

## BRAZIL, CHINA, INDIA, RUSSIA, AND TAIWAN LEAD S&E ARTICLE OUTPUT OF NON-OECD COUNTRIES

by Derek Hill

Scientific research, development, and innovation, key drivers of economic growth, have been concentrated in the 30 member nations of the Organisation for Economic Co-operation and Development (OECD).<sup>1</sup> However, countries outside the OECD have been increasing their S&E capabilities and are rivaling the OECD member countries. One indicator of scientific research capability is the production of scientific and engineering articles in the world's leading scientific and engineering journals.<sup>2</sup> OECD nations, with 584,000 articles in 2003, accounted for 84% of the world total, compared with 87% a decade ago.<sup>3</sup> Among the non-OECD countries and economies, five—Brazil, China,

India, Russia, and Taiwan—produced two-thirds of their scientific article output (figure 1). This *InfoBrief* discusses trends in output, portfolio, and international collaboration of scientific articles produced by these five countries and economies.

### S&E Article Output Trends

The article output of Brazil, China, India, Russia, and Taiwan followed different 1993–2003 growth trends (figure 2):

- China<sup>4</sup> is now dominant among the five, producing almost 40% of the group's output in 2003. China quadrupled its S&E article output in a decade and it surpassed India in 1996 and Russia 5 years later. China's world output share rose from 1% to 4% between 1993 and 2003 (figure 3), moving it into first place among all non-OECD countries and sixth place among all countries.<sup>5</sup>
- S&E article output of Brazil and Taiwan also grew rapidly, with article output tripling in Brazil and more than doubling in Taiwan from 1993–2003. The world article share of these two countries and economies roughly doubled over this period (figure 3).
- India's S&E article output remained stagnant for much of the period before showing growth since 2000. While India's output rose 31% over the decade, its world share was basically unchanged.

<sup>1</sup> OECD countries represented 82% of global R&D expenditures in 2000. See National Science Board 2006, p. 4-40.

<sup>2</sup> The article counts and coauthorship data 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 Thomson ISI. These data are extracted for NSF by ipIQ, Inc. from Thomson ISI's Science Citation Index (SCI) and Social Science Citation Index (SSCI) databases. Coverage extends to electronic journals, including print journals with electronic versions and electronic-only journals. 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 Brazil, China, India, Russia, and Taiwan. Articles are credited to countries and economies on the basis of the institutional addresses listed on the articles. Country and economy article output is based on fractional counts that assign countries and economies fractional credit based on the proportion of their participating institutions. Measurement of international collaboration is based on whole counting, which assigns one count to a country for its participation, regardless of the number of institutions. For further discussion on the ISI data, see National Science Board 2006, p. 5-37.

<sup>3</sup> OECD publication data consists of 30 member countries as of December 2000.

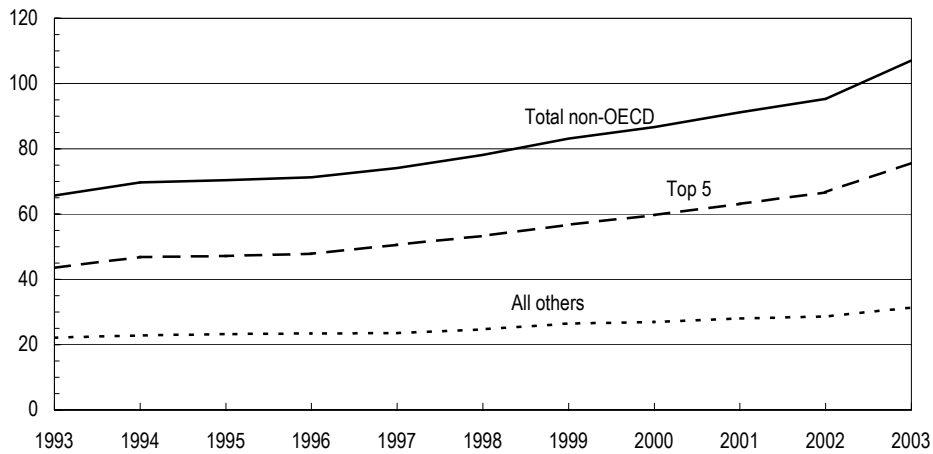
<sup>4</sup> China's article output includes Hong Kong.

<sup>5</sup> See National Science Board 2006, p. 5-38.



