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LATIN AMERICA SHOWS RAPID RISE IN S&E ARTICLES

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The number of science and engineering (S&E) articles credited to Latin American institutional authors and published in a set of the world's most influential scientific and technical journals almost tripled between 1988 and 2001.[1] This growth rate was greater than that of emerging and developing countries in other regions[2] (figure 1). This InfoBrief summarizes the origin, content, patterns of international collaboration, and perceived influence (as measured by citation frequency) of these Latin American S&E articles with a focus on Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico and Venezuela.

[1] The article counts, coauthorship data, and citations discussed in this InfoBrief are based on S&E articles published in a slowly expanding set of the world's most influential scientific and technical journals, as tracked and indexed by the Institute of Scientific Information, Inc. These data are extracted for NSF by CHI Research, Inc. from ISI's Science Citation Index (SCI) and Social Science Citation Index (SSCI) databases. SCI and SSCI appear to give reasonably good coverage of a core set of internationally recognized journals, albeit with some English language bias, which may be salient for non-English speaking countries, such as those in Latin American countries. Articles are credited to countries on the basis of the institutional address(es) listed on the article. Country publication counts are based on fractional assignments; for example, a paper with two institutional authors from different countries is counted as one half of an article for each country. Measurement of international collaboration, on the other hand, is based on whole count assignments; in the previous example, each institutional author of the country would receive one count for its coauthorship of the paper. For further discussion on the ISI data, see "Outputs of Scientific and Engineering Research: Articles and Patents," pages 5-38 of chapter 5 of *Science and Engineering Indicators—2004, Volume 1* (National Science Board 2004).

[2] Defined as countries classified low or middle income by the World Bank. Country classification and methodology available at http://www.worldbank.org/data/countryclass/countryclass.html. For country regional assignments, see *Science and Engineering Indicators—2004,* appendix table 5-35, Volume 2 (National Science Board 2004).

