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Building ties across countries: International collaboration, field specialization, and global leadership [1]

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Introduction

It has been well-established that the presence of scientifically advanced countries playing key roles in knowledge generation is associated with their capacity to recruit expertise and attract resources, obtaining a competitive advantage (Wagner et al. 2001). Scientific capacities, in terms of publications, reflect differences in economic strengths, scientific infrastructures, human capital, and educational systems (Miguel and Okubo, 1994). The scientific size of countries is highly associated with their economic strength in terms of R&D investment (Wagner et al. 2018). Countries with high research performance, in terms of activity (e.g.,

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number of publications), or citation impact, are considered as leaders in scientific production (Klavans and Boyack (2008)

Leadership in science has been operationalized based on authors' position in publications (Moed, 2000, Moya et al. 2013; Xu et al. 2014). Such position provides critical information for the allocation of credit (Lariviére et al. 2016). Although there is no "rule of thumb for identifying authors contributions", and disciplines have differing practices on authorship positions (Hu, 2009). In principle, the last position is largely associated with seniority and the provision of scientific resources (Tscharntke et al. 2007). However, corresponding authors (more likely to be first authors) are considered to take full responsibility on the administration and communication process, ensuring that all contributors abide to scientific and ethical rules (ICMJE, 2012). When collaborating internationally, research groups modify their structure, delegating this role to the main contributor of the study, and by extension, to their country and institutional affiliation. By assuming this leadership role to the corresponding author, many studies have analyzed the scientific role of countries and institutions, either as leaders or subordinates when collaborating internationally (Costas & Iribarren, 2007; Van Leeuwen 2009; Chinchilla et al, 2016; González et al. 2018). In an increasingly collaborative culture, as the scientific enterprise (Adams, 2013), it is safe to assume that correspondence is a viable proxy of scientific leadership, especially at the country level.

Within an ever more globalized research landscape, national research profiles and their fitting within global international networks are key on the development of countries. Preferences towards certain scientific disciplines will differ from one country to another (Hidalgo et al, 2007). Each country and their partners collaborate differently according to their research priorities, strategies researchers pursue when collaborating internationally, and lack of facilities and equipment (Miquel and Okubo, 1994). The concept of 'Smart specialization' refers to the identification of national strengths and weaknesses within research fields in order to establish priorities strategically. This approach aims at selecting the most relevant areas for funding agencies to invest by monitoring efforts and resources which are commonly not evenly spread. (OECD 2013). The intensity of such efforts is usually measured by the activity index, which characterizes the relative research effort a country devotes to a given disciplinary domain (Frame 1979). For a more comprehensive review of this indicator, we refer to Rousseau (2018).

R&D expenditure data is collected from organizations such as the World Bank, while bibliographic databases provide robust information about changes on authors' positioning in publications. In this study, we analyse these changes over time aiming to understand how different types of leadership characterize countries' research performance and specialization, and how internationalization can be harnessed to improve absorptive capacity, visibility and integration into global collaboration research networks. We use R&D expenditure data, domestic and international publications, the citations received, authorship positioning and the activity index. Our goal is to discern preferences of domestic and international outputs in determining the disciplinary structure in scientific relationships in terms of publications and citations and how leadership in publications at national and international level affect relationships and performance. To do that, we answer the following questions:

- Does domestic and international leadership affect the thematic specialization of countries?
- Does specialization increase or decrease to the same extent than citation impact?
- To what extent does collaborating with leading partners improve specialization and citation impact?

Given that each country has its own disciplinary profile scientific priorities, the application of this approach will reveal national strengths and weaknesses. It will also point towards signs of dependency on internal and external partners, both; at the national and international context. The underlying assumption is that differing distributions of fields in different countries reflect significant characteristics of countries patterns that stem from both explicit and implicit science policies. We believe our findings could improve the current understanding on the role of leadership, internationalization and disciplinary profiles in forming research agendas.

Data and methods

Publication data were retrieved from Clarivate Analytics Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts and Humanities Citation Index (AHCI) for the 2000–2016 period. It comprises 19,460,980 papers (articles and reviews). We considered only publications from the Biomedical Research field (based on the thematic classification of the National Science Foundation). We analyzed three periods with a total duration of 17 years (2000-2005, 2006-2011, 2012-2016), and based our comparisons on the first and third period. The analysis is limited to 94 countries producing at least 7,000 documents over the entire period and for which R&D expenditures data were available; those account for more than 98% of the world output.

