3. Regional Summary

This report examines six Asian countries—the People's Republic of China (China), India, Japan, Singapore, the Republic of Korea (South Korea), and the Republic of China (Taiwan)—which represent 77 percent of the Asian population and 42 percent of the world's population. These six countries annually produce more than one-half million natural science and engineering (NS&E) bachelor's degrees, more than twice as many as the United States (see tables 1 and A-3). They produce approximately equal numbers of engineering and natural science graduates at the bachelor's level.[4]

The United States, with one-tenth the combined population of these countries, produces comparable numbers of advanced degrees and more than twice as many doctoral degrees in science and engineering (S&E). (See tables 2, A-5, and A-7.) However, of the approximately 22,853 doctoral degrees granted in S&E in the United States in 1990, around 3,200, or approximately 14 percent, were awarded to students from these six Asian countries. Tables 2 and 3 indicate that these Asian countries depend on U.S. graduate schools to educate a significant proportion of their doctoral students.[5] In 1990, the number of S&E doctoral degrees awarded to Asians from these countries by U.S. universities was 30 percent of the number obtained within these countries.[6]

How has this pool of scientists and engineers grown during the 1970s and 1980s, and what are the prospects for the 1990s? The following section examines the growth in S&E education from 1975 to 1990 and the prospects of the Asian region producing a growing share of the world's NS&E degrees. Further sections will explore potential connections between this growth in education and Asia's needs for S&E personnel. Those needs are driven by the countries' research and development (R&D) investment, increasingly sophisticated manufacturing, and growing economies. A regional summary of these three dimensions—human resources, R&D investment, and economic growth—is followed by country-specific details on each dimension. Near-term prospects for Asia's human resources

Table 1. Bachelor's degrees in S&E in selected Asian countries and the U.S, by field: 1990

Field	Selected Asian countries	United States
Natural science	252,767	105,021
Engineering	261,410	64,705
Natural science and engineering	514,177	169,726
Social science	196,284	159,368
Total science and engineering	710,461	329,094

SOURCE: See table A-3.

[4] Natural science fields include physical; biological; earth, atmospheric, and oceanographic; agricultural; and math and computer sciences. Medical sciences are not included.

[5] Doctoral degrees received from other Asian countries, and in Canada and Europe, would raise the total number of degrees for these countries.

[6] Not all of these Asian doctoral graduates of U.S. universities return home. Percentages of those who plan to stay in the United States are given, by country, in section 7.

Table 2. Doctoral degrees in S&E in selected Asian countries and the U.S.: 1990

Field	Selected Asian countries	United States
Natural science	6,812	11,368
Engineering	2,856	4,892
Natural science and engineering	9,668	16,260
Social science	746	6,593
Total science and engineering	10,414	22,853

SOURCE: See table A-7.

Table 3. Doctoral degrees in S&E granted to Asian students by U.S. universities: 1990

Country	Acquired in U.S. university
China	940
Taiwan	906
South Korea	673
India	612
Japan	73
Total	3,204

SOURCE: National Science Foundation 1991

for science and technology are provided in a concluding section.

Human Resources

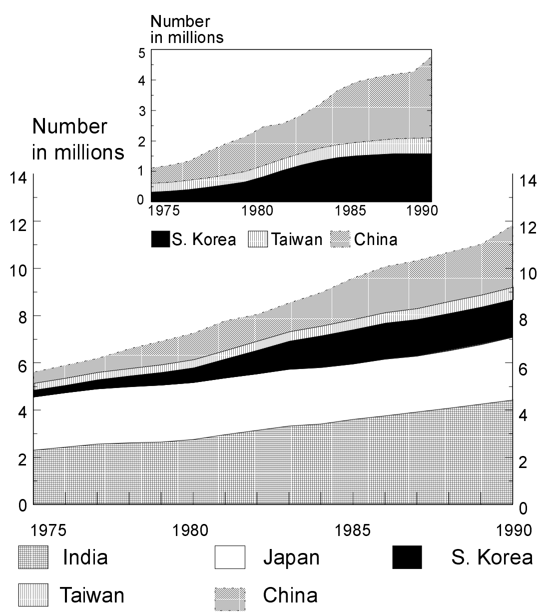
Enrollment in Higher Education

Total university enrollments in the six Asian countries studied have doubled since 1975 (see figure 1), and there are two distinct groups among these countries: those whose enrollments grew steeply in the 1950s and 1960s (India and Japan) and subsequently leveled off, and those whose enrollments have grown in the last 15 years (South Korea, Taiwan, and China) (see figure 1 inset). Even with this growth, only about 5 percent of the college-age segment of the 2.5 billion total population in the Asian region is enrolled in a university. The region has a potential for extensive further growth in university education.

India accounts for more than a third of the total enrollments. Singapore does not show up on the graph because of its small number of university students relative to other Asian countries. (See table A-1 for data on university enrollments for all six countries.)

