# Summary of Proceedings

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## Introduction

As the world's countries recast themselves as "knowledge-based" economies and build up "national innovation systems,"[1] interest in doctoral education—particularly in science and engineering (S&E)—is increasing around the globe, occasioning a reexamination of its aims and structure. Reforms in doctoral programs in Asia, Europe, and North and South America (the Americas) are aimed at similar concerns:

- strengthening and expanding doctoral education;
- making doctoral training relevant to a wider range of occupations than just academic careers; and
- educating highly qualified professionals who can address problems in the context of broader social, economic, and environmental issues.

In order to increase understanding of developments in selected countries in various regions, the Division of Science Resources Studies of the National Science Foundation (NSF) commissioned a number of papers and, on November 17, 1998, held a workshop at NSF headquarters. A number of interested persons from within the NSF, as well as other organizations, attended the workshop to hear brief presentations by the authors and to discuss some of the issues raised.

The papers are presented in the following Proceedings. This introduction attempts to provide a context for understanding recent reforms in doctoral education in an international perspective and to summarize differences in reform strategies among countries in three world regions. Insofar as the issues are relevant and data available, the authors of the workshop papers attempted to address these issues and enlarge on the topics in discussing graduate reform in their own countries. The introduction concludes with a summary of highlights concerning several topics that dominated discussions that occurred during the workshop.

## Comparison of Scale of Doctoral Programs

By broad world region,[2] Western Europe leads the Americas and Asia in number of earned S&E doctoral degrees. In 1997, doctoral degrees awarded in S&E fields by Western European institutions totaled more than 40,000—about one-fifth higher than the number of such degrees earned in the American region and twice as many as the number recorded for Asian countries. (See text table 1 and appendix table 1.)

Western Europe accounts for 50 percent of the three regions' total production of doctoral degrees in the natural sciences and 38 percent of the doctoral degrees in engineering. The America region awards less than a third

**Text table 1. Doctoral S&E degrees awarded in three selected regions: 1997 or most recent year**

| Field | Three region total | | Asia | | Western Europe | | The Americas | |
|---|---|---|---|---|---|---|---|---|
| | Number | Percent | Number | Percent | Number | Percent | Number | Percent |
| Doctoral degrees, all fields | 159,235 | 100.0 | 35,219 | 22.1 | 73,306 | 46.0 | 50,710 | 31.8 |
| Science and engineering | 90,577 | 100.0 | 18,513 | 20.4 | 40,454 | 44.7 | 31,610 | 34.9 |
| Natural sciences | 50,867 | 100.0 | 9,505 | 18.7 | 25,476 | 50.1 | 15,886 | 31.2 |
| Social sciences | 15,417 | 100.0 | 1,029 | 6.7 | 5,718 | 37.1 | 8,670 | 56.2 |
| Engineering | 24,293 | 100.0 | 7,979 | 32.8 | 9,260 | 38.1 | 7,054 | 29.0 |

**NOTES:** Natural sciences here include physical, biological, earth, atmospheric, oceanographic, agricultural, mathematical and computer sciences. Europe includes only Western Europe. Regional totals include selected countries for which recent data are available. See appendix table 1 for countries included in each region.

**SOURCES:** See appendix table 1.

[1] See, for example, recent journal articles on economic development through science and technology by a member of the German Parliament (Merkel 1998), by the French Minister of Education, Research and Technology (AllÀgre 1998), and by the Chinese State Science and Technology Commission (*Nature* 1998).

[2] This discussion of international comparisons presents data in terms of three world regions—Asia, Western Europe, and the Americas. The specific countries comprising these regions are listed in appendix table 1.

of such degrees in both the natural sciences and engineering; the Asia region awards almost one-fifth of the natural science doctorates and one-third of the engineering doctorates.

