

Global Research Report **Latin America: South and Central America, Mexico and the Caribbean**

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Author biographies

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He has a background in Computer Science, with expertise in knowledge engineering, machine learning and natural language processing. He was named a 2015 top-50 U.K. Information Age data leader for his work in creating the REF2014 impact case studies database for the Higher Education Funding Council for England (HEFCE). ORCID: <https://orcid.org/0000-0003-0347-3527>.

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About the Institute for Scientific Information

The Institute for Scientific Information™ at Clarivate has pioneered the organization of the world's research information for more than half a century. Today it remains committed to promoting integrity in research whilst improving the retrieval, interpretation and utility of scientific information. It maintains the knowledge corpus upon which the Web of Science™ index and related information and analytical content and services are built.

It disseminates that knowledge externally through events, conferences and publications whilst conducting primary research to sustain, extend and improve the knowledge base. For more information, please visit <https://clarivate.com/isi>.

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Cover image: Cocoa pods at harvest time, Bolivia, South America

The cover picture shows cocoa pods, fruits of the Cocoa tree *Theobroma cacao*. Cocoa, "kakaw" in Mesoamerican, has been domesticated in South and Central America for at least 5,000 years. The pulp of the pods can be made into a drink but the main commercial product is the beans from which cocoa butter is extracted. "Theobroma" is Greek for 'food of the gods', reflecting the impact of chocolate on European palates.

Executive summary

- Analysts at the Institute for Scientific Information report on the research publications of 34 countries in South and Central America, Mexico and the Caribbean. The report looks across the period since 1981 and at more detailed analyses for recent activity, and examines the influence of language on content. It finds:
- The number of academic research papers (articles and reviews) indexed in the Web of Science™ has grown more rapidly for the region than for most of the rest of the world (Figure 1). More than three-quarters of the region's research is in South America.
- Comparison between the numbers of papers in the English, Portuguese and Spanish languages in the Web of Science and in the regional SciELO Citation Index™ shows a similar language balance, although SciELO has many fewer of the internationally collaborative papers in English (Figure 2). A fall is evident in the number of papers authored in Portuguese as researchers in Brazil increasingly seek to publish in English-language journals (Figure 3).
- The count of collaborative and national publications shows that regional collaboration remains very low, as demonstrated by both the Web of Science and SciELO. Brazil is by far the largest research producer and 10 of the 34 countries, including Cuba and Mexico, account for the bulk of regional output (Figure 4).
- From 2016 to 2020, five countries published more than 25,000 papers, another 12 published between 1,000 and 10,000 papers while the other 17 countries published fewer than 200 papers per year on average (Figure 5).
- Research subject diversity has risen in most of the larger countries, driven both by domestic growth and by international collaboration (Figure 6). Areas of particular strength, identified through analysis of journal use and citation topic modeling, include life and environmental sciences, tropical medicine, astronomy, education and romance literature (Table 1, Figure 7).
- Impact Profiles are evidence of the progressive improvement in the comparative international research impact of larger regional research economies and annual trends indicate that national average impact is now grouped around world average. Papers authored from Cuba, in particular, have shown a marked shift into higher citation categories (Figures 8, 9).
- A country-by-country audit of collaboration reveals that regional collaboration is uniformly low, approaching just 10% of collaboration in Nicaragua and Bolivia (Figure 10). Brazil is the most collaborative country within the region. Elsewhere, the United States, Spain, Germany, France and the United Kingdom are collaborative with all the major regional economies in Latin America. China's collaboration is growing, at twice the rate of other countries (Table 2).
- The interaction between average citation impact and collaboration is shown to have a dominating influence in smaller economies. Care is required in interpreting average figures and deconstructed data are shown to be more informative for policy purposes (Figure 11).
- Open access (OA) is a successful and expanding part of regional publication patterns, but citation rates of OA papers are not yet as high as in other regions.
- In conclusion, we refer to the potential benefit of a regional research organization to enable training and capacity building and to tackle common challenges.

Research subject diversity has risen in most of the larger countries, driven both by domestic growth and by international collaboration.

Introduction

Latin America is a broad and diverse region. The term ‘Latin’ America has been used for 150 years to denote nations with predominantly ‘Romance’ (derived from Latin) language groups. This includes not only South America but also Central America, Mexico and parts of the Caribbean. In this report we assess the research profile of 34 countries in this wider region, although for brevity we will refer to the region as ‘Latin America’.

We last looked at South America in detail in our Global Research Report on Brazil (Adams and King, June 2009) when that country was described as a ‘natural knowledge economy’ that seemed likely to become the pivot of a regional network with growing links to Argentina and Mexico. Here our wider view ranges across 34 countries that vary significantly in history, size, population, economic capacity and research activity. Three of these countries (Argentina, Brazil and Mexico) are covered in our Annual G20 Scorecard, published each year to coincide with the G20 Summit. They contrast with the much smaller island economies of the Caribbean.

Latin America is a region of exceptional ecological significance. The climate and landscape ranges from Tierra del Fuego, through the Amazon and the heights of the Andes, to the rich rainforests of Central America. It has been a source of products and innovation with economic and social

impact. Ancient Mesoamericans discovered how to process latex for domestic and sporting use as long ago as 1500 BCE (Hosler et al., 1999); a visit to the Galápagos Islands off Ecuador inspired Charles Darwin to develop his Theory of Evolution; an Argentinian policeman was the first to use fingerprints to solve a murder; and Brazil has been the leader in developing biofuels for powered flight.

It is a region that has also suffered from a significant level of economic and political instability. That is not the focus of this report, but it is a factor to bear in mind when interpreting data on the region’s overall profile and some recent trends. Economies were vulnerable to the 2008 global financial crisis and political disruption in countries such as Brazil and Venezuela has worked against the development of their research base.

Differences between Latin American countries in their research publication output are substantial, so we look at research activity and publications from more than one perspective. First, we consider the total recent output of all the regional countries and trends for three sub-regions (South America, Central America and Mexico, and the Caribbean). We then explore the more detailed profiles of the most prolific countries in each sub-region. Finally, we explore two specific topics: the collaboration network of Latin America; and research specialisms, through an analysis of InCites™ Citation Topics.

The research landscape of Latin America

The scientific and scholarly publication of Latin American researchers has long received attention in the scientometric literature. Many papers offer descriptive statistics on the output and citation impact of single nations or sub-regions, often with a focus on a field (Confraria et al, 2017). Collaboration, mobility and migration of researchers in Latin America are highlighted in other studies (Marmolejo-Leyva et al., 2015; Russell et al., 2016).

A frequent topic is journal coverage in databases such as the Web of Science, which has traditionally favored international and influential English-language journals over those of national importance published in Spanish or Portuguese (Arunachalam and Manorama, 1988; Velez-Cuartas et al., 2016; Minniti et al., 2018). The Web of Science and other major journal citation databases of the Global North plainly provide only a partial representation of a nation or the region's research system in the Global South. Greater worldwide visibility is given to these journals and their contents by the [SciELO Citation Index](#). This bibliographic database, digital library and cooperative electronic publishing model of open access journals was implemented in 1997 by the São Paulo Research Foundation (FAPESP) and the Latin American and Caribbean Center on Health Sciences Information (BIREME). They were subsequently joined by Chile's national research agency (previously the National Commission for Scientific and

Technological Research [CONICYT], which, in January 2020, became the [National Agency for Research and Development \(ANID\)](#) and the Brazilian National Council for Scientific and Technological Development (CNPq). The aim of SciELO was to meet scientific communication needs of developing countries, particularly in Latin America, and to provide increased visibility and access to regional and language-specific scientific literature. SciELO is now included on the Web of Science platform, to which it was linked in 2013, and we discuss its coverage later in this report. The Emerging Sources Citation Index (ESCI)[™], introduced in 2015, has significantly expanded the Web of Science coverage of journals from this region, including many non-English language titles.

The occasional different roles of publication and scientific research itself in Latin American nations deserve recognition: education, training and local and

societal concerns may have greater importance than knowledge dissemination concentrating on topics prioritized by nations such as the United States, the United Kingdom, Germany and Japan (Chavarro et al., 2018). The uniform standard of research excellence employed by these leading industrialized nations – which we review later in this report – is not always appropriate as a framework for Latin America, two leading scientometricians argue: “More inclusive research assessments are needed to overcome the ongoing marginalization of some peoples, languages and disciplines, and to promote engagement over elitism” (Chavarro and Ràfols, 2017; see also Vessuri et al., 2014).

The multi-dimensional and variegated nature of research and publication in different geographies and cultures is a strong current trend in the scientometric literature.

“More inclusive research assessments are needed to overcome the ongoing marginalization of some peoples, languages and disciplines, and to promote engagement over elitism.”

Diego Chavarro and Ismael Ràfols

Regional research profiles

The 1981 Latin American publication output in journals indexed in the Web of Science was 5,655 papers (i.e. academic articles and reviews), rising significantly over a 40-year period to 156,000 papers by 2020. Using the 1981 figure as a baseline, the growth of research activity and publications was greater in Latin America than in any other region until the mid-2000s. Its overall growth rate was only recently overtaken by the Middle East. Nonetheless, Latin

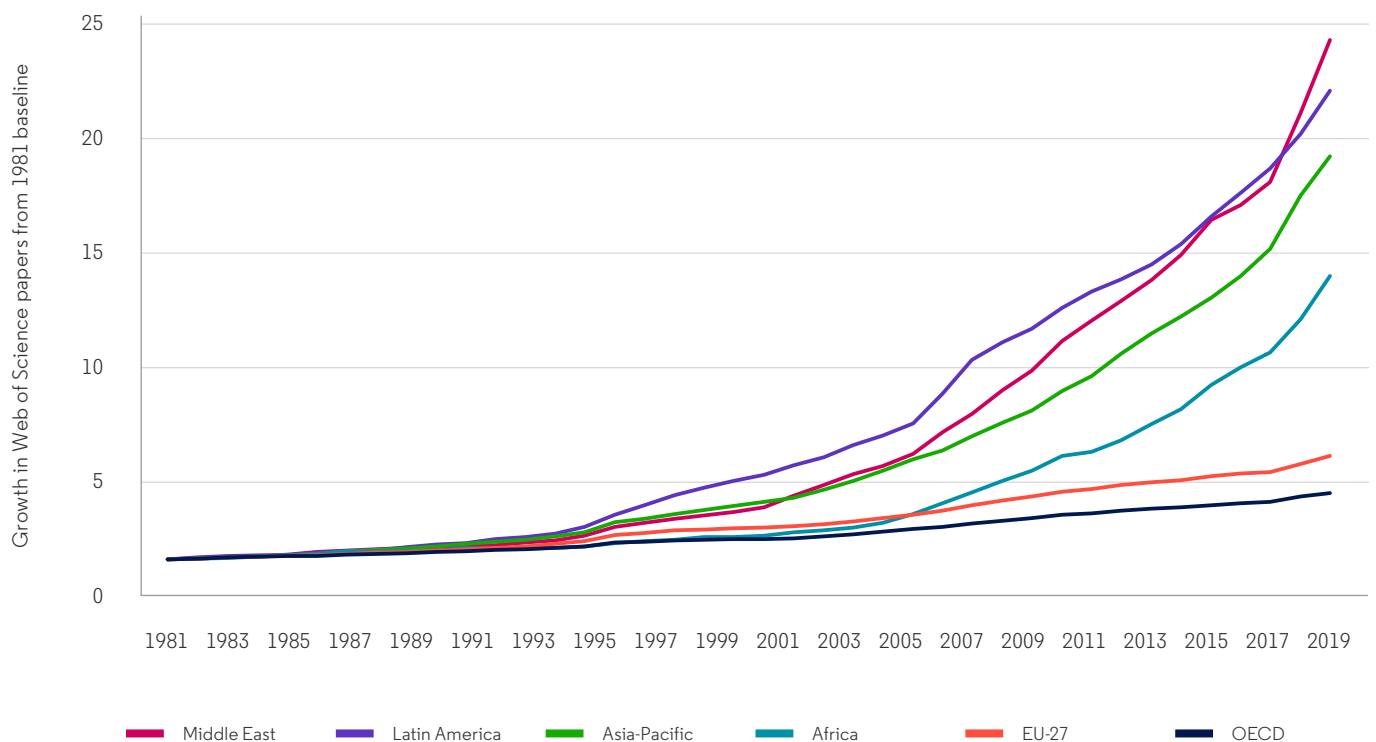
America's research publication growth has outstripped dynamic regions such as Asia-Pacific. It is far ahead of the Organisation for Economic Co-operation and Development (OECD) and the European Union, but that is unsurprising given that both groups had relatively high published output at the start of the period. (Figure 1)

Contrasts between the sub-regions in our analysis are driven by national differences. Many of the countries

with the greater publication output in the last five years are in South America (468,400 papers, 2016-2020). Central America and Mexico published around one-quarter of that during the same time period (102,300 papers) while the island nations of the Caribbean produced smaller numbers of publications (11,084 papers). However, growth rates are in fact similar between these regions and output generally doubled over the 10 years since 2010.