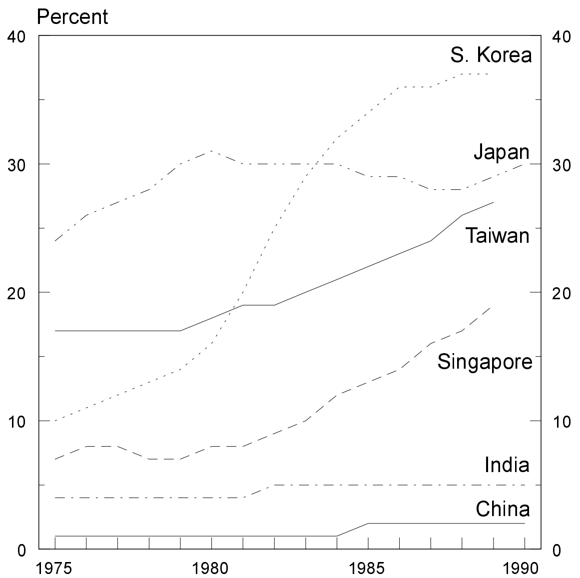
The number of people acquiring a university education affects the quality of the labor force and the economic development potential of a country. Within individual countries, the ratio of university students to the total 20- to 24-year-old population varies widely, as shown

Figure 1. Growth in enrollment in higher education in selected Asian countries: 1975-90



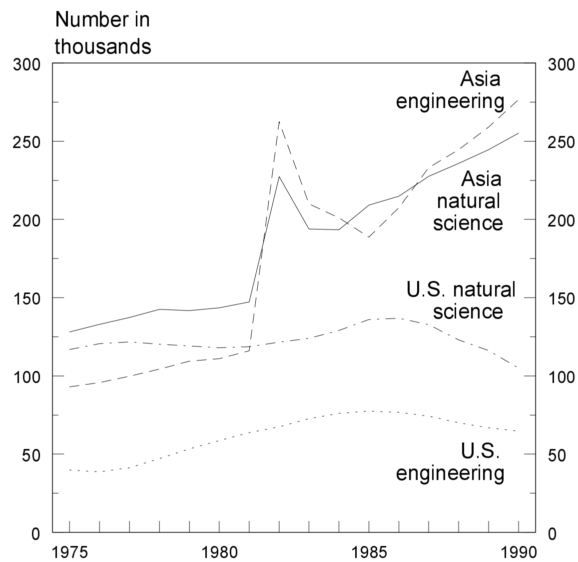
NOTE: See table A-1.

Figure 2. Ratio of university enrollments to the 20- to 24-year-old population in selected Asian countries: 1975-90



NOTE: See table A-2.

Figure 3. Bachelor's degrees in natural science and engineering in Asia and the U.S.: 1975-90



NOTES: Asian degree data include six countries: China, India, Japan, Singapore, South Korea, and Taiwan. See table A-3.

in figure 2. China is on the low end of the spectrum. Despite impressive, massive expansion of higher education systems in the 1980s, only 1.7 percent of China's young people are enrolled in universities.

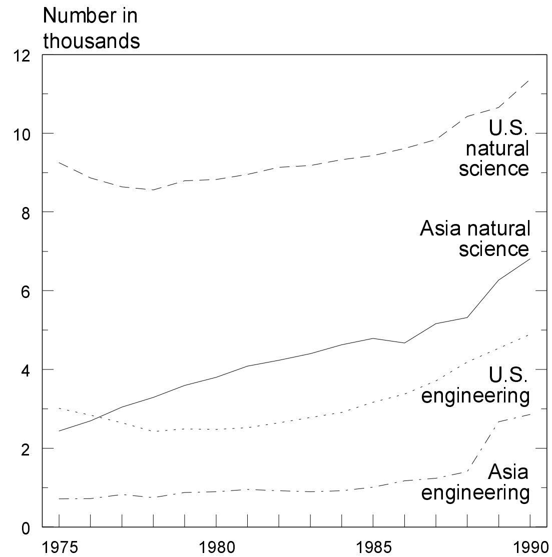
On the high end of the spectrum, South Korea tripled its enrollments from 1975 to the present and now has the highest proportion of its college-age group (36 percent) studying in universities. India, with a huge and growing population, maintained 5 percent of this age group in universities during this period. Taiwan increased from 16 to 27 percent; Japan from 24 to 29 percent. (See table A-2 on university enrollment ratios.)

Higher Education Degree Data

Over the 15-year period examined, these Asian countries together have increased their annual production of bachelor's degrees in natural sciences by 60 percent, and have tripled their annual production of engineering degrees (see figure 3). Asia's high annual number of degrees in natural sciences continues to rise as these countries attempt to go beyond "quality engineering" and low-cost production to design capability and "knowledge-based" innovative products and processes (Tufts University 1991). At the bachelor's level, the number of natural science degrees awarded in Asia is approximately equal to the number of engineering degrees. At the doctoral level, the number of natural science degrees is almost three times higher than the number of engineering degrees. This proportion is similar to that found in the United States and Europe; careers in natural science fields often require doctoral training.

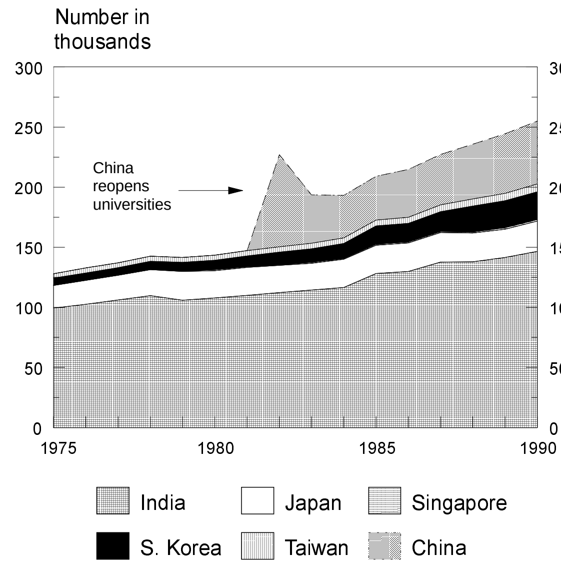
In the United States, the number of bachelor's degrees awarded in the natural sciences remained relatively stable from 1975 to 1983, grew to a peak in 1985–86, and has since declined steadily in absolute numbers. The number of natural science degrees awarded in the United States has consistently been double that of U.S. engineering degrees. At the doctorate level (see figure

Figure 4. Doctoral degrees in natural science and engineering in Asia and the U.S.: 1975-90



NOTES: Asian degree data include six countries: China, India, Japan, Singapore, South Korea, and Taiwan. See table A-7.