We used two country-level classifications. R&D expenditures data was drawn from the World Data Bank (2017) for all countries with available data except for Taiwan, for which, we use OECD data. We used the share of GDP as a proxy for countries' economic capacity. We classified countries into four groups of unequal sizes: 1) countries investing more than 2% (17 countries –green color), 2) those investing more than 1% (17 countries - blue color), 3) those investing more than 0.5% (18 countries – orange color), and 4) those investing less than 0.5% (43 countries – red color). We assigned every country to one of the seven geographical regions defined by the World Bank (2017).

For each of the countries analyzed, papers were grouped into two categories, based on their institutional affiliations: 1) all papers published domestically (i.e. same country) and, 2) papers that have at least two institutions from at least two different countries (i.e. international collaboration). For papers in international collaboration, the country in leadership position was that of the corresponding author and, conversely, to be in a non-leadership position when it was not that of the corresponding author. For papers without international collaboration, leadership is always given to the sole country of production.

The number of citations of each paper was normalized by the mean average of all papers published in the same discipline in the same year (Moed, De Bruin et van Leeuwen, 1995; Schubert et Braun, 1986; Waltman et al., 2011). We used the National Science Foundation subject classification. We calculated the normalized citation impact for leading and non-leading papers and for each collaboration type.

The Activity Index measures the relative research effort a country devotes to a given scientific domain in its total publication output against the corresponding world standard (Frame 1979). It reflects the degree of specialization of each country, and it is standardized in order to facilitate comparison among the countries. The values are in the range of [−1; 1], in which zero represents the world average specialization in the field denoted as Relative Specialization Index (RSI) (Glänzel, 2000).

Results

Different types of authorship translate in different results in terms of relative specialization (RSI) and field-normalized citations (MNCS). Figure 1 shows for each region and country, the results of domestic papers (blue line), internationally leading collaborative papers (orange line) and non-lead internationally collaborative papers (grey line) for both indicators: publication profile in terms of relative specialization index (left) and visibility in terms of normalized citation (right). The dotted line shows the "world average". Any deviation from this standard results in a deformation of the strengths /weaknesses of each country.