Figure 1.

Regional growth from 1981 in papers (academic articles and reviews) published in journals indexed in the principal citation indices of the Web of Science.



Language use in research papers

The Web of Science annually indexes the publications in around 20,000 journals across all subject areas and all countries. It does, however, have a firm criterion that all indexed material should have at least a title and abstract in English to enable global accessibility. The language balance in an index can affect the analysis of national science systems (van Leeuwen et al., 2000). For Latin America, we can also refer to SciELO which, because it has no language restrictions, complements the data in the Web of Science.

The significant Spanish and Portuguese presence, both culturally and linguistically, in the region can be traced back to the Treaty of Tordesillas (1494). Signed by the kingdoms of Spain and Portugal, this treaty demarcated the sphere of influence and exploration within the Americas between the two nations. Originally a meridian roughly equidistant between the Cape Verde islands (which were settled by the Portuguese) and the island of Hispaniola (claimed for the Spanish crown in 1492; now divided between the Dominican Republic and Haiti) within the Atlantic Ocean, the demarcation was later moved to 46°30' W of Greenwich enabling Portuguese influence to encompass the eastern coast (and eventually all) of Brazil. The two nations stayed largely true to the treaty thus accounting for the major linguistic makeup of Latin America today.

As is appropriate, SciELO's journal coverage is more regionally focused than that of the Web of Science, since the latter maintains an international focus and has a balance across all regions. A comparison between Web of Science and SciELO is an opportunity to see whether

the regional database provides a similar profile or whether there are important differences. (Figure 2)

The Web of Science carries many more English-language papers for Latin America (more than 120,000 in 2020) than SciELO (about 20,000). However, the volume of Spanish- and Portuguese-language papers is similar in both – and the data show the same rise for Portuguese-language papers to 2010 and then a more recent fall (Figure 2). This suggests that the regional coverage in the Web of Science is a reasonable and appropriate reflection of its actual research publication activity.

Some of the increase in volume has been a consequence of the global increase in international collaboration, which now accounts for as much as two-thirds of papers in areas like Western Europe. For Latin America, international collaboration on papers indexed in the Web of Science has risen from ~20% of papers in 1981, which was greater than the global average, to 37.5% of papers in 2020, which is lower than the current average for many mature economies. This shows that domestic research is continuing to contribute the greater part of national output in the region. However, collaboration between countries within the region has not developed in the same way. Regional collaboration was less than 2% in 1981 and had risen only to around 3.3% in 2020 (Figure 4). This compares with much higher levels of regional collaboration in Europe. The Middle East also experienced a relatively slow growth in regional collaborations, which climbed from 1% to 5% in the same period. These collaboration patterns are explored in more detail later in this report.

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Figure 2.

The language coverage of the Web of Science (top) and SciELO (bottom).

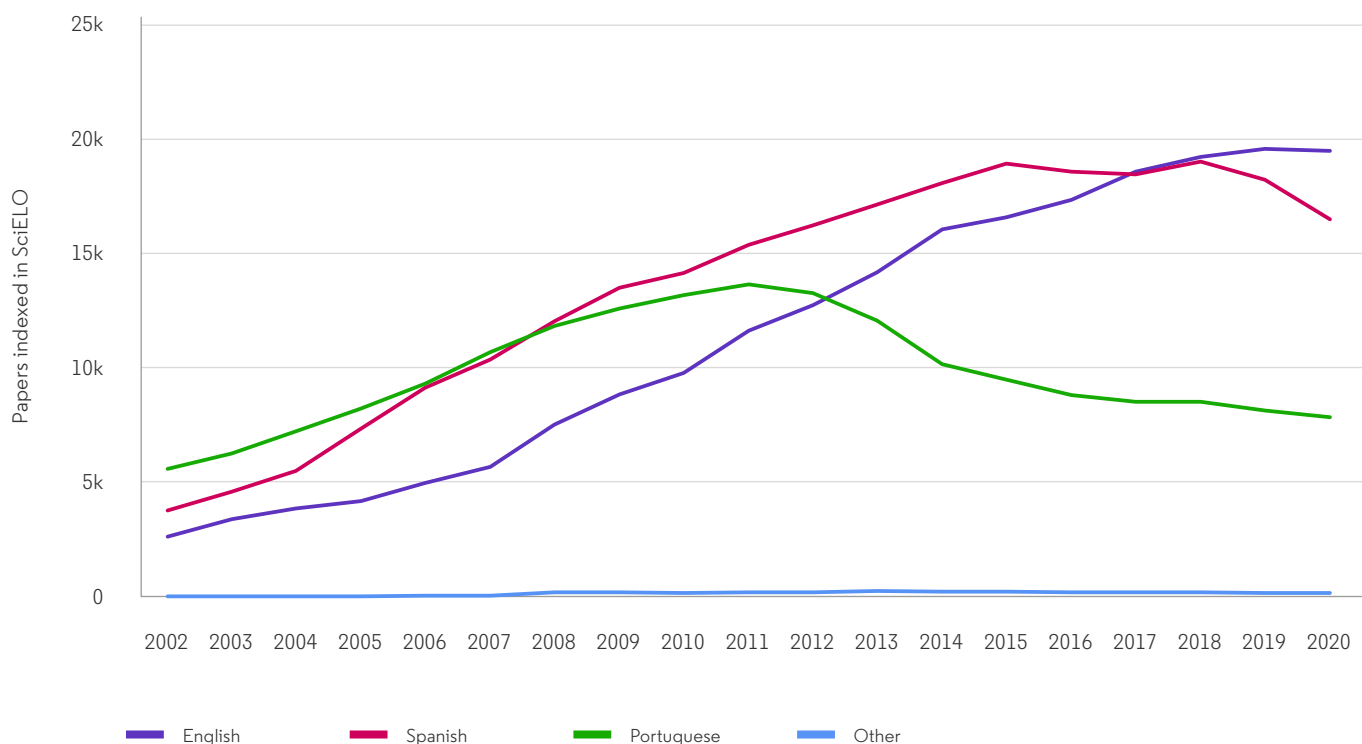
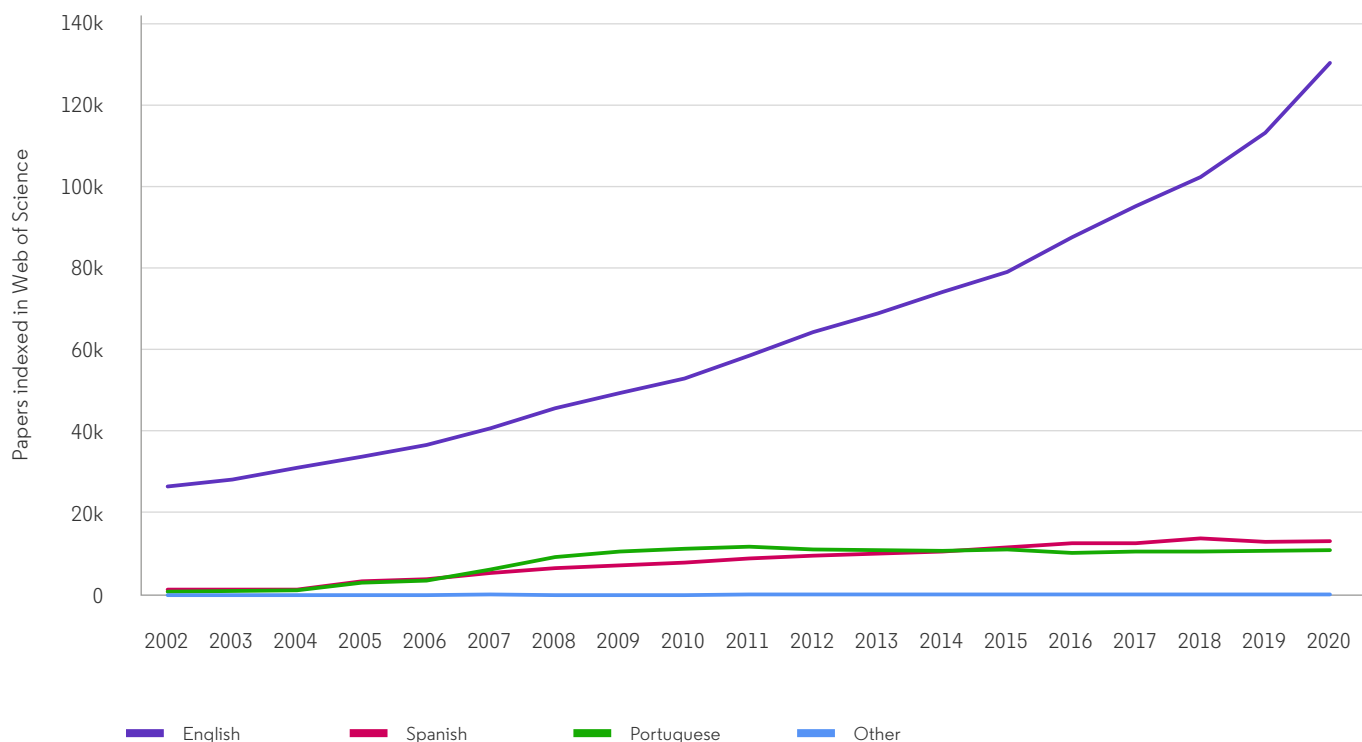
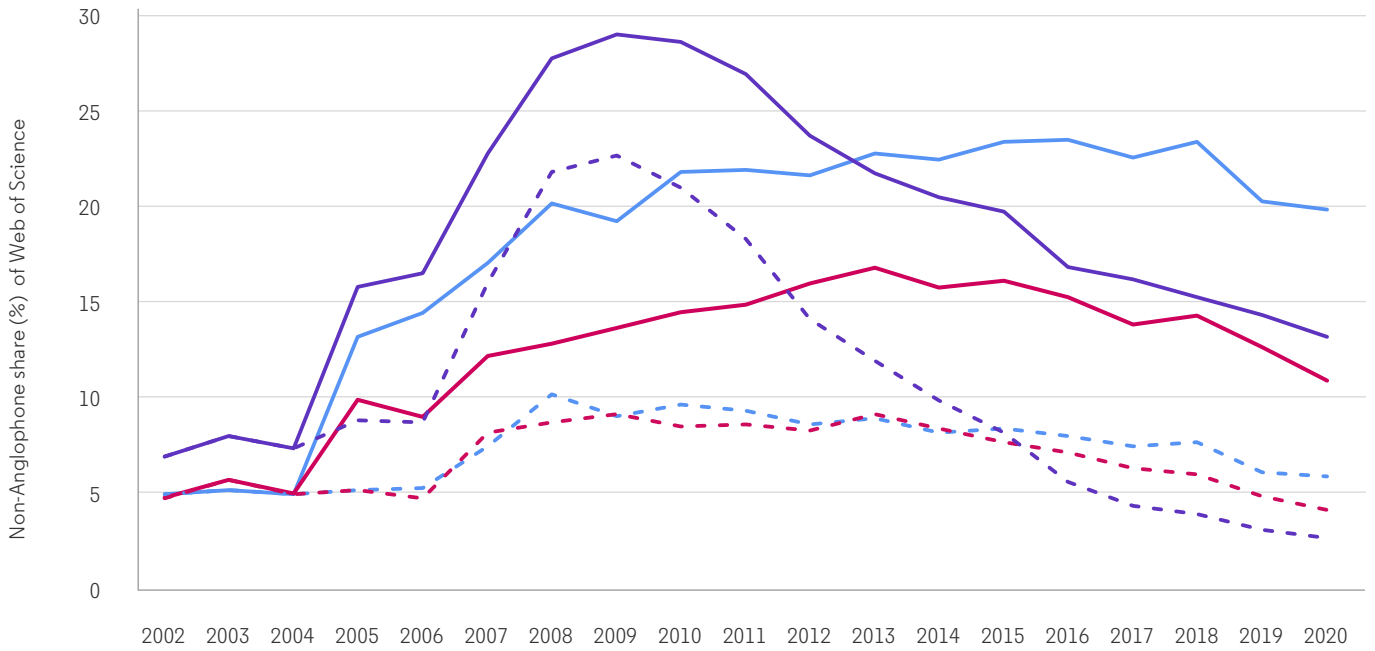
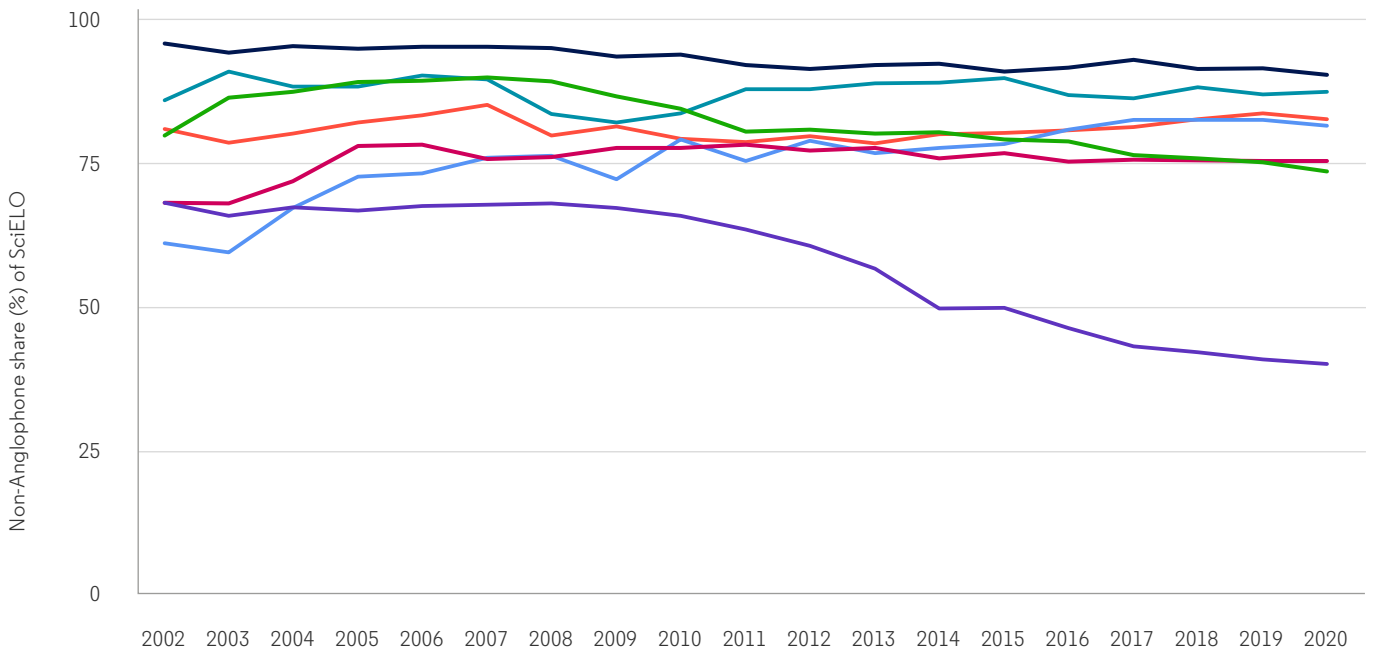