FIGURE 1. S&amp;E article output of non-OECD countries and economies: 1993–2003

Thousands of articles



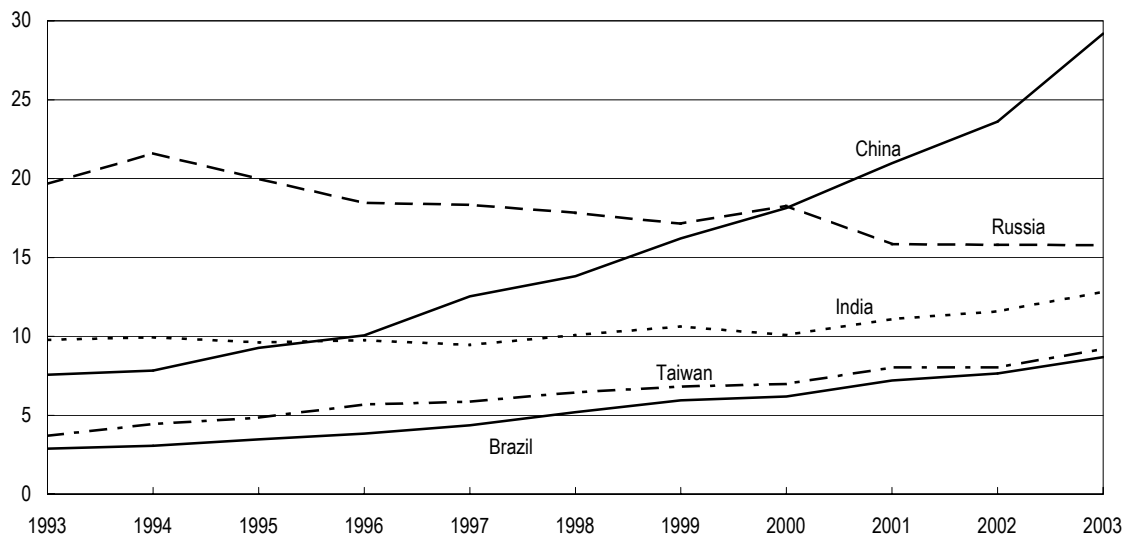
OECD = Organisation of Economic Co-operation and Development.

NOTES: The top 5, Brazil, China, India, Russia, and Taiwan, are the non-OECD countries and economies that had the largest S&E article output. For internationally coauthored articles, each region/country/economy receives fractional credit on the basis of proportion of its participating institutions.

SOURCES: Thomson ISI, Science Citation Index and Social Sciences Citation Index; <http://www.isinet.com/products/citation/>; iplQ, Inc., and National Science Foundation, Division of Science Resources Statistics, special tabulations.

FIGURE 2. S&amp;E article output of Brazil, China, India, Russia, and Taiwan: 1993–2003