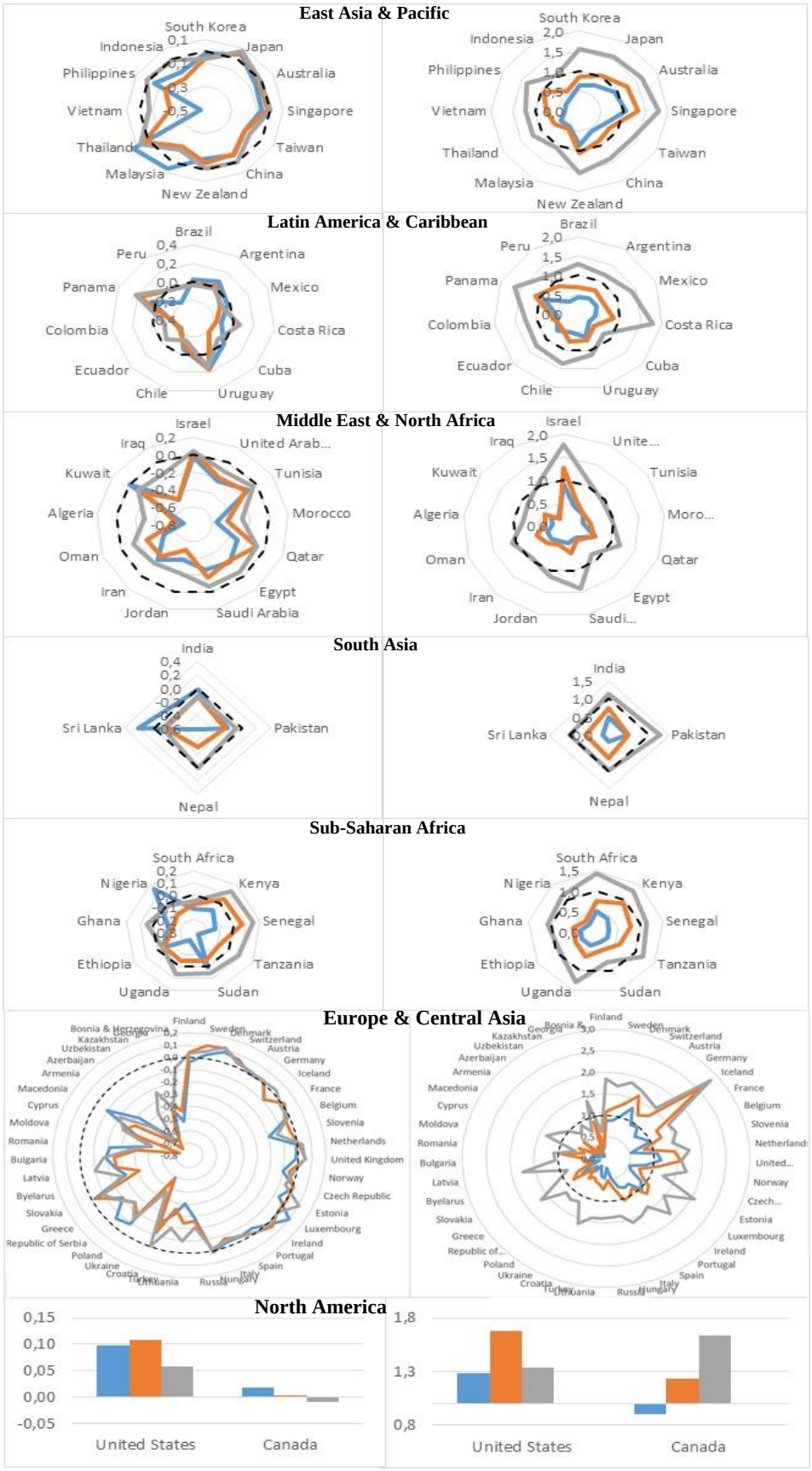
Overall, results show that non-leading internationally collaborative papers reach higher values than leading international and domestic papers, in this order. This is the most common pattern in all countries, and it is quite stable in terms of MNCS. That means that publishing internationally with leading partner's benefits more the strengths of countries. This pattern is highly relevant in those countries in which domestic and leading production are far away of the world average, e.g., Vietnam, Costa Rica, Nepal, Senegal and Tanzania. These countries present a stronger dependency on foreign collaborators specialized in the Biomedical Research area.

Countries showing higher levels of specialization in domestic papers than in leading or non-leading ones, denote a genuine capacity for developing research at the national level, e.g., Malaysia, Thailand, Argentina, Kuwait, Sri Lanka, India, and Nigeria. Few countries show high capacity of specialization while leading international research, with the exception of the United States, Canada and some European countries (e.g., Sweden, France and the Czech Republic). In general, most consolidated research systems show the highest values of specialization and visibility and the lesser differences in all types of authorship, such as some Western European and Northern American countries.

Table 1 shows the main changes during 2000-2016 in terms of publications, specialization and MNCS relative to the world output in Biomedical Research by regions. At the regional level, the highest domestic production is concentrated in the USA in contrast with Sub-Saharan Africa. In general, this production tends to drop down along the period favouring the increase of leading and non-leading production. The most specialized regions in domestic production are North America and Latin American, the latter decreasing slightly in comparison with North America (4.8%). However, the growth of domestic specialization in South Asia (74%), getting close to the world average; Sub-Saharan Africa (66%) followed by East Asia & Pacific which reach the world average, and Middle East & North Africa, is remarkable. The biggest increases of these regions could be explained by the low production at the beginning of the period. In terms of citations, only North America increases and surpasses the world average, whereas Middle East and North Africa and South Asia improves their values.

The proportion of leading papers show the lowest values for South Asia along with the highest growth (69%) along the period in contrast with Europe & Central Asia (6.6%). North America still remains as the most specialized region followed by Latin America and Caribbean, both growing at the same degree. The biggest growth is again observed in Sub-Saharan Africa that positions above the world average and South Asia. However, these growths in specialization fall down in terms of citations.

Figure 1. Relative Specialization index (left) and field-normalized citation (right) by regions and type of authorship.