Figure 3.

Latin American papers published in non-Anglophone languages (Brazil – Portuguese; others – Spanish) in the Web of Science Core Collection and its ‘flagship’ citation indices (SCIE, SSCI and AHCI) and in SciELO.



Legend for Figure 3:
 Argentina core (light blue solid line), Brazil core (dark blue solid line), Mexico core (red solid line), Argentina flagship (light blue dashed line), Mexico flagship (red dashed line), Brazil flagship (dark blue dashed line).



Legend for Figure 4:
 Cuba (dark blue solid line), Peru (teal solid line), Chile (orange solid line), Argentina (light blue solid line), Mexico (red solid line), Colombia (green solid line), Brazil (purple solid line).

English has become the dominant 'lingua americana' of science. These shifts are seen in the languages in which papers are authored. With growing international collaboration, the benefits of enabling access of research findings to a global network of researchers is beneficial to both writer and reader.

The Web of Science platform includes many different regional and specialist publication databases in addition to the 'flagship' citation indices (Science Citation Index Expanded (SCIE)[™], Social Sciences Citation Index (SSCI)[™] and Arts and Humanities Citation Index (AHCI)[™]) used in the other analyses in this report. We compared the share of papers in English, Portuguese and Spanish in the wider Web of Science Core Collection[™] and SciELO. The SciELO data show that the Spanish-speaking countries have maintained their output in that language throughout the period (2002-2020) but that there has been an evident shift towards English-language publications in Brazil. The Web of Science data are more complicated. First, we see a major expansion in coverage, particularly of non-English language papers in the Web of Science Core Collection, in the mid- to late 2000s. Second, the fall in Brazil's output in Portuguese is confirmed in both the flagship indices and the wider Web of Science Core Collection. However, there is also evidence of some change towards English usage for Mexico and, to a lesser extent, Argentina. This 'internationalization' of Latin American research literature is likely to enable further collaboration as well as alerting researchers in other regions to the quality of current research programs. (Figure 3)

Although the Web of Science data include far more internationally collaborative papers than SciELO (37% of the total vs 6.5%), both databases agree in showing a relatively low level of collaboration within the region. The Web of Science data also suggest that publication growth continued through to the present although the SciELO data peak in 2018 and then decline for all countries. This is likely to be an artefact of the time taken to process, index and report the data rather than a real difference in underlying activity. (Figure 4b)

It is evident from both databases that Brazil is a prolific contributor to South America, and collaborates with other significant research centers in Argentina, Chile, Colombia and Peru. Mexico is the second largest publishing nation and provides a key hub for Central America with Costa Rica, Panama and Guatemala. The largest research publisher in the Caribbean is Cuba, but it has few collaborative links to other islands although it is linked to both Mexico and Brazil. The balance between the countries is generally similar in the two databases but Colombia has a much more prolific output indexed

in the SciELO data (9.4% of the total) than the Web of Science (3.4%) and Chile also has a higher share in the SciELO data (6.2% cf 3.6%).

It is also apparent that Brazil's rapid output growth of the early 2000s slowed down markedly and accounts for part of the change in relative growth for Latin America seen in Figure 1.

Other countries also saw a reduction in growth rate around the same time and it is likely that the global financial crisis of the time was a common constraint to public investment and productivity.

Five countries published more than 25,000 papers in the five years from 2016 to 2020. Another 12 published between 1,000 and 10,000 papers in that period. The other 17 countries published fewer than 200 papers per year on average. Because of the presence of a few very large economies, the analysis in Figures 4a and 4b hides the national diversity of research activity in the region. A tree-map reveals the pervasive spread of research activity by looking first at the 17 countries with output over 1,000 papers in five years and then, separately, the countries with output below this threshold. (Figure 5)

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Figure 4.

Publication output of Latin America within journals indexed in the Web of Science (top) and SciELO (bottom). The figure shows the total regional output and the domestic output (with no second country as co-author) for the 17 and 11 larger publishing countries, respectively, the volume of regionally collaborative output for all 34 countries, and the volume of internationally collaborative output.