Figure 5. Bachelor's degrees in natural science in selected Asian countries: 1975-90



NOTES: Singapore is not visible because of relatively small number. See table A-3.

4), half of the U.S. degrees are awarded to foreign students. Within Asia, programs in China, South Korea, and Taiwan built up these countries' advanced degree capability and doctoral-level training in the 1980s. The jump in the number of doctoral degrees awarded in Asia in 1989 results from the inclusion of China in the Asia total in 1989, the first year for which doctoral degree data are available from China.

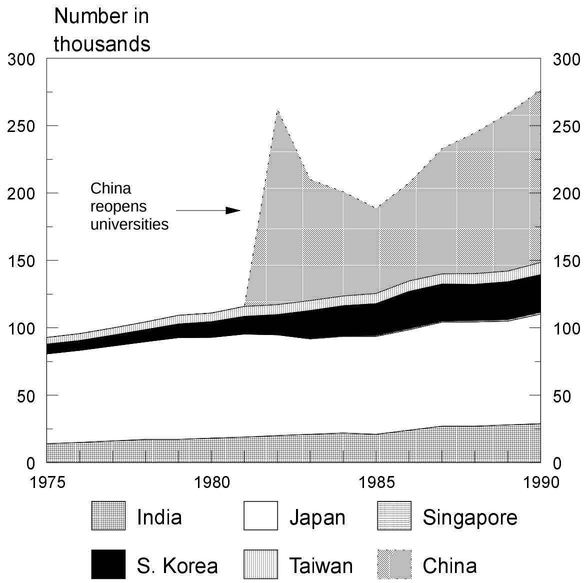
Degrees in the natural sciences in Asia. India accounts for well over 50 percent of the bachelor's degrees awarded in natural sciences in Asia, as seen in figure 5. The world's largest democracy, India is also the world's foremost educator of bachelor's- and doctoral-level natural scientists. India produced more bachelor's degrees in natural science fields than the United States in the early 1970s, and has again surpassed the United States in natural science degrees since 1987. India, with approximately 146,000 graduates in 1990, is followed at a distance by China, with 52,000 natural science graduates in 1990.

The pattern of Indian prominence in the natural sciences also occurs in advanced degrees (master's and doctorates) in Asian countries. India accounts for half of the 56,000 advanced degrees and for more than half of the 6,800 doctoral degrees in natural science in this region (see tables A-5 and A-7).

Degrees in engineering. All six Asian countries studied are increasing their production of engineering degrees, as shown in figure 6. China and Japan are and will be the main producers of bachelor's degrees in engineering for the region. China has the highest number, with 128,000 graduates in 1990.[7] Japan follows with 81,000 graduates.

[7] The very high number of engineering graduates in 1982 in the China data reflects the flood of older students completing degrees in reopened universities in the late 1970s. The number then settles down and steadily increases.

Figure 6. Bachelor's degrees in engineering in selected Asian countries: 1975-90



NOTES: Singapore is not visible because of relatively small number. See table A-3.

Rates of growth in production of engineering degrees differ widely across Asian countries. Japan has been producing approximately the same number of engineering graduates for more than 10 years, whereas China appears to be at the beginning of a growth curve. In South Korean universities, the growth in the number of engineering degrees has recently leveled off; for the past 3 years their engineering degrees have remained stable. Japan and South Korea may be already producing as many engineering graduates as possible given their declining college-age populations in the 1990s. They have 30 to 40 percent of their young people enrolled in universities and award 15 to 20 percent of all degrees in engineering. As with bachelor's degrees, China and Japan are the main producers of advanced degrees (master's and doctorates) in engineering (see tables A-5 and A-7).

Asian students in U.S. universities. The entire Asian region has dominated all other world regions in using the U.S. higher education and research infrastructure (Institute of International Education 1991a). The number of Asian students in U.S. universities has increased from 20,000 per year in 1975 to 200,000 per year in 1989–90. In 1980, 5 of the 10 leading countries of origin in foreign enrollment in U.S. institutions of higher education were Asian; by 1990, 9 of the top 10 were Asian.

Of all foreign students attending U.S. universities at the undergraduate level, 43 percent are Asian; at the graduate level, 65 percent are Asian. Of the 33,000 Chinese students enrolled in U.S. universities in 1989–90, a large majority were enrolled in graduate programs. Similarly, the majority of Indian, South Korean, and Taiwanese students in the United States were enrolled in graduate studies, as shown in table 4. A very large percentage of these Asian students are studying science and engineering in U.S. universities: 96 percent of Taiwanese students and 93 percent of Indian students were in S&E fields in 1989–90.