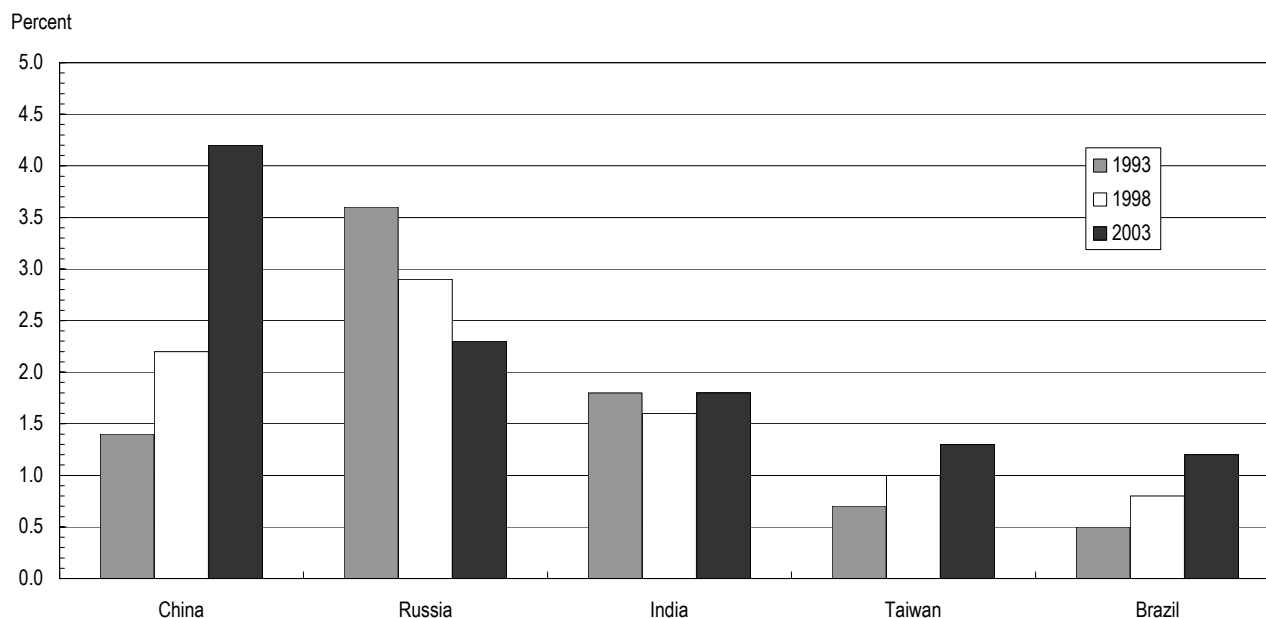
Thousands of articles



NOTES: For internationally coauthored articles, each country and economy receives fractional credit on the basis of proportion of its participating institutions. China includes Hong Kong.

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FIGURE 3. S&amp;E world article share of Brazil, China, India, Russia, and Taiwan: 1993, 1998, and 2003



NOTES: Countries and economies listed in order of their world S&E article share in 2003. For internationally coauthored articles, each country and economy receives fractional credit on the basis of proportion of its participating institutions. China includes Hong Kong.

SOURCES: Thomson ISI, Science Citation Index and Social Sciences Citation Index; <http://www.isinet.com/products/citation/>; iplQ, Inc., and National Science Foundation, Division of Science Resources Statistics, special tabulations.

- Russia's output continues to reflect the political and economic disruption of the 1990s and the restructuring and retrenchment of its S&T system. Its article output contracted by 20% over the decade, and it fell from 7<sup>th</sup> to 11<sup>th</sup> largest producer of the world's S&E articles as Italy moved ahead of Russia in the mid-1990s, then China, Spain, and Australia in more recent years.

### S&E Article Portfolio

The physical sciences (earth and space sciences, including astronomy; chemistry; and physics) and mathematics dominate the S&E portfolio of China, India, and Russia (figure 4). In 2003, these scientific fields accounted for nearly three-quarters of Russia's S&E articles and over one-half of China's and India's S&E articles. In contrast, more than half of Brazil's S&E portfolio is comprised of the life sciences (clinical medicine, biomedical research, and biology). Taiwan's S&E article portfolio is more evenly distributed over the life sciences (38%) and the physical sciences and mathematics (37%).

The S&E article portfolios of these countries and economies showed little change between 1993 and

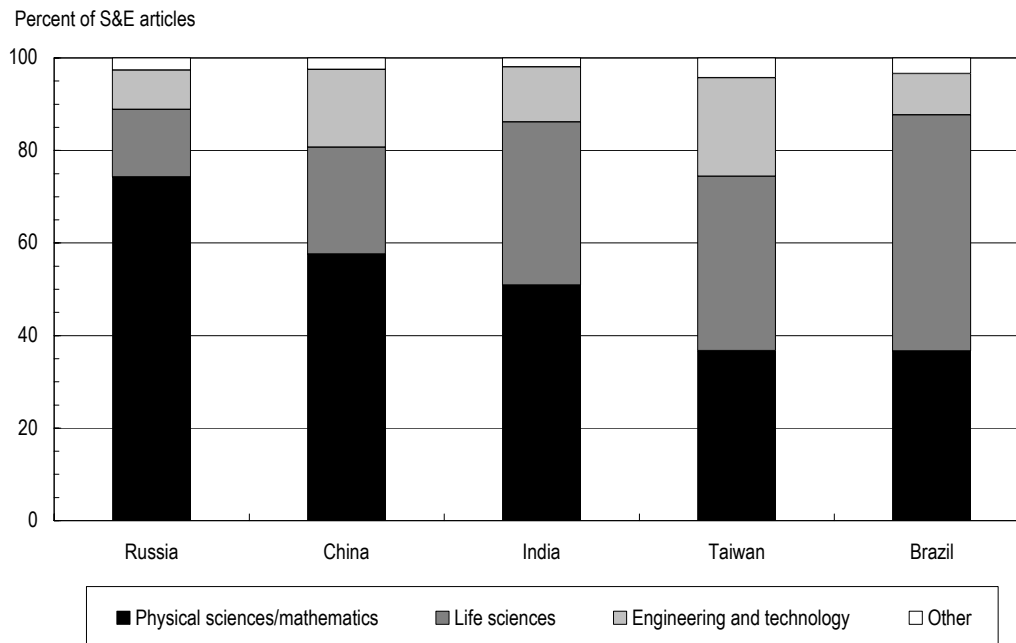
2003, with the exception of Russia's. The share of life sciences of Russia's S&E article output fell from 24% to 14% as the share of physical sciences and mathematics increased from 66% to 74% during this period.

