supported by foreign funding sources, such as EU initiatives (Wang & Shapira, 2015).

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