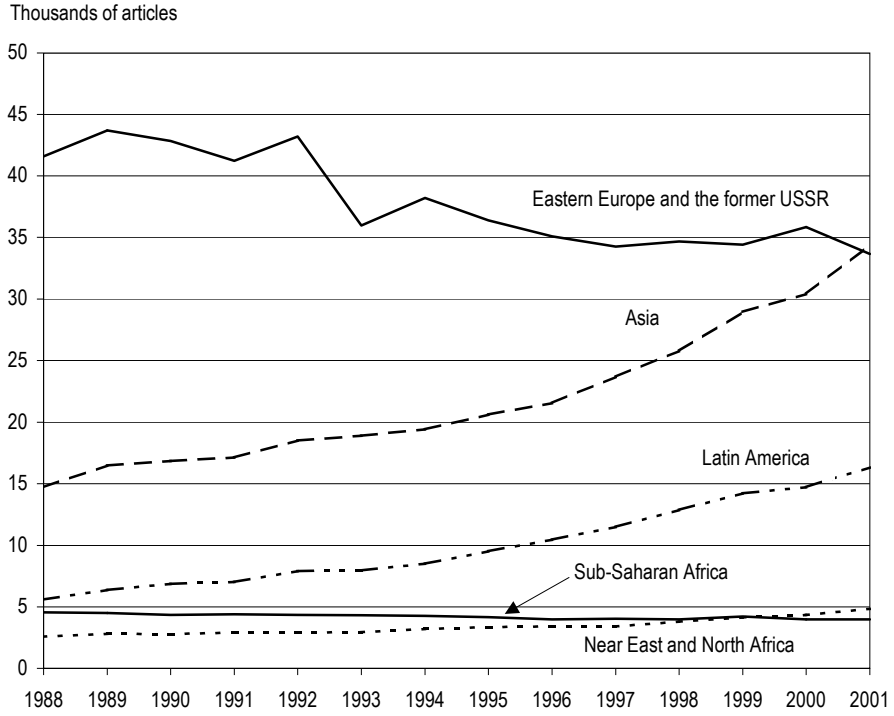
Country of Origin

Output of S&E articles by Latin American authors rose almost 200 percent between 1988 and 2001. This increase was substantially greater than for authors from emerging and developing countries in Eastern Europe and the former USSR, Asia, Near East and North Africa, and Sub-Saharan Africa during this period. Rapid growth in S&E articles pushed Latin America's share of articles authored by all emerging and developing countries from 8 to 17 percent. Despite a more than doubling of its share, Latin America remained third ranked behind Asia and Eastern Europe and the former USSR. Robust growth in articles authored from Asian countries, primarily China, pushed Asia's share from 21 percent to 35 percent in 2001, and its ranking moved from 2nd to the largest share.[3] Articles authored from Eastern Europe and the former USSR fell during this period, resulting in the number falling slightly below Asia's in 2001.

The increase in the number of Latin American articles was concentrated in four countries (Argentina, Brazil, Chile, and Mexico), which generated close to 90 percent of the region's articles in 2001 (table 1). Brazil, the largest producer of S&E articles in Latin America, experienced the most growth, with its output quadrupling between 1988 and 2001. Its share increased by more than 12 percentage points to 44 percent of the region's output. Mexico, the second largest producer of S&E articles, also showed strong growth, with its total number of articles more than tripling. Its share rose by

[3] Despite the rapid expansion of output by Asia and Latin America, S&E article output is dominated by high income countries. These countries accounted for 83 percent of S&E articles in 2001 compared to 17 percent by all emerging and developing countries.

FIGURE 1. S&E article output of emerging and developing countries by region: 1988–2001



NOTES: Developing and emerging countries consist of countries classified as low or middle income by the World Bank. Article counts are assigned to the country on the basis of the institutional address(es) listed on the article. For articles with multiple-country authors, counts are apportioned to each country on the basis of the proportion of authors from each country. Articles with institutional authors in Hong Kong are included in China.

SOURCES: Institute for Scientific Information, Science and Social Science Citation Indexes; CHI Research, Inc.; National Science Foundation, Division of Science Resources Statistics, special tabulations; and World Bank.

4 percentage points to 20 percent, moving Mexico's ranking from 3rd to 2nd. The number of articles by Argentine and Chilean authors also exhibited strong growth. These four Latin American countries share certain characteristics: a moderately high per capita income relative to other countries in the region, a relatively large pool of scientists and engineers, and recent reform of their economies and scientific enterprise. In addition, Brazil and Mexico raised expenditures for research and development (R&D) during the early and mid-1990s (Hill, 2000).

Costa Rica, Colombia, and Venezuela accounted for most of the remaining output, with the combined output of the seven countries accounting for 95 percent of the region's scientific articles in 2001. Costa Rica, particularly, shares many characteristics with the four countries that produce most of the region's scientific articles, as it has embarked on economic reform and advanced technology development. Collectively, these seven countries accounted for 86 percent of economic output in Latin America in 1999.[4] The five of the seven countries that reported R&D expenditures[5]—Argentina, Brazil, Chile, Colombia, and Mexico—together accounted for virtually all R&D expenditures reported by Latin American countries for that year.[6]

[4] Economic output is defined as gross domestic product (GDP) on a purchasing power parity (PPP) basis. Cuba is excluded due to the lack of GDP on a PPP basis (The World Bank, 2002).

[5] Costa Rica did not report R&D expenditures in 1999, and Venezuela reports "science and technology activities," a broader measure than R&D.

[6] Nine Latin American countries reported R&D expenditures in 1999 that were adjusted to a PPP basis using PPP conversion rates from *World Development Indicators 2002*. Cuba is excluded due to the lack of a PPP conversion rate (RICYT 2001).

TABLE 1. S&E article output and share of selected Latin American countries: 1988 and 2001

Rank	Country	S&E article counts		Percent of Latin America S&E article output	
		1988	2001	1988	2001
	Latin America	5,609	16,329	100.0	100.0
1	Brazil	1,766	7,205	31.5	44.1
2	Mexico	884	3,209	15.8	19.6
3	Argentina	1,423	2,930	25.4	17.9
4	Chile	682	1,203	12.2	7.4
5	Venezuela	292	535	5.2	3.3
6	Colombia	86	324	1.5	2.0
7	Costa Rica	55	92	1.0	0.6
8	Other	413	814	7.4	5.1

NOTES: Countries ranked by their 2001 share. Latin America total excludes countries classified by the World Bank as high income, which are the Bahamas and Barbados.