Japan and Singapore send their students to U.S. colleges and universities mainly at the undergraduate level. Of the 30,000 Japanese students attending U.S. universities in 1989–90, 62 percent were enrolled in undergraduate programs and more than half were in non-S&E fields. Students from other Asian countries, such as Hong Kong, Malaysia, and Indonesia, also study in the United States, mainly at the undergraduate level.

The U.S. higher education institutions are a significant source for doctoral education of Asian students. For individual countries the figures vary substantially, as shown in table 5 and figure 7. Doctoral degrees received from other Asian countries, and from Canada and Europe, would raise the total number of degrees for these countries.

As shown, the majority of Taiwan's doctoral degrees are from the United States. About one-half of South Korea's and one-third of China's are from U.S. universities. Japan obtains only a small fraction of doctoral degrees in the United States (National Science Foundation 1991, table 6), as shown in figure 7.

Foreign graduate students' enrollment in U.S. universities has increased the concentration of U.S.

Table 4. Asian students in U.S. universities in natural science and engineering, by level: 1989–90 and 1990–91

Country	Number of students 1989–90	Number of students 1990–91	Percentage under-graduate	Percentage graduate	Percentage natural science	Percentage engineering
China	33,390	39,600	12.9	82.7	44.0	20.1
India	26,240	28,860	21.1	75.5	40.9	52.5
Japan	29,840	36,610	61.7	19.5	31.0	14.0
Singapore	4,440	4,500	73.2	25.0	35.0	52.0
S. Korea	21,710	23,360	24.1	69.7	45.4	35.6
Taiwan	30,960	33,530	19.0	76.3	51.0	45.0

SOURCES: Institute of International Education 1990, 1991a

NOTES: Percentages by level and field are estimated from Institute of International Education 1990. The percentages of undergraduate and graduate students do not add to 100; balance have research appointments. The percentage of natural science and engineering fields do not add to 100; the balance are in non-S&E fields.

Table 5. Doctoral degrees in natural science and engineering awarded domestically and in the U.S. for selected Asian countries: 1990

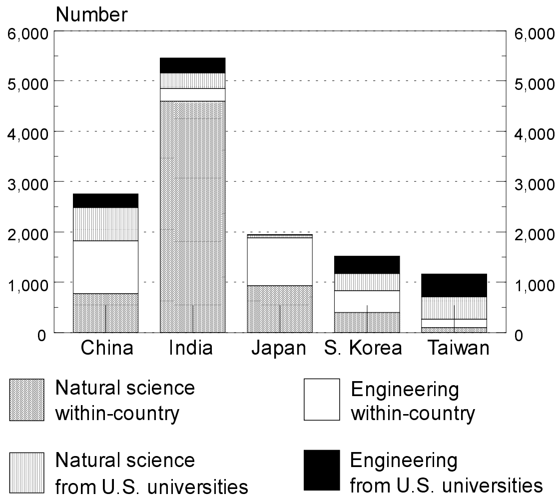
Countries	Within-country		U.S. universities	
	Natural science	Engineering	Natural science	Engineering
China	772	1,054	660 (46.1%)	280 (21.0%)
India	4,600	250	311 (6.3%)	301 (54.6%)
Japan	937	948	56 (5.6%)	17 (1.8%)
S. Korea	399	439	343 (46.2%)	350 (44.4%)
Taiwan	104	165	446 (81.1%)	460 (73.6%)

SOURCES: See table A-7; National Science Foundation 1991.

NOTE: Figures in parentheses are U.S. doctoral awards as a percentage of the country's total doctoral degrees in that field.

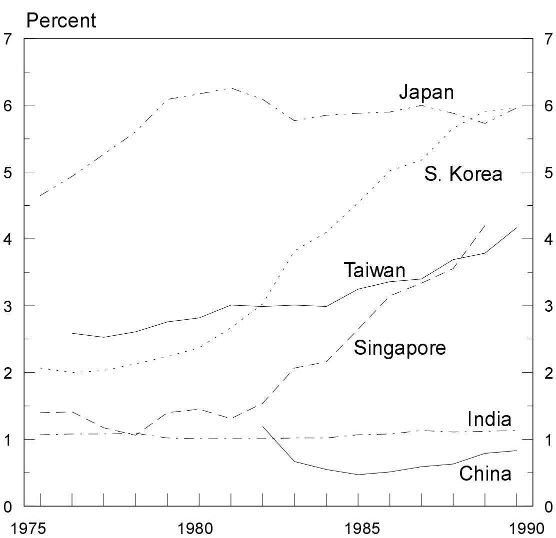
doctoral degrees in natural science and engineering. Between 1975 and 1990, the ratio of NS&E doctoral degrees to total doctoral degrees in the United States increased from 35 to 45 percent.

Figure 7. Natural science and engineering doctoral degrees awarded domestically and in the U.S. for selected Asian countries: 1990



NOTE: See table A-7.

Figure 8. Percentage of Asian 22-year-olds holding natural science and engineering bachelor's degrees in selected Asian countries: 1975-90



NOTE: See table A-13.