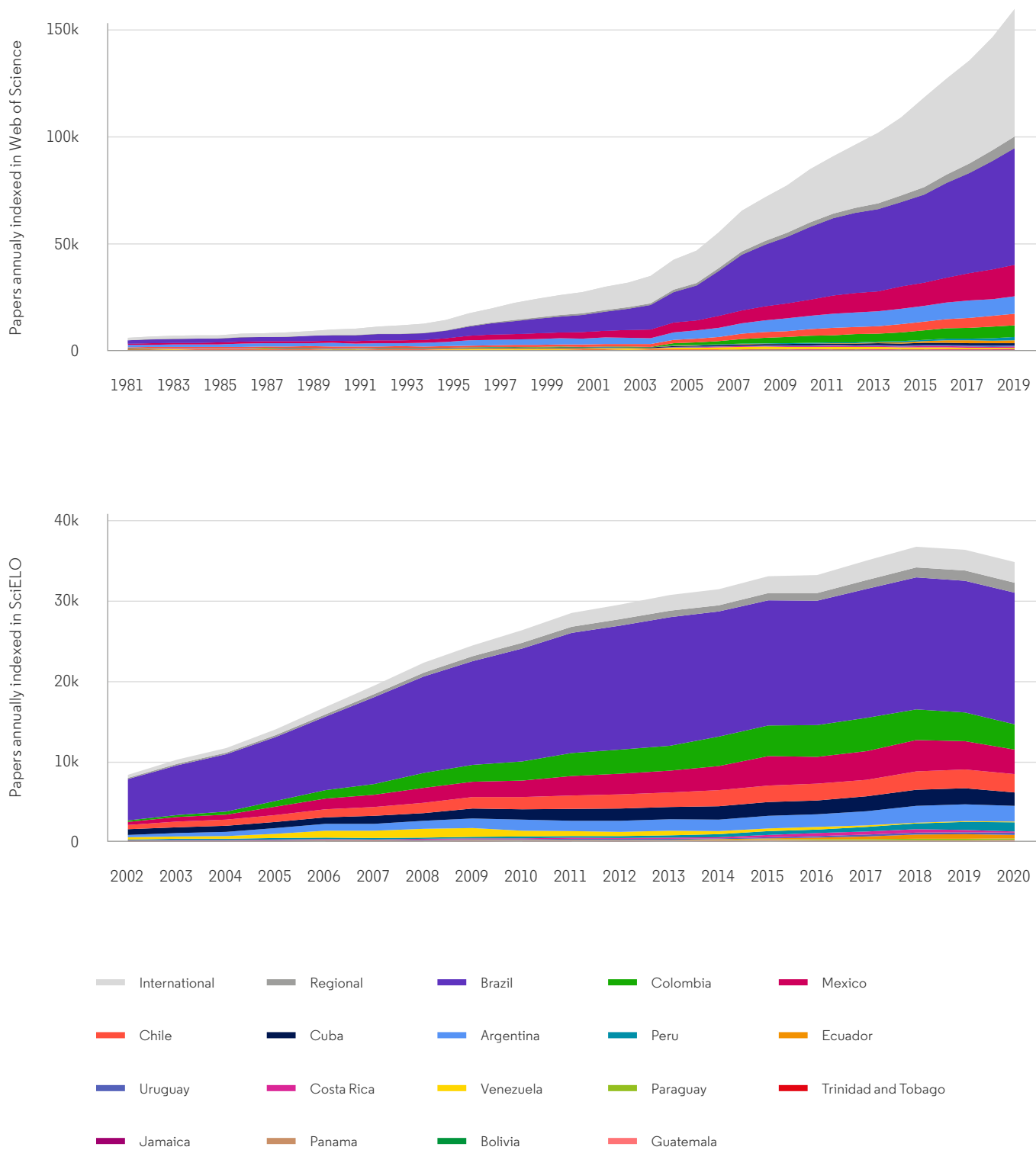
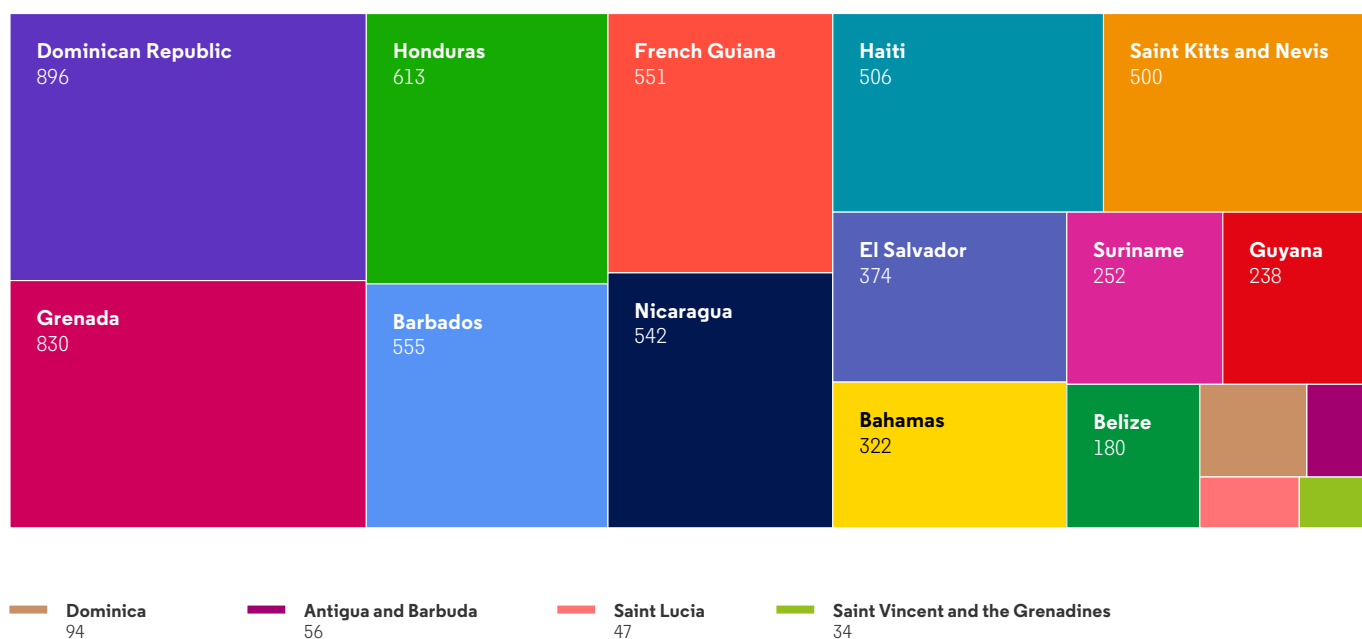
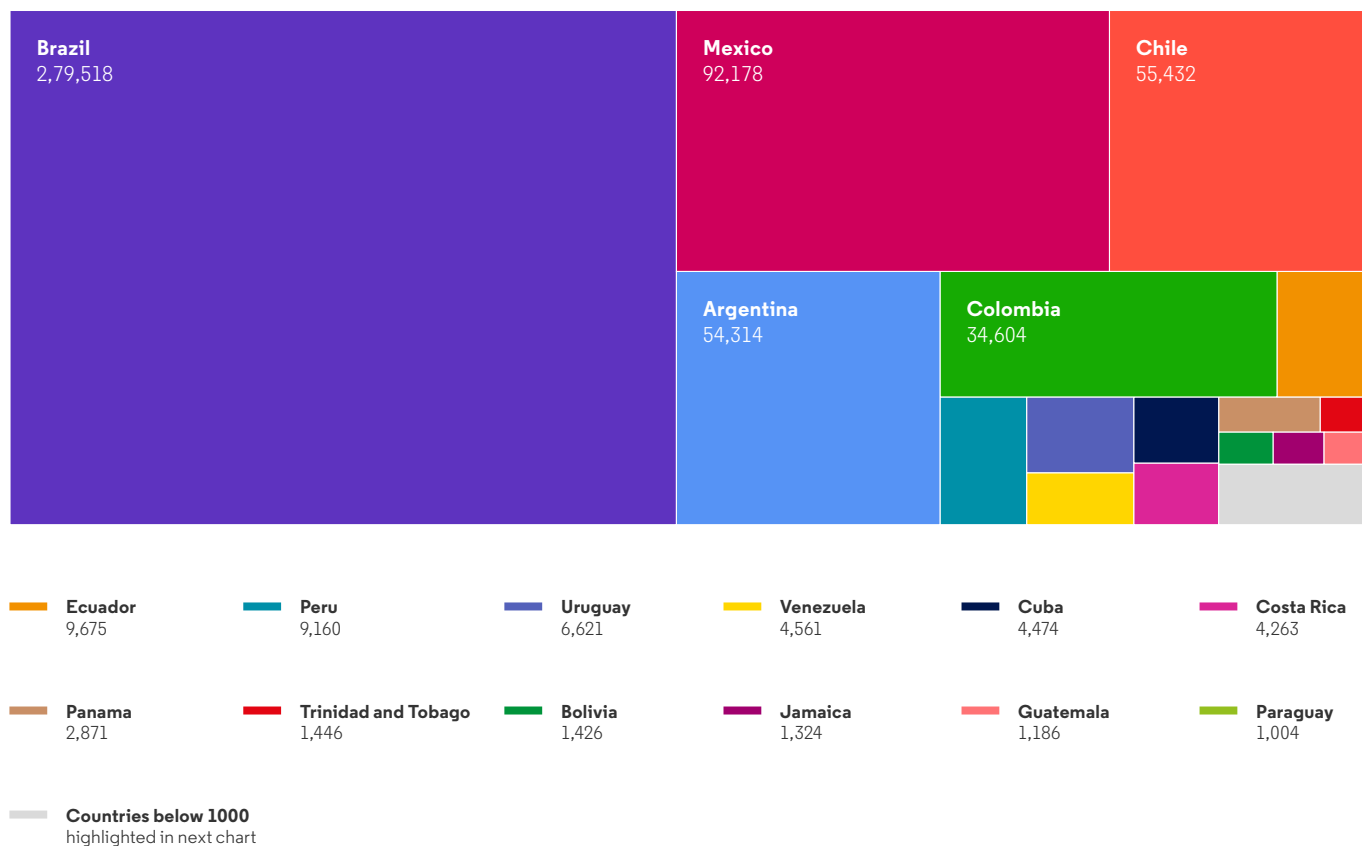


Figure 5.

Tree-map diagrams to show relative research publication output indexed in the Web of Science for the five-year period 2016 to 2020. The upper diagram shows 17 Latin American countries with output exceeding 1,000 papers during the period. The lower diagram shows 17 Latin American countries that had fewer papers than this. The five-year count is given for each country.



Subject diversity

Growth typically leads to increased capacity that can support a spread of investment across a wider range of targets. This applies to research as much as to other economic activity. Both increased domestic capacity and increased international collaboration contribute to the opportunity to develop competence in a wide range of subjects and thus tackle a greater number of technological, health, economic and social challenges. We have recently published a report on understanding and measuring [Subject diversity in research portfolios](#) (Adams et al., 2021a).

We can look at research diversity in Latin America from many perspectives. The overall diversity of the region is strongly influenced by the largest economies. It is therefore informative to consider the principal research specialisms of the largest research producers separately.

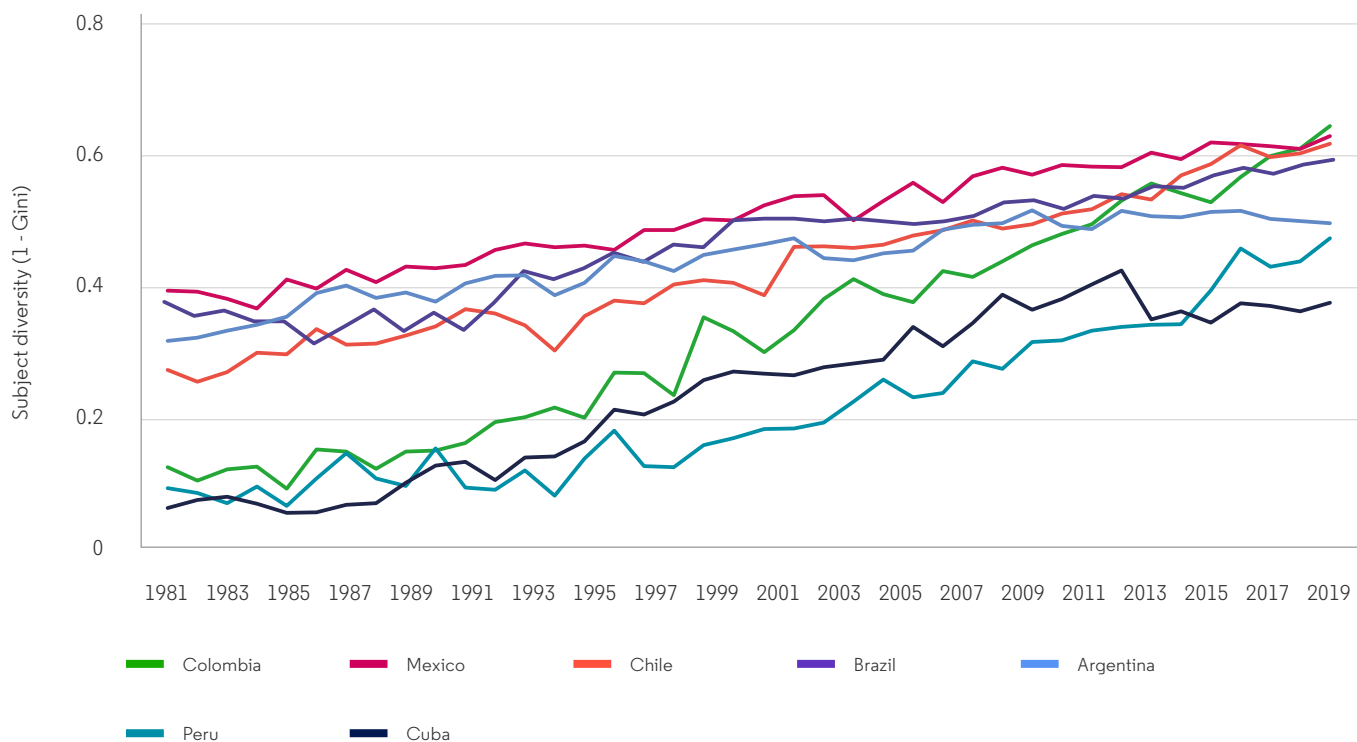
Research diversity is rising for all countries as their research base develops and as international collaboration creates the extended capacity to cover more subject areas with sufficient mass to support good research. For some more established countries (Brazil, Mexico, Chile, Argentina) the rise is smaller, but it has been sustained throughout the

last 20 years. For others (Ecuador, Peru, Cuba) the rise is much steeper, drawing on the benefits of both international collaboration and a rise in research investment.