SOURCES: Institute for Scientific Information, Science and Social Science Citation Indexes; CHI Research, Inc.; National Science Foundation, Division of Science Resources Statistics, special tabulations; and World Bank, *World Development Indicators 2002* .

On a per capita basis, Argentina and Chile produced more scientific articles than any other Latin American country, with an average of more than 70 articles published per 1 million inhabitants during 1999–2001 (table 2). The per capita output of Brazil, the largest article producer on a volume basis, was about half the level of Argentina and Chile's per capita output during this period. In terms of per capita article production, the Latin American countries—particularly Argentina, Brazil, Chile, Mexico, Venezuela, and Costa Rica—were relatively higher than many Asian countries but were below the level of several Eastern European countries.

Field distribution of articles

The increase in articles authored by the seven Latin American countries specified earlier in this report was greatest in engineering and technology, biology, and the physical sciences—chemistry, physics, and earth and space.[7] As a result, the combined share of these fields increased during this period, from 51 percent in 1988 to 59 percent in 2001 (figure 2).

[7] Scientific fields in the ISI's SCI and SSCI databases are determined by CHI Research, Inc., based on the classification of the journal in which an article appears. Journals, in turn, are classified based on the pattern of their citations. Computer science is included in engineering and technology.

In contrast, the number of articles in the social and behavioral sciences and the fields of clinical medicine and biomedical research increased at a slower-than-average rate; this resulted in a decline in their share of the portfolio. However, the life sciences accounted for nearly half of all Latin American S&E articles in 2001, a significantly higher share than all the other regions except Sub-Saharan Africa (figure 3). In Asia, Eastern Europe and the former USSR, and the Near East and North Africa, engineering and technology, and mathematics and the physical sciences—chemistry, physics earth and space sciences, are more prominent.

TABLE 2. Per capita output of scientific publications of selected emerging and developing countries: 1999–2001

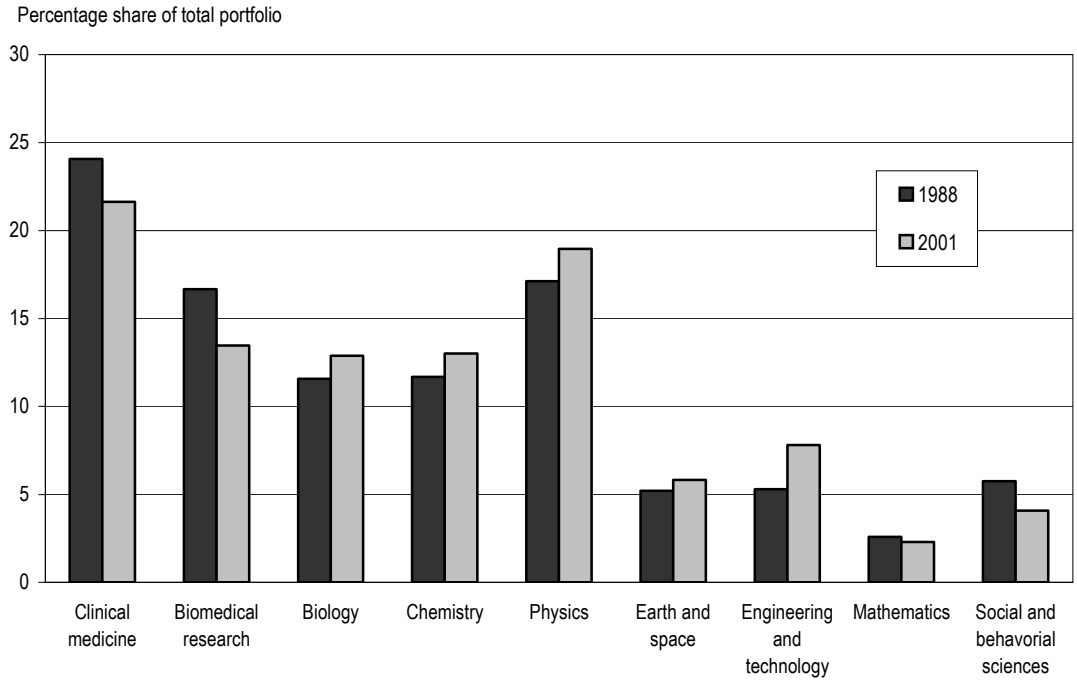
(Millions of inhabitants)