Participation Rates in NS&E Degrees at the Bachelor's Level

Most Asian countries except Japan increased the percentage of 22-year-olds receiving NS&E degrees between 1975 and 1990, as shown in figure 8. After increasing in the 1970s and 1980s, Japan's high percentage of 22-year-olds obtaining NS&E degrees (6 percent) has fallen slightly since 1987 as both preferences for education in natural science and engineering and the college-age population declined (Myers 1992). South Korea dramatically increased its NS&E degrees from 2 to 6 percent of its 22-year-olds since 1975. Taiwan increased its NS&E degree awards from 2 to 4 percent of its 22-year-old population over the last decade. China and India, with their huge populations, are maintaining their participation rates of 0.8 percent and 1.1 percent, respectively. If China and India continue to maintain these rates, the world stock of science and engineering graduates will be greatly augmented. (See table A-13 on participation rates in NS&E degrees.)

Ratio of science and engineering degrees to total degrees. Asian universities award a higher proportion of their degrees in fields of natural science and engineering than do U.S. or European universities: between 25 and 55 percent, as shown in figure 9.

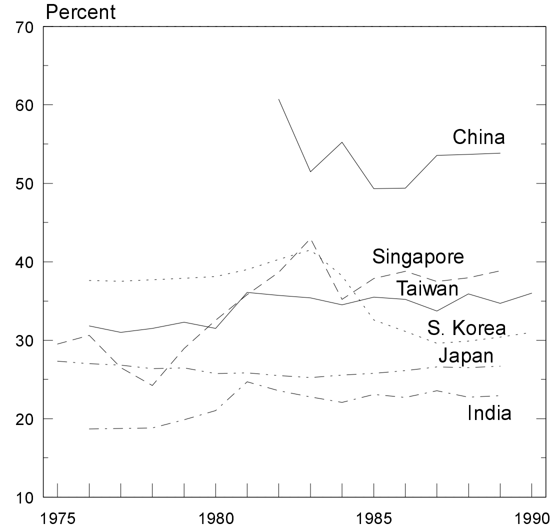
Asian countries (except India) especially favor engineering. Forty percent of all China's university degrees are given in engineering fields (see figure 10). India has a different pattern than the other five Asian countries. India has very large numbers of natural science degrees and a high ratio of natural science degrees to total degrees; however, there is not an equal emphasis on engineering. The ratio of engineering degrees to total degrees is the lowest in Asia. India's pattern is the reverse of Japan's, which has more than 20 percent of its degrees in engineering, but relatively few people studying basic sciences. (See table A-12.) When social science degrees are included, Japan has the highest proportion of S&E degrees in the Asian region; close to 66 percent of its university degrees are given in natural science, engineering, or social science.

Demographic changes. In the 1990s there will be decreases in the absolute numbers in the college-age population in the highly industrialized countries of the United States, Western Europe, and Japan. In Japan, the number of 18-year-olds will decrease by one-half million between 1992 and 2000. Government policy is to attract older adults and foreign students to Japanese universities. Japan has a "tenfold-increase policy" for foreign students and is projecting an enrollment of 100,000 foreign students by the beginning of the 21st century (Government of Japan, Science and Technology Agency 1991b, p. 16). (See also tables A-14 and A-19 to see the slow growth of Japan's population and labor force in the 1990s. See table A-15 to see the decline in the number of 20- to 24-year-olds in Japan from 10 million to 8.5 million between 1995 and 2000.)

However, among developing Asian countries, the college-age population of India will continue to increase and will surpass that of China after the year 2002, as shown in figure 11. In the year 2000, China is expected to have 95 million people in the 20- to 24-year-old group; India will have 89 million. For comparison purposes, in the year 2000, Japan will have 8.5 million people in the college-age population, South Korea will have 3.9 million, and Taiwan will have 1.9 million. Western European countries will have between 3 and 4 million people in their college-age populations, and the United States will have around 19 million (Bos, Vu, and Levin 1992).

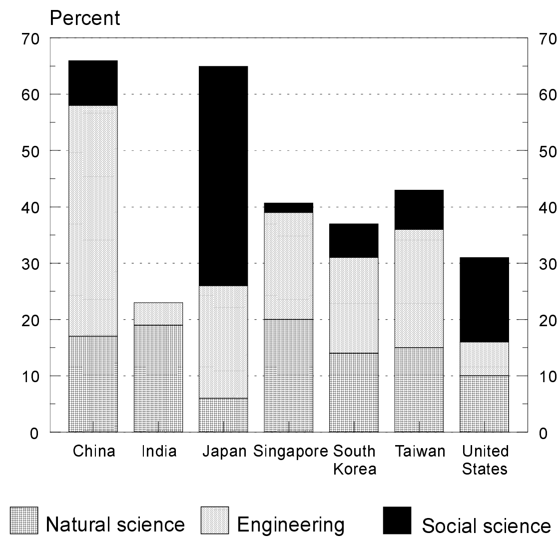
Can India and China develop these vast potential human resources for science? It will be an extremely difficult task because only a small percentage of their populations now obtain science degrees. These countries are, at great sacrifice, expanding university education and stressing science and engineering. Will they be able to employ all the S&E graduates? The next sections will describe Asian R&D investment and GDP. An attempt will be made to show relationships among these science and economic indicators in section 7, Prospects for the Future.