# Trends in Graduate Programs

## Doctoral Degree Production

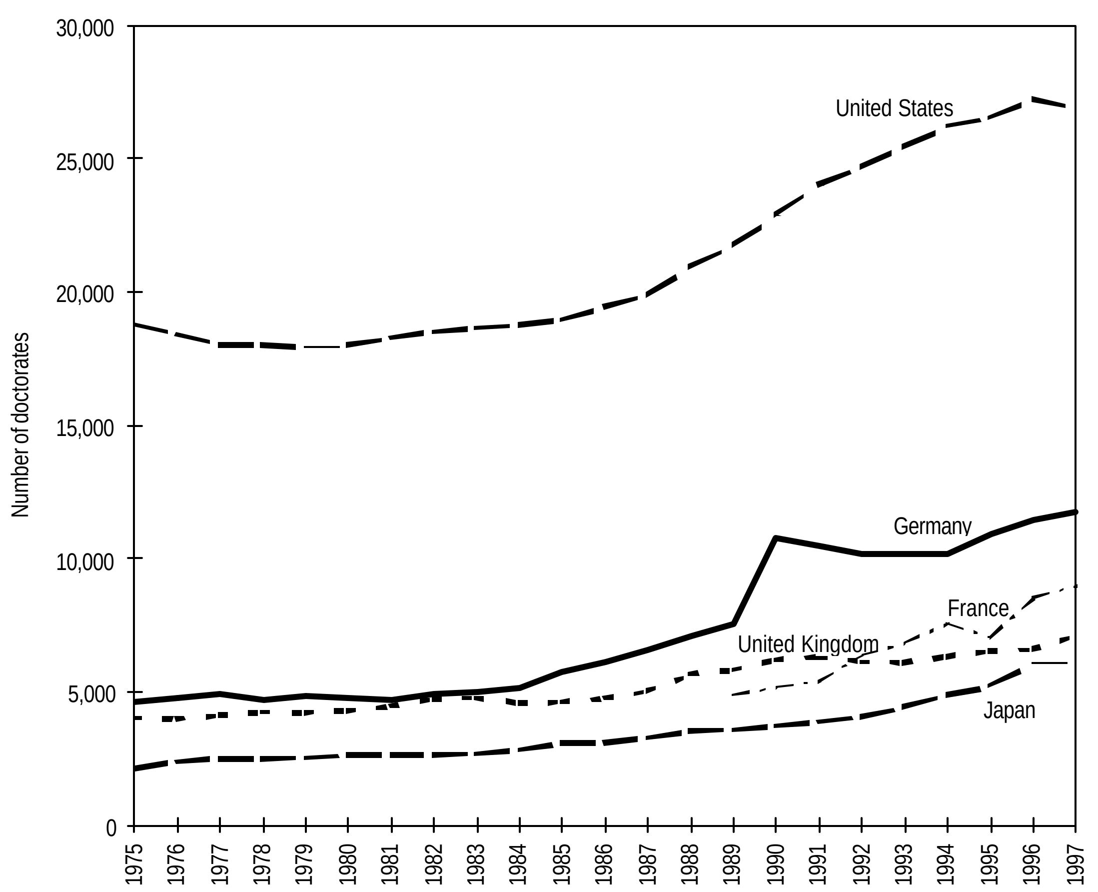
By individual country, the United States leads in the number of doctoral degrees earned in S&E fields. In 1997, U.S. universities awarded about 27,000 S&E doctoral degrees—more than twice the number of S&E degrees awarded in any of the other major industrial countries. (See figure 1.)

However, foreign students account for about 34 percent of the S&E doctoral degrees earned within U.S. universities. Asian students comprise the majority of U.S. foreign doctoral recipients in S&E. (See figure 2.)

S&E doctoral degrees in the former West Germany grew faster than overall doctoral degrees between 1975 and 1995. The number of natural science degrees increased 5.1 percent annually, engineering increased 4.8 percent annually, and overall degrees increased 3.4 percent annually during this 20-year period. (See appendix table 2.) France undertook a reform of doctoral studies in 1988 in an effort to double the number and improve the quality of S&E doctoral degrees awarded within 8 years. The effort has largely succeeded: the number of S&E Ph.D. degrees awarded increased from 5,000 in 1989 to 9,000 in 1996—nearly a-75 percent increase (Government of France 1996).