Rank	Country	1999–2001
1	Czech Republic	241.4
2	Hungary	233.6
3	Russia	116.4
4	Poland	139.9
5	Argentina	77.8
6	Chile	75.7
7	Turkey	56.9
8	South Africa	55.8
9	Uruguay	47.9
10	Romania	42.4
11	Brazil	38.8
12	Tunisia	31.9
13	Mexico	31.8
14	Saudi Arabia	30.7
	Average	23.9
15	Egypt	23.2
16	Costa Rica	22.8
17	Venezuela	22.5
18	Malaysia	21.9
19	China	14.8
20	Thailand	10.8
21	India	10.8
22	Colombia	7.3
23	Algeria	6.9
24	Vietnam	1.8
25	Indonesia	0.9

NOTE: Emerging and developing countries are defined as low- and middle-income countries as classified by the World Bank.

SOURCES: Institute for Scientific Information, Science and Social Science Citation Indexes; CHI Research, Inc.; National Science Foundation, Division of Science Resources Statistics, special tabulations; and World Bank, *World Development Indicators 2002.*

FIGURE 2. Portfolio of S&E articles for seven Latin American countries: 1988 and 2001



NOTE: The seven countries are Argentina, Brazil, Chile, Colombia, Costa Rica, Mexico, and Venezuela. Article counts are assigned to the country on the basis of the institutional address(es) listed on the article. For articles with multiple country authors, counts are apportioned to each country on the basis of the proportion of authors from each country. Fields are defined and classifed by CHI Research, Inc. Computer science is included in engineering and technology. Social and behavorial sciences consist of psychology, social sciences, health sciences, and professional fields.

SOURCES: Institute for Scientific Information, Science and Social Science Citation Indexes; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

Citation of Latin American articles

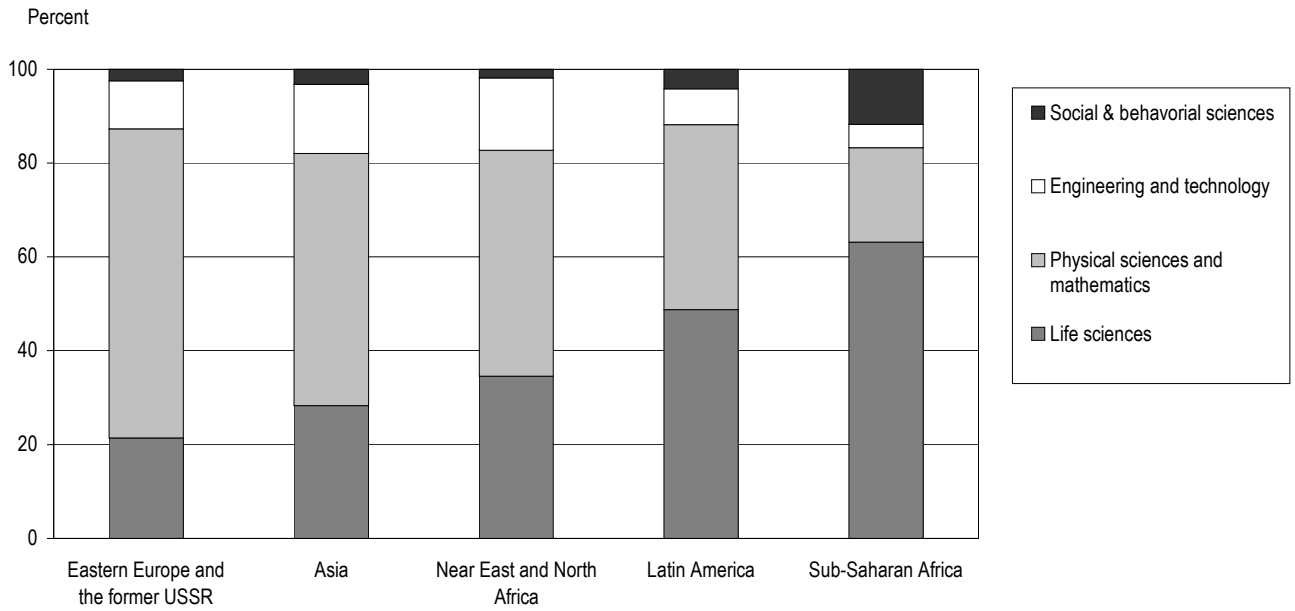
Perhaps of greater interest than the number of scientific and technical articles published is the degree of their use, for which citations can serve as a measurement. The number of citations to Latin American S&E literature nearly tripled between 1988 and 2001, the fastest growth rate by region of emerging and developing countries. This rapid growth pushed Latin America's share from 14 percent to 20 percent of all emerging and developing countries during this period. Citations to Asian literature also rose strongly, increasing Asia's share from 24 percent to 30 percent during this period.[8] Citations to literature from Eastern Europe and the former USSR rose at a far slower pace compared to Latin America or Asia, resulting in a 10 point decline of its share to 36 percent in 2001.