Figure 9. Ratio of natural science and engineering degrees to total bachelor's degrees in selected Asian countries: 1975-90



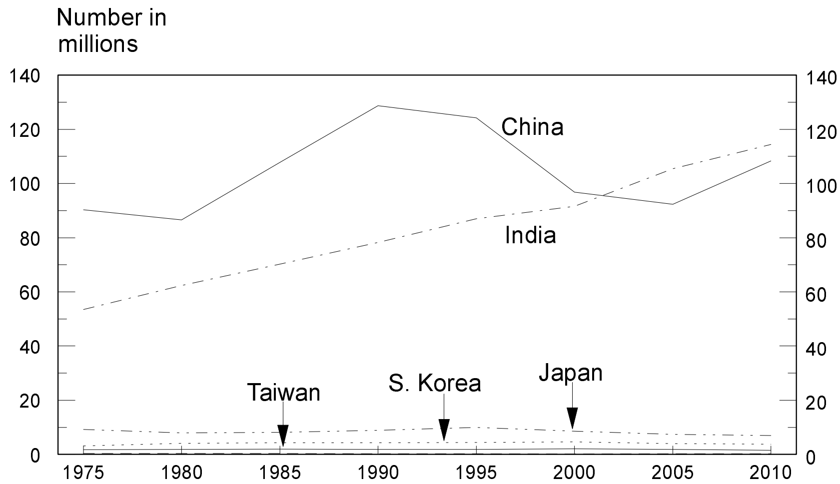
NOTE: See table A-12.

Figure 10. Ratio of S&E degrees to total bachelor's degrees in selected Asian countries and the U.S.: 1990



NOTES: India does not report social sciences. See table A-12.

Figure 11. Number of 20- to 24-year-olds in selected Asian countries: 1975-2010 (projected)



NOTE: See table A-15.

Research and Development Expenditures

In 1990, the combined R&D expenditures of the six Asian countries studied were approximately $91 billion in 1987 constant purchasing power parity dollars ($PPPs). (Throughout this report, dollar amounts will be in 1987 constant $PPPs.) Asian R&D amounted to 1.5 percent of the countries' combined GDP. In the same year, the U.S. total R&D was $130 billion, as shown in figure 12, amounting to 2.65 percent of the national GDP.

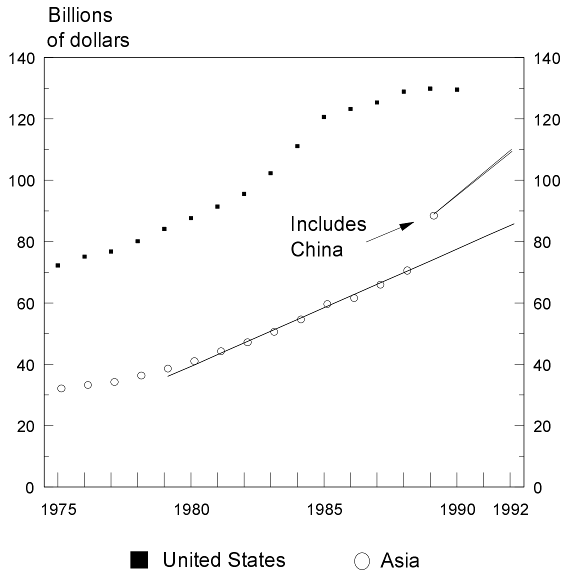
National R&D surveys and reporting, from which these data are derived, are well developed in most of the six Asian countries, but are just being organized in China.[8] Japan, Taiwan, and South Korea have been conducting national R&D surveys for decades. India has been conducting R&D surveys and reporting biennially since the early 1970s. Singapore has conducted biennial national R&D surveys for the past 10 years.

The R&D spending in five Asian countries was combined to arrive at a regional total for each year between 1975 and 1989. Only China was excluded from the total Asian R&D because data from China, with a consistent definition of R&D, exist for only 1 year. The growth rate of the combined R&D spending was approximately 9 percent between 1975 and 1989. Estimations to 1992 use this 9 percent growth rate.

To estimate Chinese R&D spending to 1992, a low growth of 2.5 percent and a high growth of 6 percent were assumed. With the past 9 percent growth in the region, and China's high and low estimates for R&D spending added, the overall Asian R&D budget estimate for 1992 is $110 billion, as shown in figure 12. In 1990, the United States had 1.4 times the overall R&D investment as the six Asian countries combined, but with a lower growth rate than Asian countries. The U.S. growth rate (net after inflation)

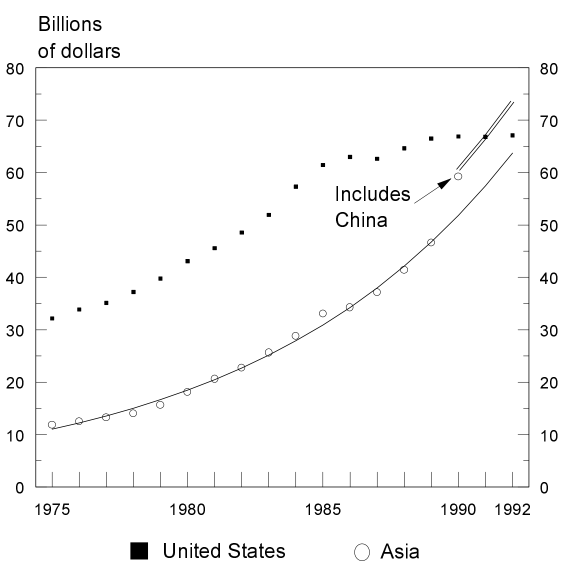
[8] China is also just developing its science and technology (S&T) indicators capability. Although R&D data exist for several years, S&T indicators staff in the State Science and Technology Commission caution that uniform definitions for R&D have only been in place since 1990.