When considering countries with high non-leading production, North America shows the lowest proportion of papers in the first period but the biggest increase in the last period in comparison with the remaining regions. Sub-Saharan Africa, South Asia, and Latin America show the highest proportions of papers lead by external collaborators. In the case of Sub-Saharan Africa, collaborating with leading partners allows achieving higher values in terms of specialization and impact, than in domestic and leading papers. The same pattern is observed in South Asia.

Table 1. Percentage of publications by type of authorship, relative advantage comparative (RAC), and normalized citation (MNCS) by group

DOMESTIC

	% papers		RSI		MNCS		growth		
	2000-5	2012-16	2000-5	2012-16	2000-5	2012-16	papers	RSI	MNCS
East Asia & Pacific	48,3	43,6	0,7	1,0	0,6	0,6	-9,6	39,7	-2,4
Europe & Central Asia	46,3	35,0	0,7	0,8	0,5	0,6	-24,4	1,8	8,7
Latin America & Caribbean	36,5	27,6	0,9	0,9	0,5	0,4	-24,5	-0,2	-18,9
Middle East & North Africa	41,9	28,3	0,5	0,6	0,3	0,5	-32,5	36,7	32,9
North America	65,8	50,6	1,1	1,1	1,1	1,1	-23,0	-4,8	3,0
South Asia	41,6	41,8	0,5	0,9	0,3	0,3	0,6	73,9	18,2
Sub-Saharan Africa	21,8	17,3	0,5	0,8	0,3	0,4	-20,9	65,9	26,5

LEAD

	% papers		RSI		MNCS		growth		
	2000-5	2012-16	2000-5	2012-16	2000-5	2012-16	papers	RSI	MNCS
East Asia & Pacific	15,0	18,5	0,7	0,9	0,9	0,9	23,6	27,6	5,0
Europe & Central Asia	18,6	19,8	0,7	0,7	0,8	0,9	6,6	3,9	19,0
Latin America & Caribbean	16,6	20,8	0,9	1,0	0,8	0,7	25,4	13,2	-0,8
Middle East & North Africa	17,5	20,5	0,4	0,6	0,5	0,6	16,8	31,0	34,6
North America	16,1	20,3	1,1	1,1	1,4	1,5	25,6	-3,8	11,5
South Asia	9,1	15,5	0,5	0,7	0,8	0,5	68,9	51,8	-33,0
Sub-Saharan Africa	15,4	19,4	0,6	1,0	0,7	0,6	26,0	62,2	-14,6

NON-LEAD

	% papers		RSI		MNCS		growth		
	2000-5	2012-16	2000-5	2012-16	2000-5	2012-16	papers	RSI	MNCS
East Asia & Pacific	36,6	37,9	0,9	1,0	1,2	1,6	3,5	7,6	28,2
Europe & Central Asia	34,8	45,3	0,8	0,8	1,2	1,8	30,0	1,3	57,8
Latin America & Caribbean	46,8	51,8	1,0	1,0	1,2	1,5	10,5	3,1	29,7
Middle East & North Africa	39,6	50,1	0,8	0,8	1,0	1,3	26,3	-1,2	31,6
North America	18,2	29,2	1,1	1,1	1,4	1,6	60,0	-2,5	17,6
South Asia	48,7	42,8	0,9	0,8	1,0	1,3	-12,2	-6,2	34,1
Sub-Saharan Africa	63,6	63,5	1,0	1,1	1,1	1,2	-0,2	12,7	13,4

The largest differences in research performance by type of authorship are located in countries with the lowest R&D investment. Figure 2 shows the positions of countries in the two indicators by type of authorship in the four groups defined by R&D expenditures. Countries with the highest research investment show higher specialization and visibility despite the type of authorship. That means that countries with larger research investment are more likely to serve as leaders and garner higher specialization and impact when leading. However, non-leading publications have the highest impact and specialization. However, specialization is more spread out than citation impact. Countries with the lowest R&D investment are more likely to be dependent of external collaborations (non-lead) to reach or surpass the world average, especially in citations. That demonstrates the strong importance of collaboration for impact research in less developed countries (Figure 3).