This increase in citations to Latin American literature could reflect the well-documented tendency among authors to cite articles from their own country. An indicator that shows a country's share of citations adjusted for its share of S&E articles, *the relative citation index*, shows that the increase of citations to S&E literature of three Latin American countries—Argentina, Brazil, and Chile—was mainly from authors outside their own country. This suggests that these three countries, which account for nearly 70 percent of citations to the region's literature, increased their relative standing in the international scientific community.

The relative citation indexes of these three countries and Mexico are comparable to other emerging and de-

[8] The literature of high-income countries constitutes most of the citations of S&E literature. In 2001, these countries accounted for 95 percent of citation of S&E articles compared to 5 percent for emerging and developing countries.

FIGURE 3. Portfolio distribution of S&E articles of developing and emerging countries by regions: 2001



NOTES: Regions ranked by their share of life sciences. Emerging and developing countries defined as middle or low income as classified by the World Bank. Fields are defined and classified by CHI Research, Inc. Life sciences consist of clinical medicine, biomedical research, and biology. Physical sciences consist of chemistry, physics, and earth and space sciences. Social & behavioral sciences consist of psychology, social sciences, health sciences, and professional fields. Computer sciences is included in engineering and technology.

SOURCES: Institute for Scientific Information, Science and Social Science Citation Indexes; CHI Research, Inc; National Science Foundation, Division of Science Resources Statistics, special tabulations; and the World Bank.

veloping countries, such as the Eastern European countries (table 3). In the earth and space sciences, Chile has the highest relative citation rate among all countries,[9] and Brazil and Mexico, respectively, have the first and third highest rates of emerging and developing countries.[10] In biomedical research, Chile and Mexico, respectively, are first and third among emerging and developing countries. Chile also ranks high in mathematics, where it is the most widely cited emerging and developing country in this field.

Patterns of Collaboration

Growing internal and international collaboration accompanied the increases in publication and citation of Latin American authors, paralleling a worldwide trend. The share of coauthored articles rose from 50 to 71 percent of all Latin American articles between 1988 and 2001.

[9] A paper is allocated to a country or countries based on the location (not nationality) of its institutional author(s). Chile is home to major telescopes used by international scientists.

[10] Source: ISI SCI and SSCI database and CHI Research, Inc.

International collaboration was a major factor behind the increase in coauthorship of Latin American articles, with the share of internationally coauthored articles rising from 29 percent of all articles in the region in 1988 to 43 percent in 2001. The rate of international collaboration by Latin American countries was comparable to emerging and developing countries in Asia and Eastern Europe and the former USSR, and exhibited a similar pattern of generally lower rates by the major article producers and higher rates by countries with smaller article output and/or developing science base (figure 4.) During the period between 1988 and 2001, the number of countries collaborating with Latin American countries rose sharply, a development that may reflect the emergence both of new countries and the Internet and World Wide Web. The number of countries collaborating with Brazil nearly doubled, increasing from 46 countries in 1988 to 103 in 2001.