Figure 12. R&D in selected Asian countries and the U.S.: 1975-92



NOTE: Data are estimated for 1991 and 1992. See table A-16.

Figure 13. Industrially funded R&D in selected Asian countries and the U.S.: 1975-92



NOTE: Data are estimated for 1991 and 1992. See table A-17.

over the last 6-year period has been approximately 1.1 percent.

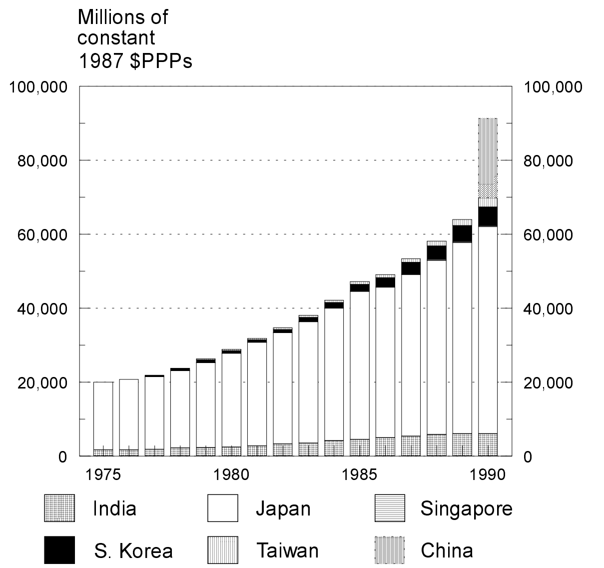
These Asian countries' nondefense R&D in 1990 is uncertain. Only Japan and India publish figures on their military R&D budget. Japan's defense R&D is 1 percent of the total; India's defense R&D has been between 15 and 20 percent. Taiwan and South Korea do not include defense research in their R&D reporting; Singapore and China include defense R&D in their 1990 R&D reporting, but do not specify the percentages. More refined R&D data are required to compare civilian research budgets.

Industrially Funded R&D

In 1990, U.S. private industries funded more R&D than the industries of the six Asian countries combined. However, industrially funded R&D in the six Asian countries is growing faster than their overall R&D, and is estimated to reach approximately $73 billion in 1992, slightly more than the $67 billion in the United States, as shown in figure 13. The U.S. growth rate in this area has slowed to 1.5 percent over the last 6 years, down from 7 percent during the period 1975 to 1985.

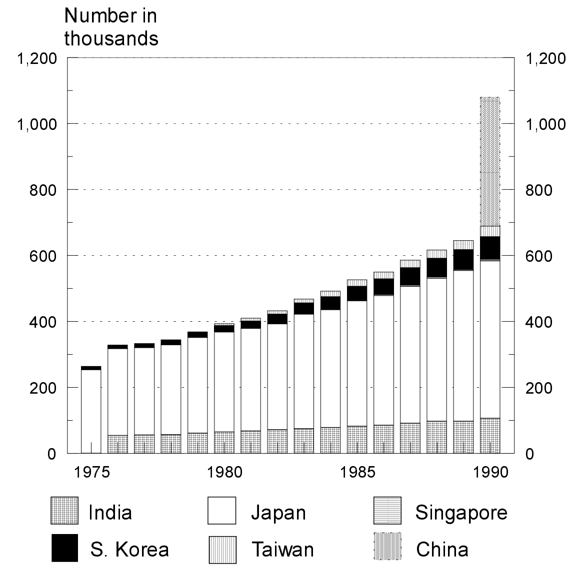
According to one recent analysis, all Asian countries in proximity to Japan that now assemble products for labor-short Japan would like to increase their R&D and hence the technological sophistication of their own products. Singapore, Taiwan, and South Korea, as well as other Association of Southeast Asian Nations (ASEAN) countries, are establishing science parks to strengthen indigenous R&D, attract foreign high technology firms, and allow shared research facilities between industries and universities. South Korea, Taiwan, Singapore, and Hong Kong are particularly interested in joint ventures with the United States and multinationals that include technology transfer (Institute of Electrical and Electronics Engineers, Inc. (IEEE) 1991).

Figure 14. R&D expenditures in selected Asian countries: 1975-90



NOTES: Only data for 1990 were available for China. Singapore is not visible because of relatively small number. See table A-16.

Figure 15. Scientists and engineers in R&D in selected Asian countries: 1975-90



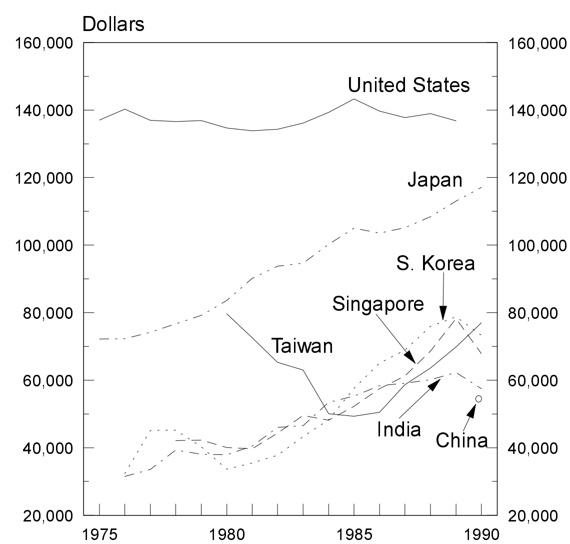
NOTES: Only data for 1990 were available for China. Singapore is not visible because of relatively small number. See table A-19.