Figure 2. Relative specialization and normalized citation by type of authorship and R&D expenditures' group

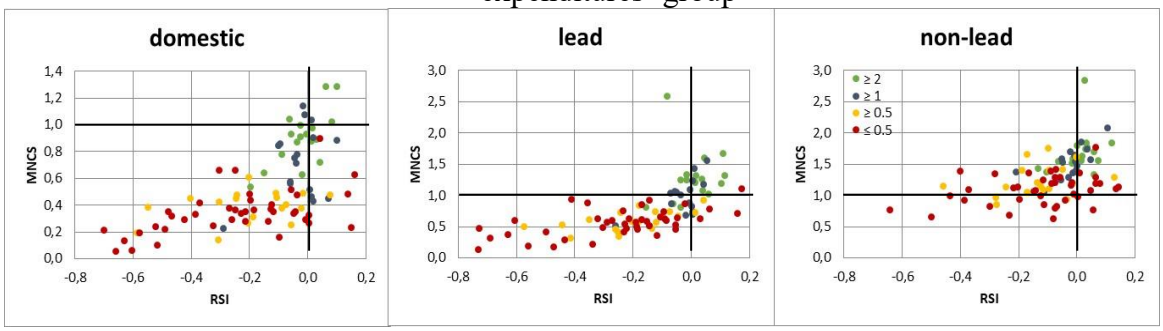
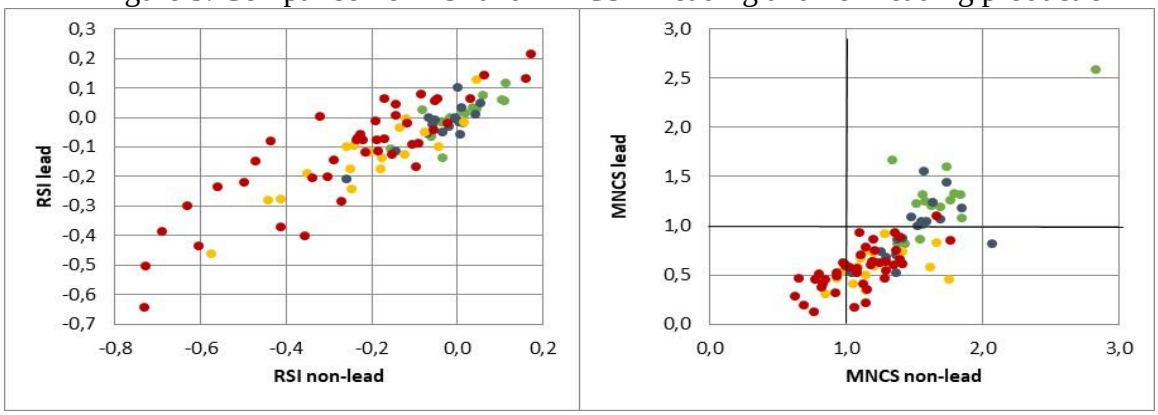
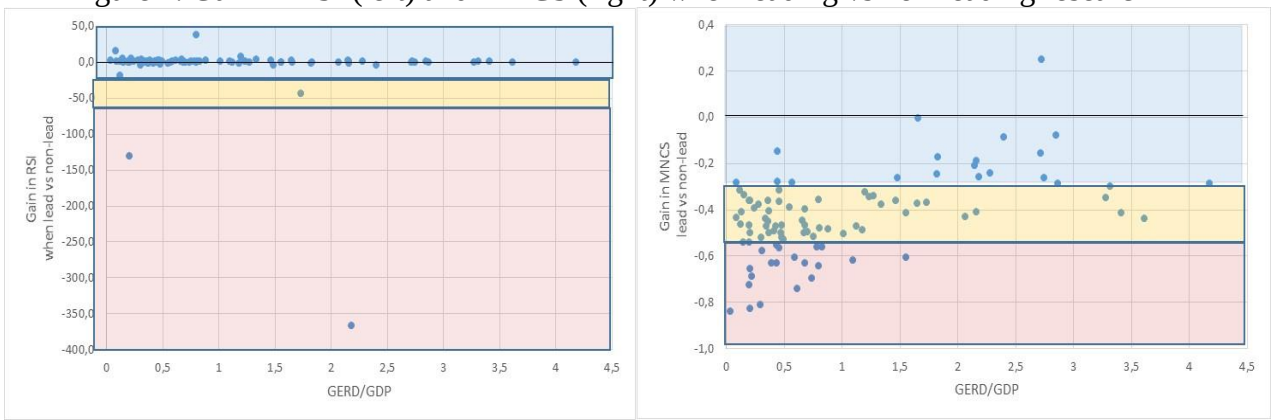