The U.S. is the largest collaborator of any country in the top four publishing Latin American countries. The U.S. had a share of 35-42 percent of all foreign coau-

TABLE 3. Citation of S&E literature of selected emerging and developing countries: 1992, 1996, and 2001
(Relative citation index)

Country	1992	1996	2001
Hungary	0.38	0.44	0.49
Chile	0.32	0.38	0.43
Argentina	0.28	0.34	0.39
Czech Republic	na	0.32	0.38
Mexico	0.40	0.34	0.37
South Africa	0.33	0.33	0.37
Brazil	0.30	0.37	0.35
Poland	0.26	0.31	0.34
Saudi Arabia	0.25	0.20	0.26
India	0.16	0.20	0.25
China	0.20	0.22	0.20

na = not applicable.

NOTES: Relative prominence of scientific literature is measured on the basis of the relative citation index of the country. The relative citation index excludes the country's citation of its own scientific literature. An index of 1.00 would indicate that the country/economy's share of cited literature is equal to the country/region's world share of scientific literature. An index greater (less) than 1.00 would indicate that the country/economy is cited relatively more (less) than is indicated by the country/economy's share of scientific literature. Countries ranked by their 2001 relative citation index. China does not include Hong Kong.

SOURCES: Institute for Scientific Information, Science Citation and Social Citation Indexes; CHI Research, Inc.; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

thorships on internationally coauthored articles in each of these countries compared to a 12–19 percent share by the next largest collaborating country in 2001 (table 4). U.S. collaboration in each of these four countries is particularly high in two fields where U.S. published research is prominent and highly cited—biomedical research and clinical medicine. In 2001, the U.S. coauthorship share of international articles in each of these four countries was 47–52 percent and 43–62 percent, respectively, for these two fields. As noted in the previous section, the biomedical literature from Chile and Mexico are highly cited, suggesting that U.S. science in this field may play a key role in the prominence of these countries' published research. However, the U.S. share of articles coauthored with these countries has fallen over the past two decades (a development that mirrors a worldwide trend) as Latin American countries have expanded their collaboration with other countries. Spain has become a key partner, with its scientific collaboration coinciding with its pursuit of greater economic integration in Latin America.[11] Other key collaborators include France, the United Kingdom, Germany, Italy, and Canada, reflecting the importance of educational, historic, and cultural ties as well as Latin America's aspiration to partner with more advanced countries.

Intraregional collaboration among the Latin American countries also increased, but remained modest in comparison with intraregional collaboration in Western Europe or Asia (NSB 2002). Brazil was a key collaborator among its Latin American neighbors, most of whom increased their rate of collaboration with Brazil over the past two decades (table 5).