Science and Engineering Personnel

The combined sum of R&D expenditures of the six Asian countries has more than quadrupled over the period 1975 to 1990 (see figure 14), and the number of S&E personnel in R&D has followed the same growth curve (see figure 15). In 1990, with China data included, research scientists and engineers numbered more than 1 million, comparable to the numbers of research scientists and engineers in the United States.

R&D expenditure per research scientist and engineer (RSE) is an indication of the level of support and quality of the science infrastructure available to research scientists and engineers. Figure 16 shows the trends in support of science during the last 15 years. All of the Asian countries studied have reached more than $50,000 per research scientist and engineer; Japan is approaching $120,000.

Figure 16. R&D expenditures per research scientist and engineering in selected Asian countries and the U.S.: 1975-90



NOTES: Only data for 1990 were available for China. See table A-20.

Gross Domestic Product

The six Asian countries studied have had the fastest growing economies in the world in the last 15 years. Figure 17 shows the growth in gross domestic product (GDP) for each country in $PPPs. (GDP using official exchange rates would be far lower for China and India.[9]) As shown in figure 18, in 1975 the U.S. GDP was somewhat larger than that of the six Asian countries combined. Between 1975 and 1992, however, the positions reversed, and the combined GDP of the six Pacific Rim countries is now somewhat larger than that of the United States.

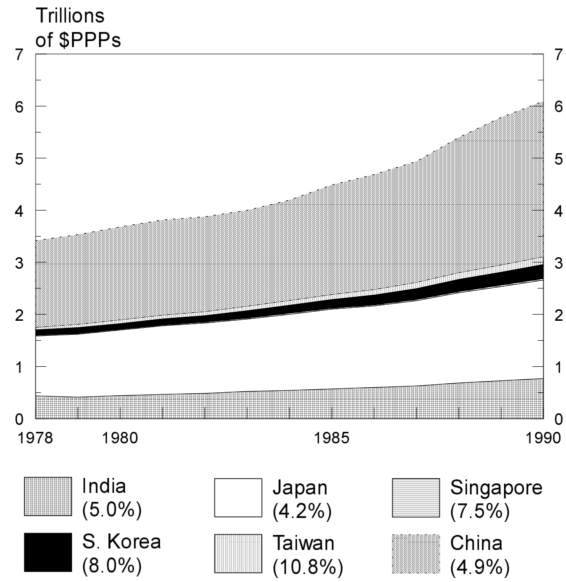
Related S&E Indicators

The overall economic performance of a country appears to be related to several S&T indicators. The percent of GDP invested in R&D (see table 6) correlates with related indicators of support for S&E personnel. The Asian countries studied fall into three groupings in their standard of living and support for R&D personnel. China and India have the lowest GDP per capita, the lowest percent of GDP in R&D, the lowest number of S&E personnel per 10,000 of the population, and the lowest R&D investment per research scientist and engineer.

Singapore, Taiwan, and South Korea form a midrange in these indicators. Japan has the highest GDP per capita and support for S&E personnel, approaching that of the United States.

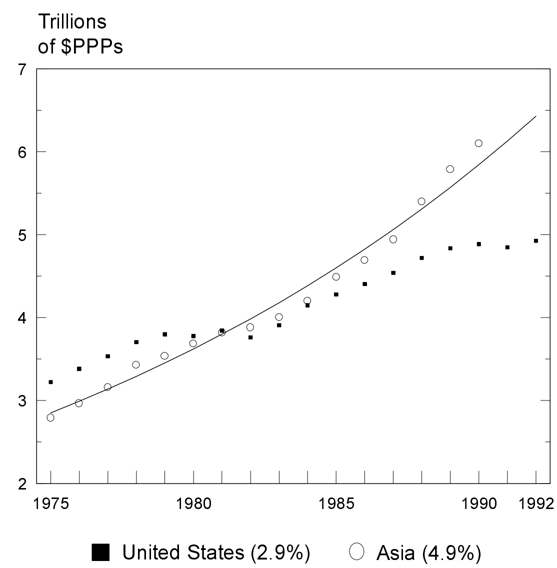
9 For a discussion of this difference in China, see Survey of China 1992.

Figure 17. Growth in GDP in selected Asian countries: 1978-90



NOTE: See table A-22.

Figure 18. Growth in GDP in selected Asian countries and the U.S.: 1975-92



NOTES: Data are estimated for 1991 and 1992. See table A-22.

Table 6. Support for R&D and S&E personnel by level of per capita GDP in selected Asian countries and the U.S.: 1990

Country	Per capita GDP ($PPPs) [1]	R&D as a percentage of GDP	S&E personnel in R&D	S&E personnel in R&D per 10,000 of labor force	R&D expenditures per scientist and engineer ($PPPs)
United States	19,600	2.7	949,000[2]	75.6 [2]	136,800[2]
Japan	15,296	2.9	477,866	74.9	117,068
Singapore	10,850	0.9	4,298	30.4	67,855
Taiwan	7,193	1.7	32,145	38.2	77,032
South Korea	6,342	1.9	68,831	37.2	73,297
China	2,636	.7	391,100	5.6	54,884
India	907	.8	106,000	3.3	57,465

(1) $PPPs = purchasing power parity dollars
(2) U.S. data are for 1989, the latest year for which data were available.

SOURCES: Computed, tables A-19 and A-22