For Colombia, the rise in diversity has been spectacular. Figure 3 showed that Colombia's publications are relatively more frequent in SciELO data so this diversity suggests that a significant part of the country's output is in non-English language journals, and that this less well-known part of its research product enables it to maintain a richer portfolio than might be expected from Web of Science data alone. (Figure 6)

Figure 6.

Research subject diversity, calculated as a Gini coefficient for the relative number of papers in each of the 254 Web of Science journal categories (Adams et al., 2021). Diversity is calculated for the most prolific research-publishing countries in each of the three sub-regions.



We compared the output of the set of countries tracked in Figure 6 with global totals in each journal category to identify 10 research areas, in which each contributed a relatively large share of the world's papers during the last decade. Note that journal categories, which are grouped by shared topics, vary a great deal in size. Some medical

areas have many journals, each containing numerous papers every year. Some technology topics are small by comparison. Consequently, global share identifies strengths better than the absolute paper count.

Looking across these categories, there are four broad areas where

the larger Latin America research publishers have multiple categories with relatively high shares: tropical biomedicine related to parasites and infection; whole-organism biology and conservation; particle, nuclear and space physics; and select areas in social science and humanities. (Table 1)

Table 1.

Web of Science journal categories in which the more prolific countries in each of the three sub-regions published the most papers relative to global publication output during 2011-2020. Figures show each country's share of world output as a percentage. Note that because journal categories vary in scope and size, these may not be absolutely the most frequent publication areas.

Journal categories		Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Peru
Medical	Parasitology	2.34	15.3		1.1	0.2		0.62
	Tropical medicine		15.7		3.4	0.26		1.37
	Infectious diseases							0.61
	Microscopy					0.2		
Life sciences	Plant sciences					0.13	2.92	
	Agriculture		13					
	Forestry		9.74				2.37	
	Zoology	2.68	9.7		1.12		2.41	0.33
	Ornithology	4.38			1.07			0.5
	Entomology	2.57	9.22		0.99		3.51	
	Mycology	2.09				0.8	2.7	
	Conservation	2.02					4.2	0.38
Palaeontology	6.69							
Physical sciences	Astronomy and Astrophysics			5.05	2.56			
	Physics, nuclear				1.03	0.36		
	Physics, particles			2.26	1.93	0.23	2.58	
	Geology	2.33						
	Mining and minerals			1.47				
Humanities	Anthropology	2.12		1.67				0.42
	Archaeology	2.84						0.38
	Romance literature			4.04				
	Development studies					0.99		0.44

Citation topics

Table 1 summarizes the Web of Science journal categories in which papers from Latin America's researchers are relatively frequent. Another perspective on research specialisms comes from an analysis of [InCites Citation Topics](#).

Citation Topics, developed by the Institute for Scientific Information (ISI) at Clarivate and the Centre for Science and Technology Studies (CWTS), Leiden University (see Waltman & van Eck, 2012) are a document-level classification schema that uses citation relationships to pull documents together into discrete clusters of related material. These clusters, which draw on shared citations and are independent of a paper's other contents and journal category, represent domains where authors are actively citing each other's papers. The clusters are separated into three levels of granularity: macro (10 topics), meso (326 topics) and micro (2,444 topics) to allow multi-level analyses. These cluster topics are manually (in the case of macro and meso) and algorithmically (micro) labeled – based on their pooled content – to identify their predominant subject matter.

Output at the meso-topic level for the seven more prolific countries across the three sub-regions (Argentina, Brazil, Chile, Colombia, Cuba, Mexico, Peru: Figure 7) identified 11 topics (out of a possible 326) with significant contributions. Although arrived at by a separate analytical route, these topics are related to the journal categories that included relatively large contributions for some, or all, of the countries (Table 1).

Chile's significant contribution to Astronomy and Astrophysics is clear (~9%). This reflects its status as a key center for astronomical observations which include the Very Large Telescope (VLT) array and the Atacama Large Millimeter Array (ALMA) in the Atacama Desert. Such work is highly collaborative – almost 98% of Chile's output in this topic involves international partners.

Chile also has a relatively large share of content in Marine Biology (~3.5%), reflecting its significant coastline and biodiversity. These factors also explain why Marine Biology accounts for more than a 2% share of output for four of the other nations (Argentina, Brazil, Mexico, Peru).

However, this research is generally more nationally focused (e.g., Mexico's international collaboration is 41%; Argentina's is 38%). Additionally, given the expanse of the Amazon rainforest, agricultural and life sciences also feature prominently for several nations. Approximately 6% of Peru's output focuses on Forestry and Phylogenetics & Genomics, though this research is highly internationally collaborative (>88%), possibly reflecting Peru's relatively smaller research capacity. Argentina's status as an important location for palaeontological, anthropological and geological research is reflected in Archaeology having its highest output share (~3%). This research is also significantly nationally based (~30% international collaboration).

Other major global projects are also reflected in the figure: Chile and Colombia have a relatively large share of Particle & Fields articles, reflecting

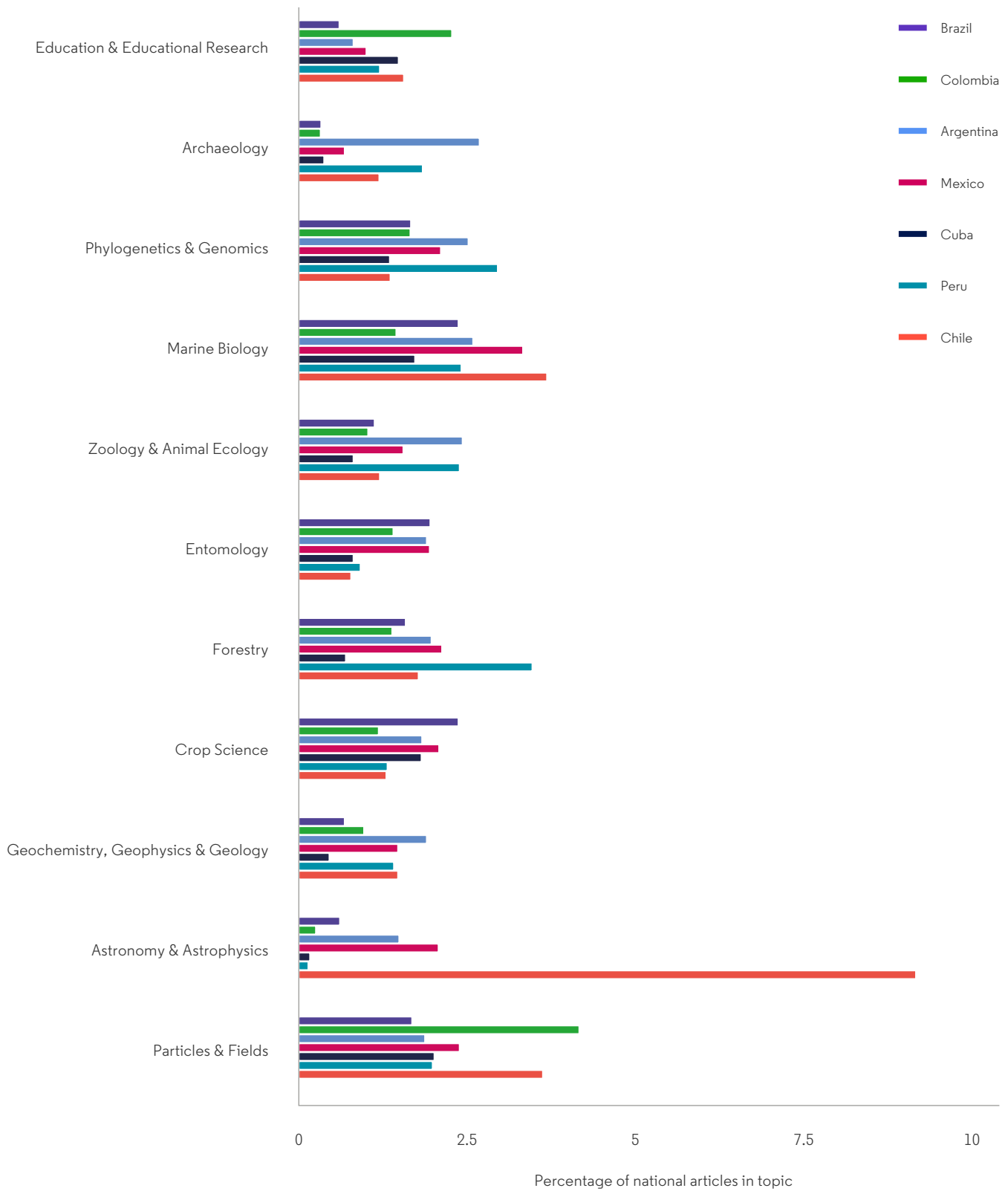
their contribution to physics at CERN (Chile's international collaboration in this topic is 80%; Colombia's is 93%). All countries have at least ~2% output share in this topic, further demonstrating its international reach.

More national and local matters are reflected in Education & Educational Research (international collaboration varies between 18 and 42%), particularly for Colombia whose share (2.2%) is greater than all the selected topics except Particles & Fields.

Though, in absolute terms, some of these share outputs are small, it is important to reiterate that the meso level covers 326 topics and countries could easily cover subject matter in more than one-third of these.

Figure 7.

Citation Topics for the seven larger countries as a percentage of their total national output (2009-2018).



Research impact

The impact of research publications is reflected in the influence they have on subsequent research activity. We cannot identify this directly, but it is generally agreed by analysts that for reasonably large samples of papers the average numbers of citations they receive is a sound indicator (Waltman, 2016). Citation counts rise over time at a rate that is field dependent, so we correct for this variance by comparing the observed citation count for each paper with the expected average for its category and year of publication. This is called Category Normalized Citation Impact (CNCI) and the average of this is calculated for the set of papers in a national sample. CNCI values are thus shown relative to a world average of 1.0.

Although CNCI is a useful indicator and provides a rapid reference to the average citation impact of a large sample of papers, it can be misleading and does not provide any information about the spread of high and low impact. One potential factor influencing interpretation is the characteristically skewed distribution of all citation data, with many uncited or infrequently cited papers and a much smaller number of papers that have been cited frequently and have widespread influence. This means that the CNCI, as an average, is invariably higher than the midpoint (or median) of the dataset. We use an Impact Profile to get a better picture of the distribution and the balance of uncited and very highly cited papers (Adams et al., 2007; 2019).

The procedure is to calculate CNCI for each sampled paper and then separate the pool into cited and uncited, and then further subdivide the cited papers into pots with halving or doubling relative impact

either side of world average. Above world average this is 1-2 times world, 2-4, 4-8 and above 8 with mirrored groups below world average. This is effectively applying a log transformation and grouping. By plotting the data in this way, a curve is produced that looks similar to a familiar 'normal' distribution.