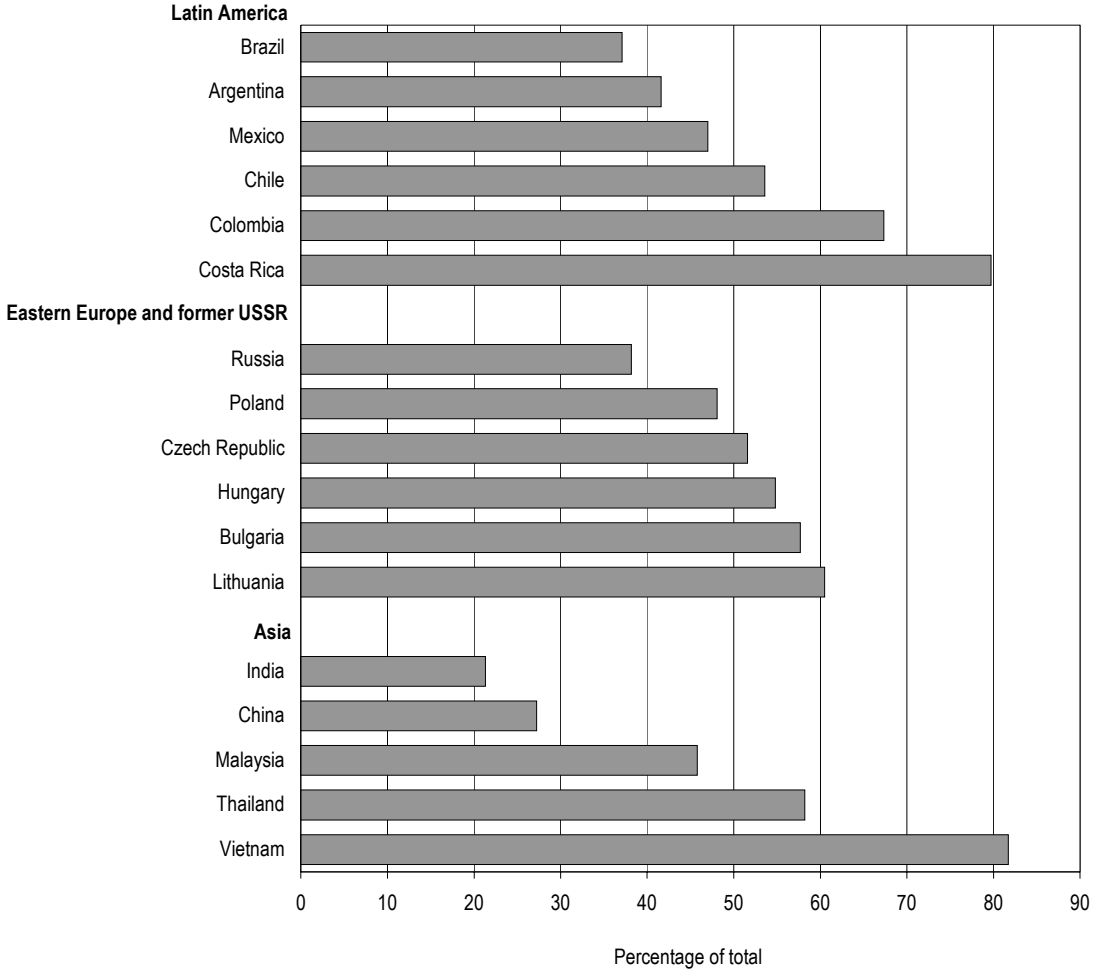
However, Brazil itself had a relatively low rate of collaboration within the region, instead directing much of its collaborative effort toward the United States and Europe. This is similar to the pattern of international collaboration by the major article producer of Eastern Europe and the former USSR, Russia, and the two leading article producers in Asia, China and India.

Summary

Overall, the preceding data show that scientists based in Latin America, primarily Argentina, Brazil, Chile, and Mexico, substantially increased their rate of publication in influential and internationally recognized scientific and technical journals during the past two decades. This growth rate was higher than other regions consisting primarily of emerging and developing countries, including Asia and Eastern Europe and the former USSR, which produce more articles than Latin America. Citation of three Latin American countries' S&E literature outside their own countries also increased, suggesting that the visibility and prominence of their science has improved somewhat. Many of these articles are collaborative efforts with scientists from the United States, Western Europe, and within the Latin American region, notably Brazil. A key difference between the articles of Latin America and other regions is subject matter: the portfolio of Asia and Eastern Europe countries is more heavily weighted toward the physical sciences, while the portfolio of Latin American countries is weighted more toward the life sciences.

[11] Hosono (2001) reports that Latin America received $12.4 billion of foreign direct investment from Spain in 1998 compared to $4.0 billion in 1996.

FIGURE 4. International collaboration on S&E articles of selected emerging and developing countries: 2001



NOTES: International collaboration defined as share of a country's articles with at least one nondomestic institutional coauthor. Authorship determined by institutional address listed on scientific article. Emerging and developing countries defined as countries classified as low and middle income by the World Bank.

SOURCES: Institute for Scientific Information, Science and Social Science Citation Indexes; CHI Research, Inc.; National Science Foundation, Division of Science Resources Statistics, special tabulations; and the World Bank.