### International Collaboration Trends of Brazil, China, India, Russia, and Taiwan

The number of S&E articles that reflected international collaboration by these countries and economies rose rapidly between 1993 and 2003 (table 1). However, trends in their rate of international collaboration, as measured by the share of their articles with international authors, were divergent.<sup>6</sup> In Russia and India, which had declining and modest growth in total S&E article output, respectively, the rate of international collaboration increased markedly during this period. In Brazil, China, and Taiwan, which had rapid growth in S&E article output, the rate of international collaboration rose in Taiwan, showed little change in China, and declined in Brazil.

<sup>6</sup> International S&E articles have at least one coauthor from within a country and one coauthor from outside that country.

FIGURE 4. S&amp;E article portfolio of Brazil, China, India, Russia and Taiwan: 2003



NOTES: Countries and economies ranked by their S&E article share of physical sciences/mathematics. Physical sciences consist of chemistry, physics, and earth and space sciences. Earth and space sciences includes astronomy. Life sciences consists of clinical medicine, biomedical research, and biology. Biology includes agricultural sciences. Engineering and technology includes computer sciences. Other consists of social sciences, psychology, health sciences, and professional fields. For internationally coauthored articles, each country and economy receives fractional credit on the basis of proportion of its participating institutions. China includes Hong Kong.

SOURCES: Thomson ISI, Science Citation Index and Social Sciences Citation Index; <http://www.isinet.com/products/citation/>; iPLQ, Inc., and National Science Foundation, Division of Science Resources Statistics, special tabulations.

The most frequent collaborators with these five countries and economies, as measured by their respective coauthorship shares, are the United States and European Union (EU) (table 2).<sup>7</sup> The United States had the largest share in 2003 for Taiwan and China and was second to the EU for the three other countries and economies. The U.S. share remained about the same for China, fell slightly for Russia and Brazil, declined for India, and fell sharply for Taiwan between 1996 and 2003. The EU's share fell slightly for Brazil, China, India, and Russia and increased slightly for Taiwan during this period.

With the exception of Russia, these countries and economies increased their collaboration within their respective regions between 1996 and 2003 (table 2), notably in the Asian countries and economies. The coauthorship

share of Asia<sup>8</sup> more than doubled for India and Taiwan and increased by about five percentage points for China during this period. In 2003, the share of coauthorship with Asian collaborators was at least 20% of China and India's internationally coauthored articles and exceeded 30% for Taiwan's, at least double the coauthorship share of Brazil and Russia in their respective regions.

The growing intraregional collaboration of the three Asian countries and economies was centered in East Asia (table 3). Japan, the largest Asian collaborator with China, India, and Taiwan, increased its share for these countries and economies between 1996 and 2003, notably in India and Taiwan. China's share increased significantly for India and Taiwan during this period, and its share nearly equaled Japan's for Taiwan. India's share of Taiwan's

<sup>7</sup> EU consists of the current 27 member countries.

<sup>8</sup> Asia consists of China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

TABLE 1. International S&amp;E article collaboration of Brazil, China, India, Russia, and Taiwan: Selected years, 1993–2003

Country/economy	1993	1995	1997	1999	2001	2003
<b>Brazil</b>						
Total S&E articles	3,708	4,550	5,653	7,552	9,078	10,779
Internationally coauthored articles	1,459	1,906	2,301	2,898	3,369	3,794
Internationally coauthored as share of total (%)	39.3	41.9	40.7	38.4	37.1	35.2
<b>China</b>						
Total S&E articles	8,907	10,916	14,622	18,922	24,638	34,110
Internationally coauthored articles	2,395	2,966	3,784	5,026	6,703	9,132
Internationally coauthored as share of total (%)	26.9	27.2	25.9	26.6	27.2	26.8
<b>India</b>						
Total S&E articles	10,546	10,469	10,352	11,792	12,561	14,529
Internationally coauthored articles	1,414	1,591	1,660	2,166	2,685	3,187
Internationally coauthored as share of total (%)	13.4	15.2	16.0	18.4	21.4	21.9
<b>Russia</b>						
Total S&E articles	21,912	23,109	22,053	21,306	20,356	20,630
Internationally coauthored articles	4,035	5,515	6,506	7,281	7,774	8,363
Internationally coauthored as share of total (%)	18.4	23.9	29.5	34.2	38.2	40.5
<b>Taiwan</b>						
Total S&E articles	4,107	5,421	6,500	7,607	9,115	10,448
Internationally coauthored articles	754	1,038	1,154	1,419	1,897	2,178
Internationally coauthored as share of total (%)	18.4	19.1	17.8	18.7	20.8	20.8