A 'normal' curve is an easy image to retain and also enables us to see more detail on how a country's publications performed and then to relate this to other countries or to track changes across time. For clarity, the analysis in this instance is restricted to five countries (three from South America plus Mexico and Cuba) and is applied to papers published in three five-year time windows (Figure 8). In all cases it draws on citations up to the present: older papers have had more time to accumulate citations, but they are benchmarked against their year of publication.

In the earliest (1981-1985) period there are many uncited and poorly cited papers. The four mainland countries are led by Colombia, but Cuba is very different and has few papers above world average. Twenty years later (2001-2005) the picture has changed. The proportion of uncited papers has dropped significantly, the peaks of the curves for Argentina, Brazil and Mexico have shifted towards higher cited categories and Cuba is being cited more often. For the recent window (2016-2020) the uncited share has re-emerged, but this is because few very recent papers will have been cited and this will undoubtedly change. What is more important is that all curves have shifted upwards again and are looking much more 'bell-shaped' with a good balance around world average between

low and highly cited papers. Cuba now follows a similar pattern to the other countries. Unquestionably, these analyses show progressive improvement in relative global research quality based not on a single average but by looking across the full portfolio for each country. They demonstrate that a significant body of research is now cited well above world average.

One potential factor influencing interpretation is the characteristically skewed distribution of all citation data, with many uncited or infrequently cited papers and a much smaller number of papers that have been cited frequently and have widespread influence.

Figure 8a.

Impact profiles 1981-1985:
Many papers still uncited and a large percentage cited less than world average.
Colombia has a greater share of its national output above world average (25%) but others are well below 20%.

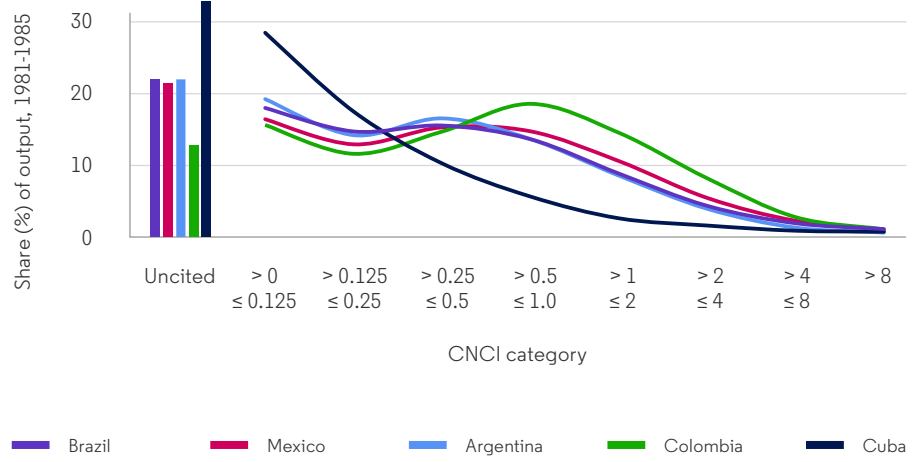


Figure 8b.

Impact profiles 2001-2005:
The percentage of uncited papers has dropped substantially although the percentage cited below world average has changed only a little. Countries have similar shares above world average, typically just over 20% of their total output.

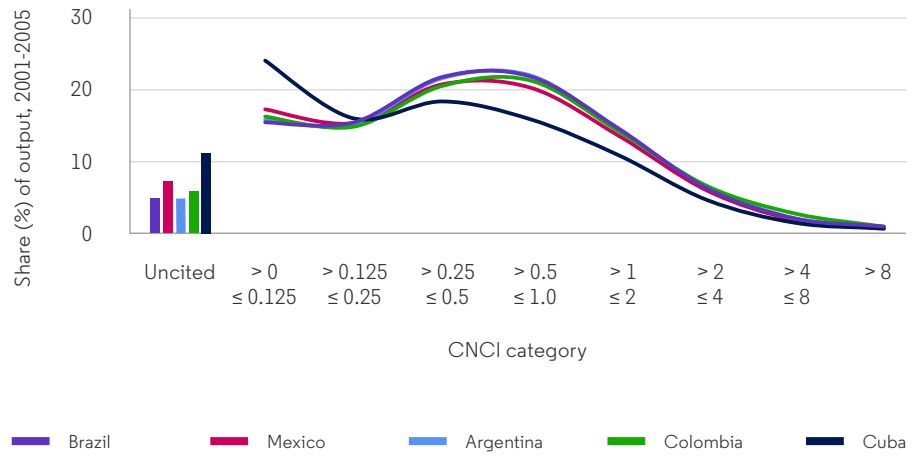
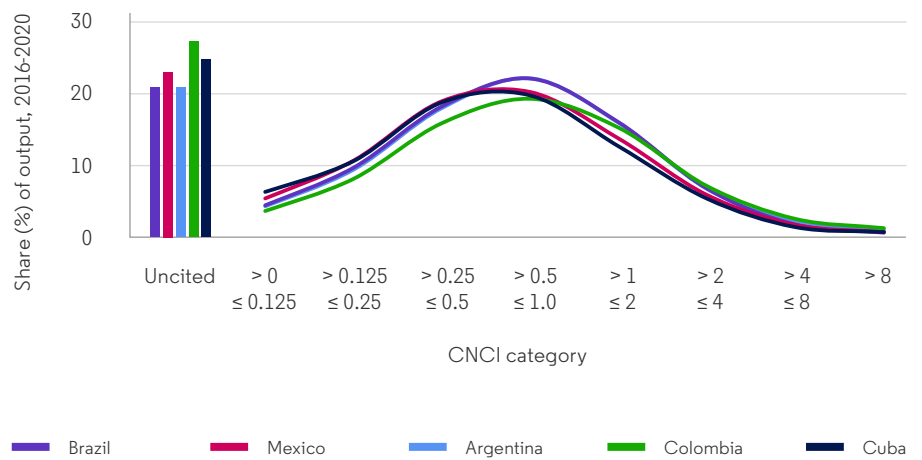


Figure 8c.

Impact profiles 2016-2020:
Uncited papers are frequent because many are recently published, but the overall curve is now much more balanced. The percentage of low cited papers has dropped; more than 25% of most countries' papers are cited above world average and Cuba, an outlier, has risen above 20%.



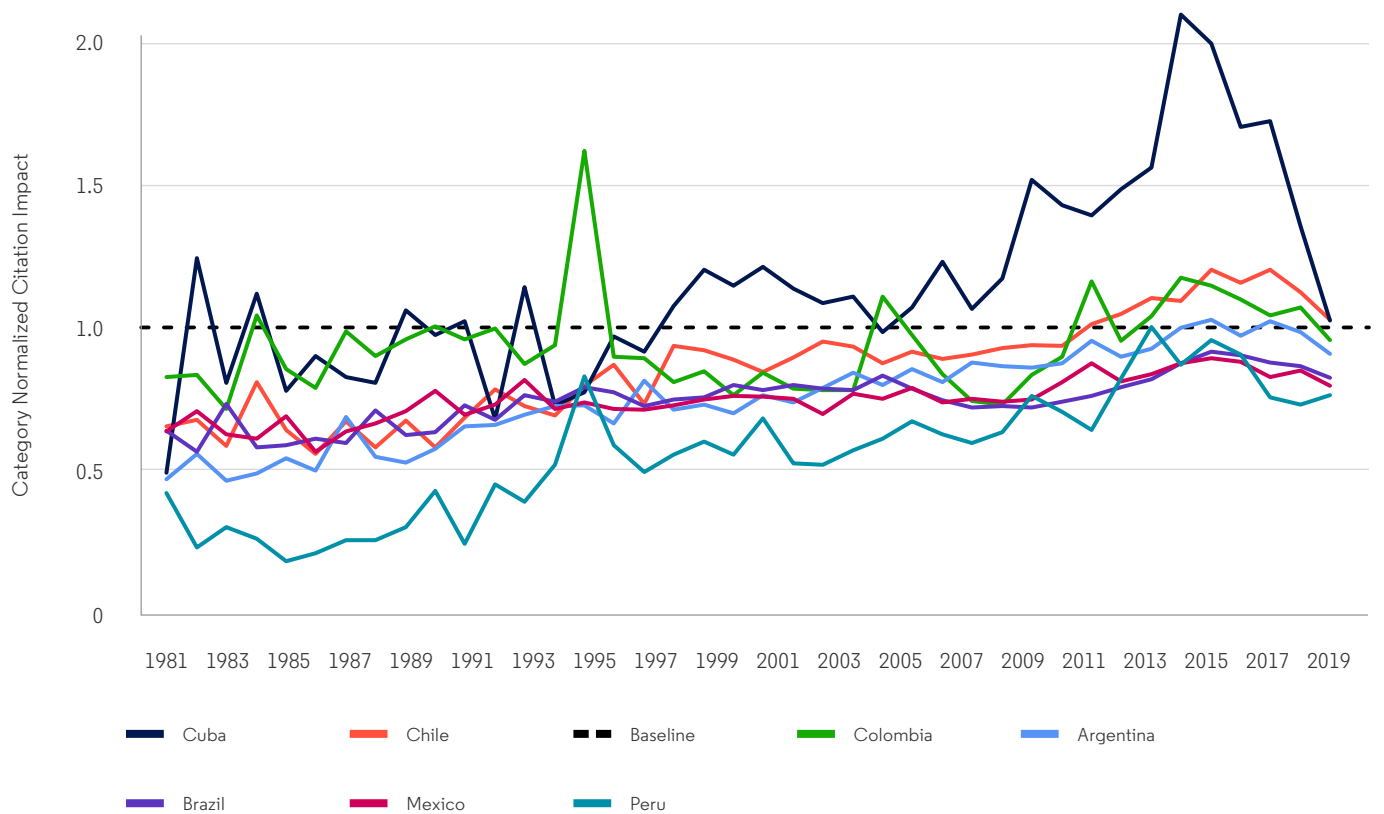
For a more continuous picture of performance change over time we revert to annual average citation impact. The CNCI trajectories of the seven largest research economies in Latin America (Figure 9) suggest that the most prolific research publishers (Brazil, Mexico, Argentina) appear, surprisingly, to have lower average citation impact. However, they have relatively stable CNCI profiles, whereas some of the other countries such as Colombia and Peru (and smaller economies not included in this graph) have marked annual fluctuations. Both average impact and volatility are driven by international collaborations, where papers are usually cited more frequently than purely domestic papers (see Figure 11).

Cuba, which has less international collaboration, is on a rising trajectory as already evidenced in Figure 8, driven primarily by strong domestic research.

There are two important conclusions to take from this analysis. First, the impact of research in Latin America is evidently rising. The general trend over 40 years seems to be from around half of world average impact towards close to world average. Second, because these averages are based on a broad spread of individual CNCI values, we must be wary of looking at CNCI on its own without also considering the extent to which each national sample is made up of both domestic and internationally collaborative activity (Szomszor et al., 2021).

Figure 9.

Annual trends in Category Normalized Citation Impact for the most prolific research-publishing countries in each of the three sub-regions.