TABLE 4. International coauthorship on S&E articles of four selected Latin American countries: 2001

(Number of international articles in parentheses)

	Argentina (1,587)		Brazil (3,369)		Chile (954)		Mexico (2,066)	
Rank	Country	Percent	Country	Percent	Country	Percent	Country	Percent
1	United States	34.9	United States	39.0	United States	39.2	United States	42.2
2	Spain	18.8	France	13.8	Spain	16.1	Spain	11.7
3	Brazil	12.6	United Kingdom	12.8	France	15.7	France	11.4
4	France	10.9	Germany	10.7	Germany	15.4	United Kingdom	10.6
5	United Kingdom	10.6	Italy	7.0	United Kingdom	10.3	Germany	7.4
6	Germany	10.3	Spain	6.9	Argentina	7.4	Canada	6.4
7	Italy	6.0	Argentina	5.9	Italy	6.8	Russia	6.1
8	Canada	4.6	Canada	4.8	Brazil	6.1	Brazil	5.3
9	Chile	4.5	Russia	4.0	Canada	5.5	Italy	4.7
10	Mexico	4.3	Japan	3.5	Mexico	4.1	Cuba	4.5

NOTE: The percents are the share of the country's coauthorships on internationally co-authored articles. The sum of the collaborating countries exceed 100 percent because the number of coauthorships exceed the total number of internationally coauthored papers. This is because countries are each credited one whole count for their participation on internationally coauthored papers.

SOURCES: Institute for Scientific Information, Science Citation and Social Citation Indexes; CHI Research, Inc., Science Indicators database; and National Science Foundation, Division of Science Resources Statistics.

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TABLE 5. Intraregional scientific collaboration in selected Latin American countries: 1988 and 2001

Country of author	Number of international articles	Percent of a country's international articles with a coauthor from selected Latin American countries						
		Argentina	Brazil	Chile	Colombia	Costa Rica	Mexico	Venezuela
Argentina								
2001	1,587	na	12.6	4.5	2.2	0.1	4.3	1.1
1988	266	na	9.8	4.5	0.0	0.4	1.1	1.1
Change	1,321	na	2.8	0.0	2.2	-0.3	3.2	0.0
Brazil								
2001	3,369	5.9	na	1.7	1.7	0.5	3.3	1.0
1988	621	4.2	na	2.6	0.0	0.0	1.0	0.6
Change	2,748	1.7	na	-0.9	1.7	0.5	2.3	0.4
Chile								
2001	954	7.4	6.1	na	1.2	0.2	4.1	1.3
1988	247	4.9	6.5	na	0.0	0.4	2.0	1.6
Change	707	2.6	-0.4	na	1.2	-0.2	2.1	-0.4
Colombia								
2001	373	9.4	15.0	2.9	na	0.8	12.3	3.5
1988	59	0.0	0.0	0.0	na	0.0	3.4	0.0
Change	314	9.4	15.0	2.9	na	0.8	8.9	3.5
Costa Rica								
2001	145	0.7	12.4	1.4	2.1	na	4.8	0.7
1988	47	2.1	0.0	2.1	0.0	na	4.3	2.1
Change	98	-1.4	12.4	-0.7	2.1	na	0.6	-1.4
Mexico								
2001	2,066	3.3	5.3	1.9	2.2	0.3	na	1.8
1988	321	0.9	1.9	1.6	0.6	0.6	na	0.3
Change	1,745	2.4	3.5	0.3	1.6	-0.3	na	1.5
Venezuela								
2001	434	4.1	8.1	2.8	3.0	0.2	8.5	na
1988	124	2.4	3.2	3.2	0.0	0.8	0.8	na
Change	310	1.7	4.8	-0.5	3.0	-0.6	7.7	na

na = not applicable.

NOTES: Internationally coauthored papers are on a whole-count basis, where each country is credited a whole count for an author. For example, Argentina, Brazil, and Chile would each receive a whole count for a paper with at least one listed institutional author from each country.

SOURCES: Institute for Scientific Information, Science Citation and Social Citation Indexes; CHI Research, Inc; and National Science Foundation, Division of Science Resources Statistics, special tabulations.

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