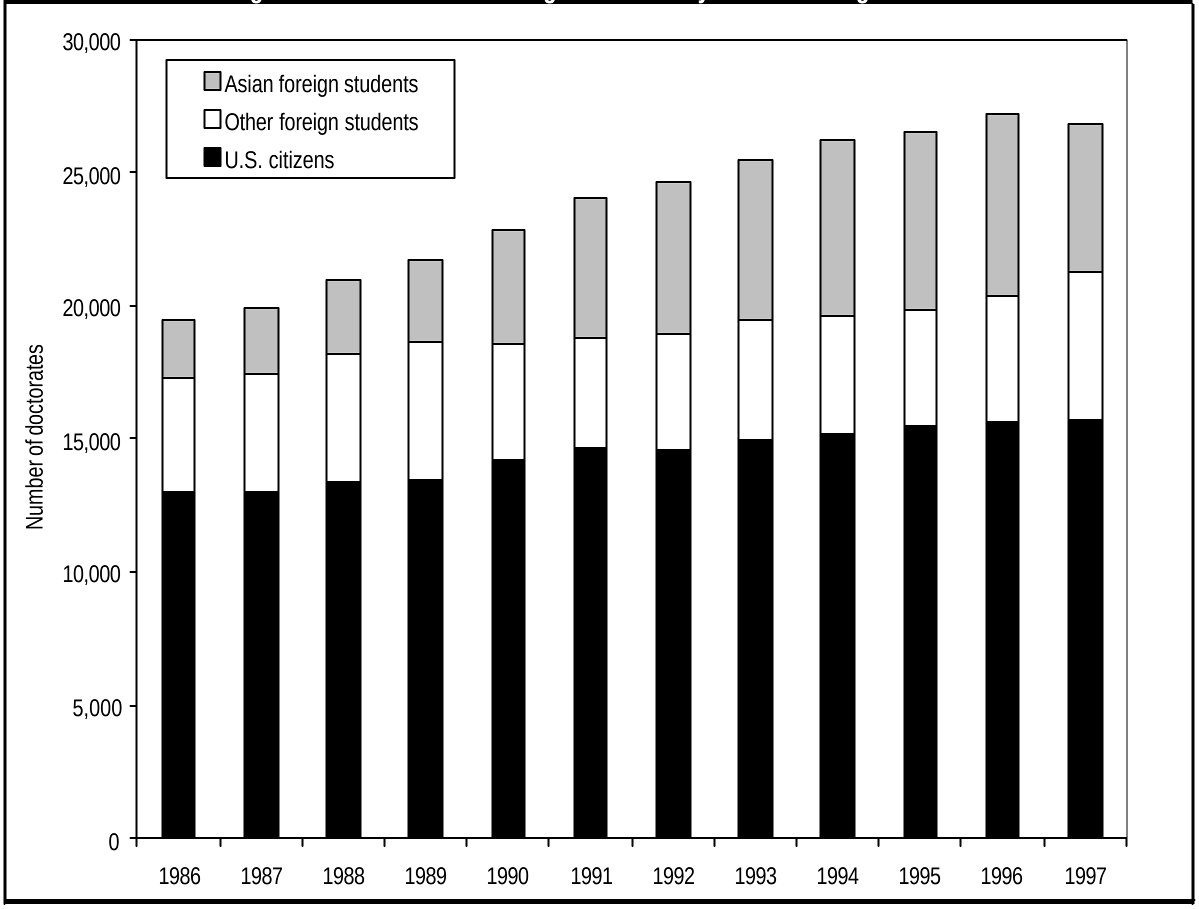
The scale of graduate education in Japan has been small by international standards. Until recently, most doctorates in the natural sciences and engineering in Japan were earned by industrial researchers after many years of research within Japanese companies. Doctoral reforms of 1989 called for the expansion and strengthening of graduate schools and the establishment of a new type of university exclusively for graduate study. The country's