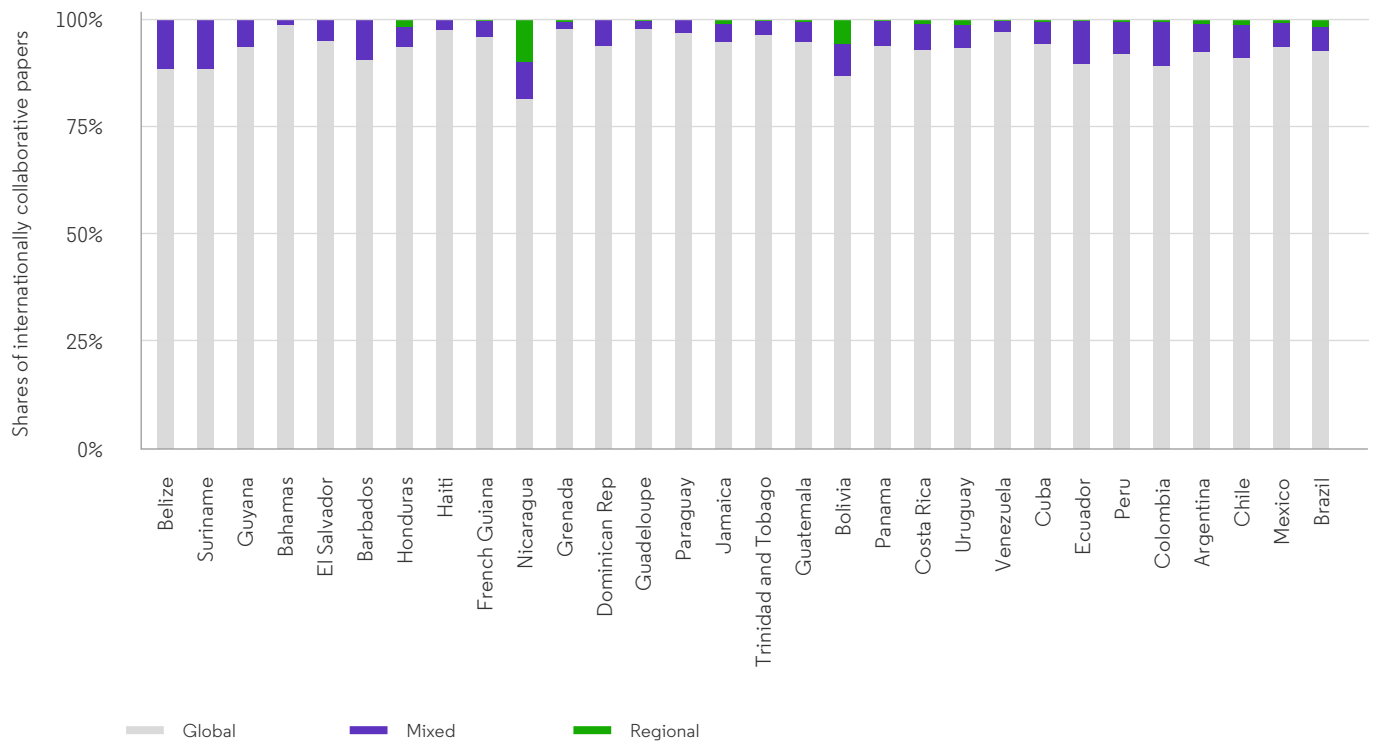
Collaboration and regional networks

International research collaboration is increasing for countries in Latin America (Figure 3) while regional collaboration remains relatively small. Out of 127,400 total collaborative papers, Brazil has 10,000 papers that include a regional co-author but only one-quarter of these are authored solely within the region. Only Nicaragua and Bolivia have similar numbers of solely and partially regional papers. (Figure 10)

Out of 127,400 total collaborative papers, Brazil has 10,000 papers that include a regional co-author.

Figure 10.

Balance of internationally collaborative output for Latin American countries with more than 100 papers indexed in the Web of Science in the last 10 years. The figure shows the share of papers (2009-2018) with solely regional partners, with both regional and global partners and with global partners only. Countries are ordered by volume of internationally collaborative output (see Figure 5) from Belize (206 collaborative papers) to Brazil (137,370 papers).



The United States is the most frequent collaborative partner for all Latin American countries, as it is generally across the globe. This is because of its historical scale and pre-eminence as a research and knowledge producer. Over a recent 10-year period its count of papers shared with the larger research economies has increased 2- to 3-fold. An exception is Cuba, where the United States is

the fourth most frequent partner after Spain, Mexico and Brazil. Brazil is also a relatively frequent partner for Argentina, Colombia and Peru but since there are few purely regional papers it must be assumed that these tend to be with international consortia. For most countries, including Brazil, Spain is the second most frequent partner. (Table 2)

Table 2.

Internationally collaborative papers with authors from the most prolific research publishing countries in each of the three sub-regions and their major international partners. Data show the count for 2018 and the growth over the previous 10 years (2018 count/2009 count).

Journal categories		Argentina	Brazil	Chile	Colombia	Cuba	Mexico	Peru
U.S.	Count	1,824	7,447	2,534	1,587	153	3,226	669
	Growth	1.9	2.5	2.9	3.3	3.1	2.0	2.6
Spain	Count	1,242	2,652	1,980	1,225	177	1,855	245
	Growth	2.0	3.9	4.7	3.5	1.3	2.6	3.8
Brazil	Count	1,022		955	1,015	210	852	366
	Growth	2.1		4.5	4.5	2.3	3.7	5.3
Germany	Count	837	2,519	1,242	680	83	934	167
	Growth	2.3	3.3	3.5	5.4	2.1	2.7	5.1
France	Count	754	2,519	1,122	676	87	985	197
	Growth	2.2	2.5	3.6	3.8	2.0	2.2	3.9
U.K.	Count	702	3,144	1,404	729	78	1,048	277
	Growth	2.4	3.6	5.3	4.4	1.6	2.6	4.0
Portugal	Count	271	2,023	341	388	21	337	59
	Growth	5.4	4.8	10.3	32.3	1.0	6.7	9.8
China	Count	351	1,300	515	492	71	667	122
	Growth	4.0	6.7	13.6	6.6	14.2	4.4	8.7

The other relatively frequent collaborators across the region are the major Western Europe nations: France, Germany and the United Kingdom. It is likely that they will often be additional collaborators on papers that also include Spain, as part of a consortium working with Latin American partners. Portugal continues to be a frequent partner with Brazil and its growth rate with other countries in the region is notable, particularly the near-trebling of its collaboration with Colombia.

Also of interest is the increase in collaboration with China, much of which is bilateral rather than through consortia and where it is now a more frequent partner for all except Brazil. The growth rate here has been much higher than with established partners in North America and Europe and is likely to be an increasingly important part of the Latin American portfolio in the future.

International research collaboration is associated with publications that receive higher average citation counts. A study by the ISI showed that it was informative, in terms of interpreting the sources of a country's citation impact, to split publications into groups based on whether they were domestic or internationally collaborative in nature and, if so, how many co-authoring countries were associated with each paper (bilateral, trilateral and multilateral [i.e., quadrilateral-plus collaboration]) (see Potter et al., 2020). Review papers generally have higher citation rates than articles in the same field and year, so we consider these two document types separately. For Latin America as a whole, the most frequent type of article is one with domestic collaborative co-authorship (35%), followed by single-institution articles (27%). However, international bilateral articles are rising in frequency (now 25%, up from 20% over 10 years) and are likely soon to exceed single-institution items.

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Collaboration and citation impact

Latin America's multilateral collaboration articles typically have an average CNCI of about three times world average. The average CNCI for other international collaborations is just above world average (trilateral) or just below world average (bilateral) while domestic papers have a much lower average CNCI. It is important to note that these comments refer to an average and that a more detailed examination of the distribution of impact values across the full portfolio will identify many individual papers with a much higher CNCI.

Brazil is one of the less internationally collaborative countries in the region. Just under 40% of its papers over the last five years had an international co-author and this total had grown from around 30% of its output in the 1990s. By comparison, Mexico (47%) and Argentina (51%) are clearly more international, and Colombia (63%) and Chile (67%) are more in line with typical European Union nations. Most other Latin American countries have greater than 80% internationally collaborative papers. Some, such as Panama (93%), have very little purely domestic research activity. These balances are reflected in the deconstructed CNCI data. (Figure 11)

International collaboration contributes a disproportionate share of national citations, and this is true for G7 countries as much as for Latin America and others. In this general context, Brazil's overall research profile includes a balance between domestic and internationally collaborative research and would allow a sound interpretation of its performance and achievement at subject level. For Chile, we must note the contribution of highly multilateral articles and the effect these have. That will be a factor in both Astronomy (Table 1, Figure 7) and the overall national average citation impact. Cuba's achievements are difficult to assess because its substantial domestic output has very low citation rates, yet it is obviously also publishing in indexed international journals after rigorous peer review. This suggests a literature that needs better exploration, and the Impact Profile (Figure 8) demonstrates Cuba's direction of travel as its research achieves greater recognition and influence. The overwhelming contribution of international collaboration to Panama's portfolio means that the data tell us very little about that country's true research strengths and we would have to interpret any citation indices as unreliable.

Latin America's multilateral collaboration articles typically have an average CNCI of about three times world average.

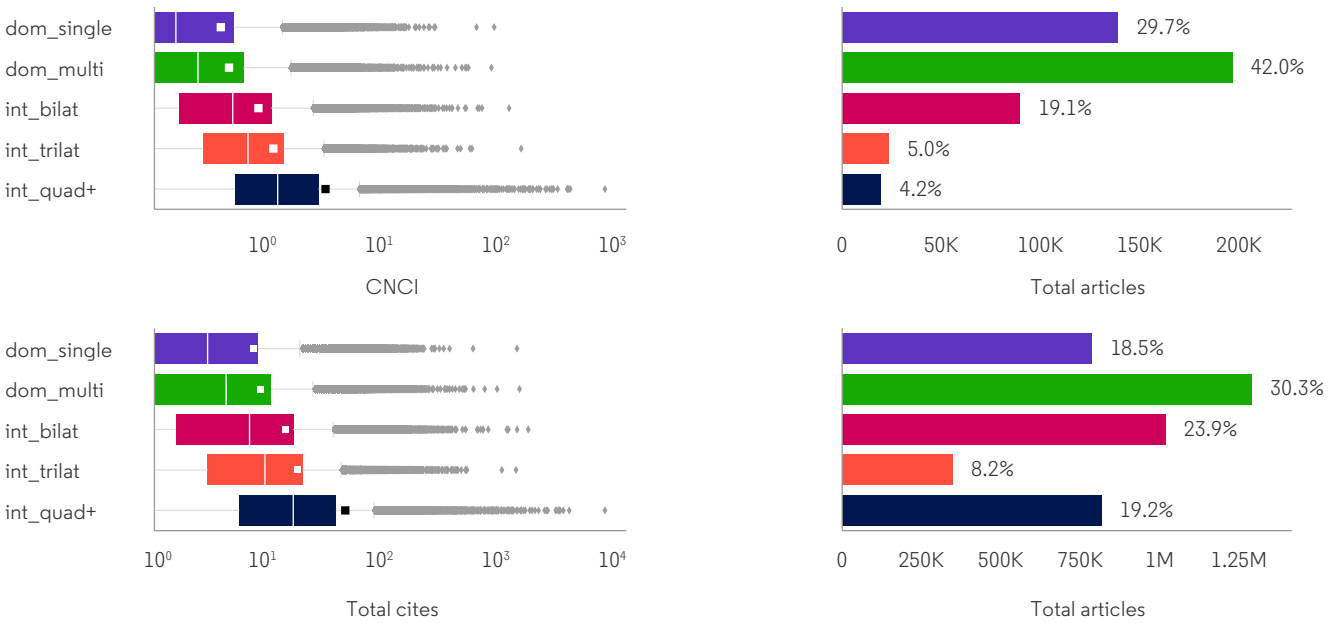
Figure 11.