NOTES: Internationally coauthored articles have at least one collaborating institution from outside of indicated country/economy. China includes Hong Kong.

SOURCES: Thomson ISI, Science Citation Index and Social Sciences Citation Index; <http://www.isinet.com/products/citation/>; iplQ, Inc., and National Science Foundation, Division of Science Resources Statistics, special tabulations.

TABLE 2. International coauthorship of S&E articles of Brazil, China, India, Russia, and Taiwan, by region and country: 1996 and 2003  
(Percent)

Region/country	Brazil		China		India		Russia		Taiwan	
	1996	2003	1996	2003	1996	2003	1996	2003	1996	2003
Internationally coauthored S&E articles (number)	2,090	3,794	3,341	9,132	1,719	3,187	5,827	8,363	1,103	2,178
Coauthorship share										
United States	35.7	33.2	32.8	33.1	34.9	28.2	19.5	18.5	65.6	44.8
European Union	41.7	40.4	31.9	27.1	39.3	36.4	58.8	58.3	11.4	13.4
Asia-10	3.9	5.1	19.9	24.8	9.1	20.0	5.0	9.7	15.3	31.4
Latin America	8.0	10.1	0.9	0.9	1.7	2.2	1.6	1.8	0.6	0.6
Former USSR	2.6	2.4	1.2	1.3	3.0	3.1	6.4	4.0	1.1	3.1
Other	8.1	8.8	13.3	12.9	12.0	10.1	8.7	7.8	6.0	6.7

NOTES: Internationally coauthored articles have at least one collaborating institution from outside of indicated country/economy. Coauthorship share is a region's/country's/economy's fractional share of indicated country's/economy's international S&E articles. Asia-10 consists of China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

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TABLE 3. Intraregional coauthorship share of internationally coauthored S&amp;E articles of China, India, and Taiwan, by country: 1996 and 2003

Rank	China			India			Taiwan		
	Collaborating country/economy	Percent share		Collaborating country/economy	Percent share		Collaborating country/economy	Percent share	
		1996	2003		1996	2003		1996	2003
1	Japan	13.0	14.4	Japan	6.1	10.2	Japan	7.3	11.7
2	Singapore	1.6	3.3	South Korea	0.3	2.7	China	5.0	11.0
3	South Korea	1.6	2.8	China	1.2	2.5	India	0.3	3.2
4	Taiwan	1.9	2.7	Taiwan	0.1	2.3	South Korea	0.7	2.6
5	India	0.5	0.8	Malaysia	0.5	0.9	Singapore	1.4	2.2
	Share of Asia-10	19.9	24.8	Share of Asia-10	9.1	20.0	Share of Asia-10	15.3	31.4
Internationally coauthored S&E articles (number)		3,341	9,132		1,719	3,187		1,103	2,178

NOTES: Internationally coauthored articles have at least one collaborating institution from outside of indicated country/economy. Coauthorship share is a region's/country's/economy's fractional share of indicated country's/economy's international S&E articles. Asia-10 consists of China, India, Indonesia, Japan, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand. China includes Hong Kong.

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internationally coauthored articles grew from less than 0.5% in 1996 to 3% in 2003, the third-ranked collaborating Asian country. Other East Asian countries with ties to these countries and economies included Singapore and South Korea. South Korea's share more than doubled for India and Taiwan between 1996 and 2003. Singapore's share of China's internationally coauthored articles doubled during this period, and it became the second-ranked Asian collaborator with China in 2003.

### Reference

National Science Board (NSB). 2006. *Science and Engineering Indicators 2006*. Arlington, VA: National Science Foundation (volume 1, NSB 06-1; volume 2, NSB 06-1A). Available at <http://www.nsf.gov/statistics/seind06/>.

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