Figure 3. Comparison of RSI and MNCS in leading and non-leading production



To investigate to what extent collaboration with leading partner's benefits research performance in terms of specialization and citation impact, we calculated the difference between the specialization and the MNCS when countries are in leading and non-leading positions (Figure 4). As shown, few countries benefit in terms of specialization, when playing a leading role on scientific publications. However, in terms of citations, benefits are much more significant. There is a greater citation gain on average, when countries assume a non-leading position, especially for those with lower R&D investment. We coloured different zones of the graph to graphically visualize the degree of dependency of external collaborators acting as leaders of the research. We differentiate three zones: in blue, those countries with the lowest benefit (30%), in yellow (50%), countries with moderate levels of autonomy, and in red, countries with a high degree of dependency on international collaboration.

Figure 4. Gain in RSI (left) and MNCS (right) when leading vs non-leading research



Discussion

This work presents a preliminary analysis of the role of leadership and collaborative relationships in constituting the disciplinary specialization among countries and its research performance. We aim to understand how different types of leadership, operationalized by corresponding authorship, facilitates the analysis of collaborative practices and their association with concepts like leadership or dominance and smart specialization, and how internationalization can be harnessed to improve absorptive capacity, visibility, and integration of peripheral countries into a global network of scientific exchanges.

In the biomedical research field, the results show that different types of leadership in publications translate into different levels of specialization and citations. The disciplinary specialization in some countries is due to their international production more than their domestic one. Then collaboration allows these countries to be more specialized. Furthermore, non-leading collaborative papers reach higher citation values than leading international and domestic papers. This pattern is highly relevant in those countries in which domestic and leading international production are far away from the world average. It shows that some countries are more dependent on their collaborators in terms of performance. Whereas there are other countries with higher level of specialization in domestic than in leading or non-leading papers. Those countries show a genuine capacity for developing highly specialized research at the national level and could be seen as strategic leading partners for collaboration in this field. If some policies have been implemented to foster internationalization and/or smart specialization, this approach allows monitoring changes over time and potential adjustments in research agendas.

Types of collaboration show that in some regions, internationalization, specialization and citations growth faster than domestic production. Although in general, all regions increase their performance when collaborating with leading partners, the largest differences in leading research performance are located in countries with the lowest investment in R&D. That reflects the gain in collaborating with leading partners, as well as an increase not just in outputs but also in their absorptive capacity in terms of specialization; even though they do not generate world frontier knowledge, (most of them do not reach the mean average citation world). In any case, citation average reaches with international leading partners widely surpass the country average of citations. That is a historical gain effect of international collaboration Glänzel, Schubert, and Czerwon (1999). The relationship between international collaboration and citations is more advantageous for less advanced than for more industrialized countries, although the latter also benefitted. In this case, identify what are the collaborators countries involved in this production could be interesting way to encourage mobility programs for reinforce their absorptive capacities.

On the other hand, countries with the largest research investment are more likely to serve as leaders and garner higher specialization and citations (both in domestic and lead publications). That means that they are able to incorporate new knowledge into their scientific system and generate frontier knowledge. However, this capacity is unevenly distributed in the richest countries.

The approach can contribute to an understanding of how the system of research fields of each country functions, and how domestic or internationalization production could be reinforced for improving absorptive capacity, harnessing specific specialization strengths. Further analysis using this approach could help to fortifying some of the areas that prove competitive at the national and international level. Comparative analyses of the role of leadership in the

disciplinary structure and visibility of countries can be useful for informing policies. For example, by motivating further collaboration relationships in the definitions of research agendas that favour smart specialization. We provide evidence that reflect the main strengths and weaknesses, making the results useful for improving a country's strategies and efforts within the global scientific system.

Further analysis will be conducted to overcome some limitations related with the Activity Index that reflects a relative position against the standards of reference, but it does not reflect the actual visibility of research in a given field (Rousseau 2018). Additional multivariate analyses can provide more exploratory information on the indicators studied.

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