Breakdown of article count and citation impact by five collaboration types (2009-2018: domestic, single authored [dom_single] domestic, multi-authored [dom_multi]; internationally collaborative, bilateral [int_bilat]; trilateral [int_trilat]; or four or more countries [int_quad+] (see also Potter et al., 2020). For each set of collaboration types: the left-hand graphs show the box-plots for the spread of CNCI and actual citation counts for individual articles; the right-hand graphs show the count of articles and of cites with the percentage each contributes to the national total

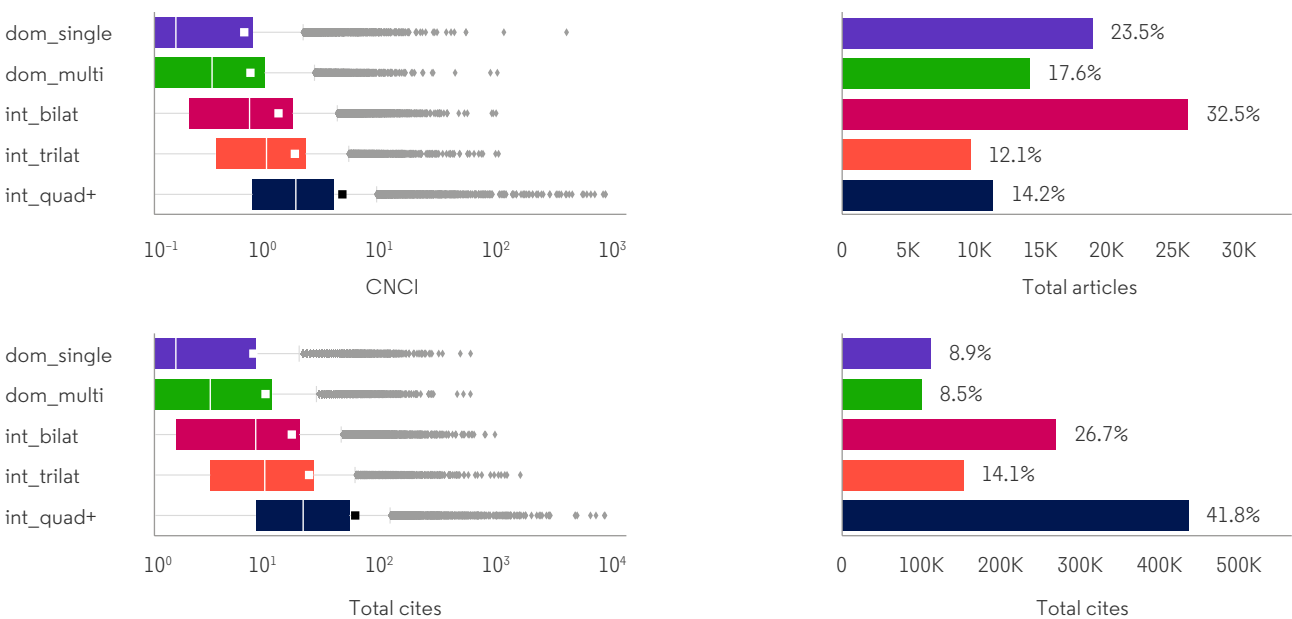
Brazil had roughly 70% domestic articles and these contributed ~50% of its total citations.

Some 19% of articles were bilateral with a single partner country and these led to ~24% of cites.

Multilateral collaborations (4.2%) produced 19.2% of total citations.

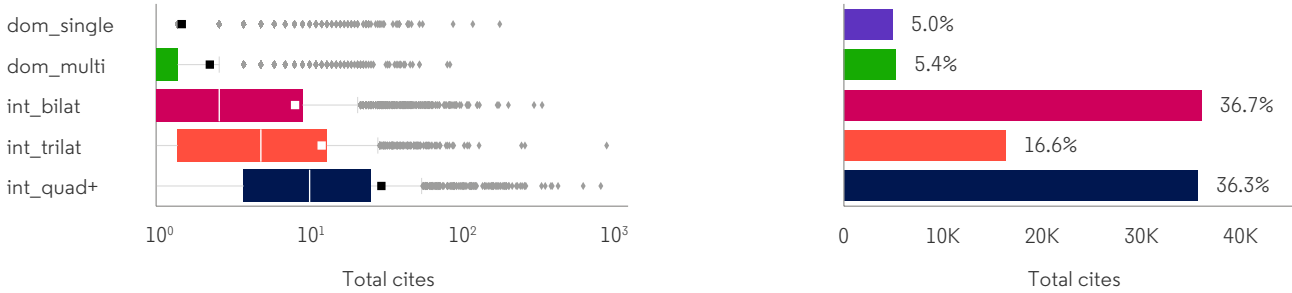
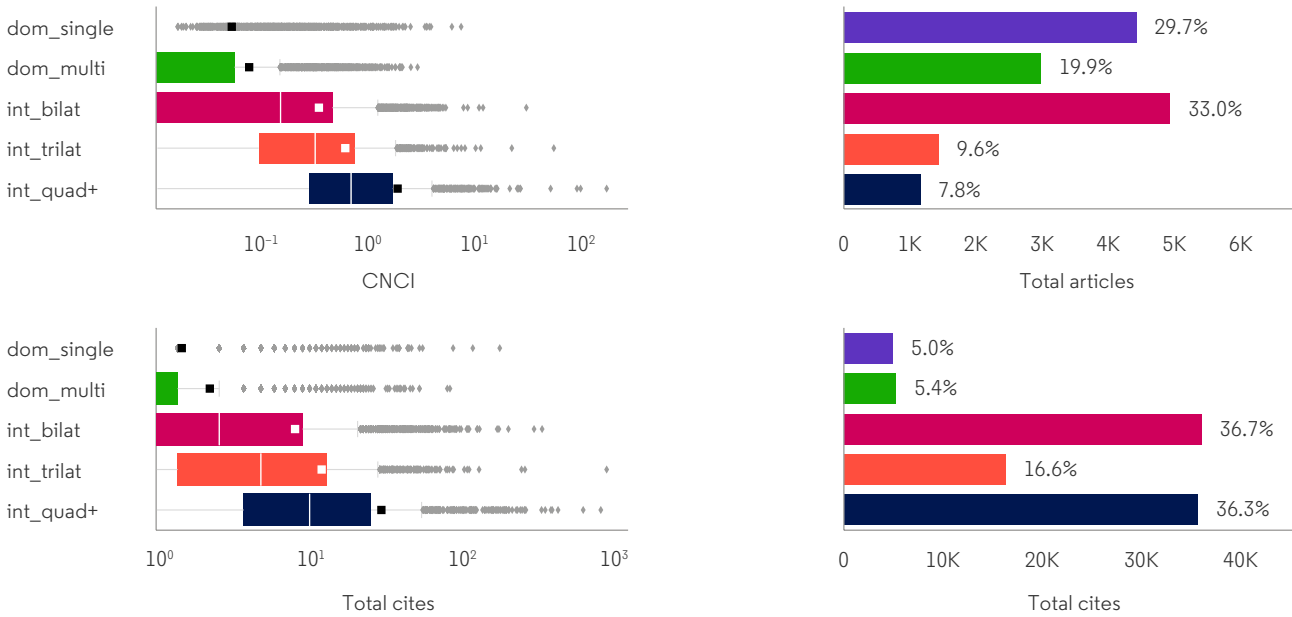


Chile had just over 40% domestic articles which accounted for 17.5% of its citations. It had many international collaborations, notably in astronomy, and 41.8% of its citations came from the 14.2% of multilateral articles.



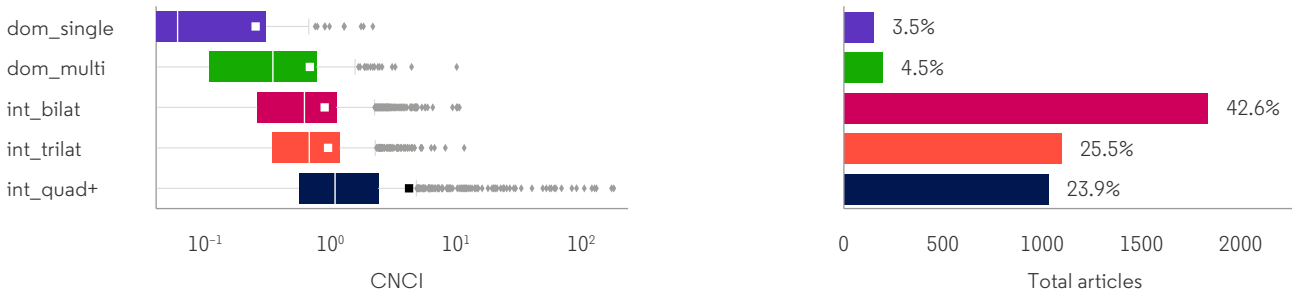
About half of Cuba's articles were domestic and half were collaborative, with ~33% of the total being bilateral.

Only just over 10% of its citations came from the domestic work so its average citation indices do not fully reflect the value of the national research.



Less than 10% of Panama's articles had domestic authorship and these led to just 2% of national citations.

With such a high proportion of citations coming from a relatively large international contribution, it is not possible to determine true research impact.



Open access

A key feature of SciELO is its emphasis on open access (OA) publications. OA is becoming an important route for research dissemination to ensure that publicly funded research outcomes are publicly available, to enable authors to increase the visibility of their work and for readers to easily access literature for their own research needs. This is particularly relevant in developing research economy countries with a less well-funded research base, such as those within the Latin America region.

Latin American researchers publishing in journals indexed in the Web of Science have embraced OA, with 43% of the region's papers in SCIE, SSCI and AHCI between 2011-2020 being open access. Of these documents, 83% have been cited, which demonstrates both a high readership and significant influence, though this figure is almost indistinguishable from that for non-OA content.

The average CNCI value for OA content is greater (0.93) than that of comparable non-OA material (0.76). Compared to regions with similar total output Latin America has a higher OA percentage than the Middle East (~28%) and is only slightly lower than the Nordic region (~46%). However, OA CNCI values are higher in both of those regions (1.16, 1.66 respectively), indicating that the impact of Latin America's OA material has not yet reached world average.

Overview

The expansion of the research base in Latin America is amply evidenced by the region's publications and their citations indexed in the Web of Science. It has been a region of relatively rapid growth (Figure 1) and progressive improvement in research impact (Figures 8, 9). Although recently that growth became disrupted by economic and political challenges, there is every reason to expect that progress will be restored in due course.

There are a number of broader challenges that the region must face. Technological, social and health issues, profound economic inequalities and widespread environmental threats give the research base many challenges to address and its research strengths are already focused on some of these (Table 1, Figure 7). Brazil, notably, showed that its research base was pre-adapted to the challenge of the COVID-19 crisis (Adams et al., 2021a), although its government failed to benefit from this competency.

Many issues are common to many countries. It is therefore most concerning that research collaboration within the region remains extremely low.

This, surely, suggests the need for a better trans-national research organisation that can pool some part of national resources to drive shared programs and projects to mutual benefit. We commented on related needs in our report on [The changing research landscape of the Middle East, North Africa and Turkey](#) (Adams et al., 2021b). That region has a similar pattern to Latin America, with much international collaboration but largely facing out to Europe and North America. This compares with the successful model of collaboration through the European Commission's Framework Programmes which have unquestionably raised the overall quality of research across Europe as well as addressing pressing regional problems.

A pan-American research network led by the larger research economies could be of significant benefit to all parties and raise both impact and awareness of the region's intellectual and academic achievement. Collaboration within the region as well as with the rest of the world will also enhance the quality of scientific research, accelerate access to new markets and allow the financial costs of research to be shared. This could be mediated by a joint funding organization, supported by all and linked to national budget capacity, led by the outstanding scientists who are publishing evidently high-quality research across the region (Figure 8), staffed by an international secretariat and with transparent peer review of the highest international standards.

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