**Figure 1. Doctoral S&E degrees in selected countries**




**SOURCE:** See appendix tables 2 and 3.

Figure 2. U.S. S&E doctoral degrees earned by U.S. and foreign citizens




**SOURCE:** See appendix table 4.

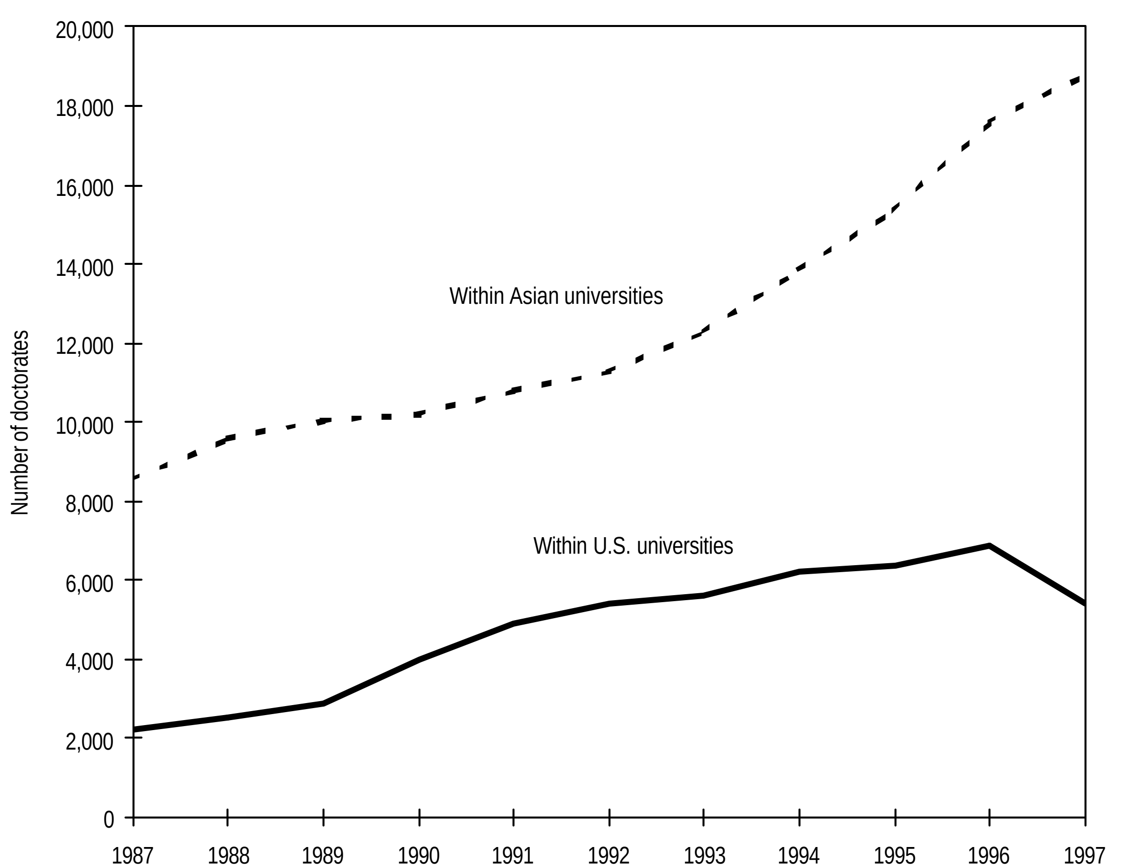
Ministry of Education began increasing support to universities to improve facilities and greatly accelerate doctoral programs in natural science and engineering fields. In 1994, Japanese engineers earned more doctoral degrees for research within university laboratories than within industrial research laboratories—53 and 47 percent respectively (NSF 1997).

Asian graduate education reforms are also strengthening and expanding doctoral programs in China, Taiwan, and South Korea. Thus, some Asian countries are becoming less dependent on U.S. universities for advanced training in S&E. In 1997, S&E doctoral degrees earned within major Asian countries (China, India, Japan, Korea, and Taiwan) reached over 18,000, representing a-12 percent average annual increase from 1993-97. In contrast, such degrees earned by Asian students within U.S. universities peaked at 6,500 in 1996, (representing less than a-5 percent average annual growth rate from 1993-96), and declined in 1997. (See figure 3.)

China has invested heavily in graduate education to "embrace the era of knowledge economy"(*Nature* 1998). While the number of S&E doctoral degrees earned by Chinese students within U.S. universities showed a decade-long increase until 1996, the number of such degrees earned within Chinese universities continues to increase, and at a faster rate. (See figure 4.) By 1997, Chinese students earned more than twice as many S&E doctorates within Chinese universities as within U.S. universities.

Other Asian countries are also increasing their capacity in providing S&E graduate education. In the 1980s, the Korean Advanced Institute of Science and Technology was established to increase support for postgraduate training within the country. More recently, the industrial giant, Pohang Iron and Steel Corporation established Pohang University of Science and Technology, much as early U.S. industrialists founded institutions such as Stanford and Carnegie-Mellon. Korean universities

**Figure 3. S&E doctoral degrees earned by Asian students within Asian and U.S. universities**




**SOURCE:** See appendix table 5.

awarded almost 2,200 doctoral degrees in S&E in 1997, up from 945 such degrees in 1990. (See figure 5 and appendix table 3.)

## Trends in Academic R&D

Since doctoral degree production is closely tied to university research, trends in research and development (R&D) performed in universities are important to consider. A trend of increasing budgets for university research has continued for two decades across these three regions, paralleling the expansion of graduate S&E education. Throughout the 1980s, university-performed research in North America and Western Europe increased at an average annual rate of over 5 percent; university-performed research in Asian countries grew more slowly, at 3.8 percent annually. This trend has recently been reversed, however. In the 1990s, university-performed research is growing faster in Asia (6.3-percent average annual increase) than in Western Europe (3.7 percent) and North America (3.3 percent). (See figure 6.)

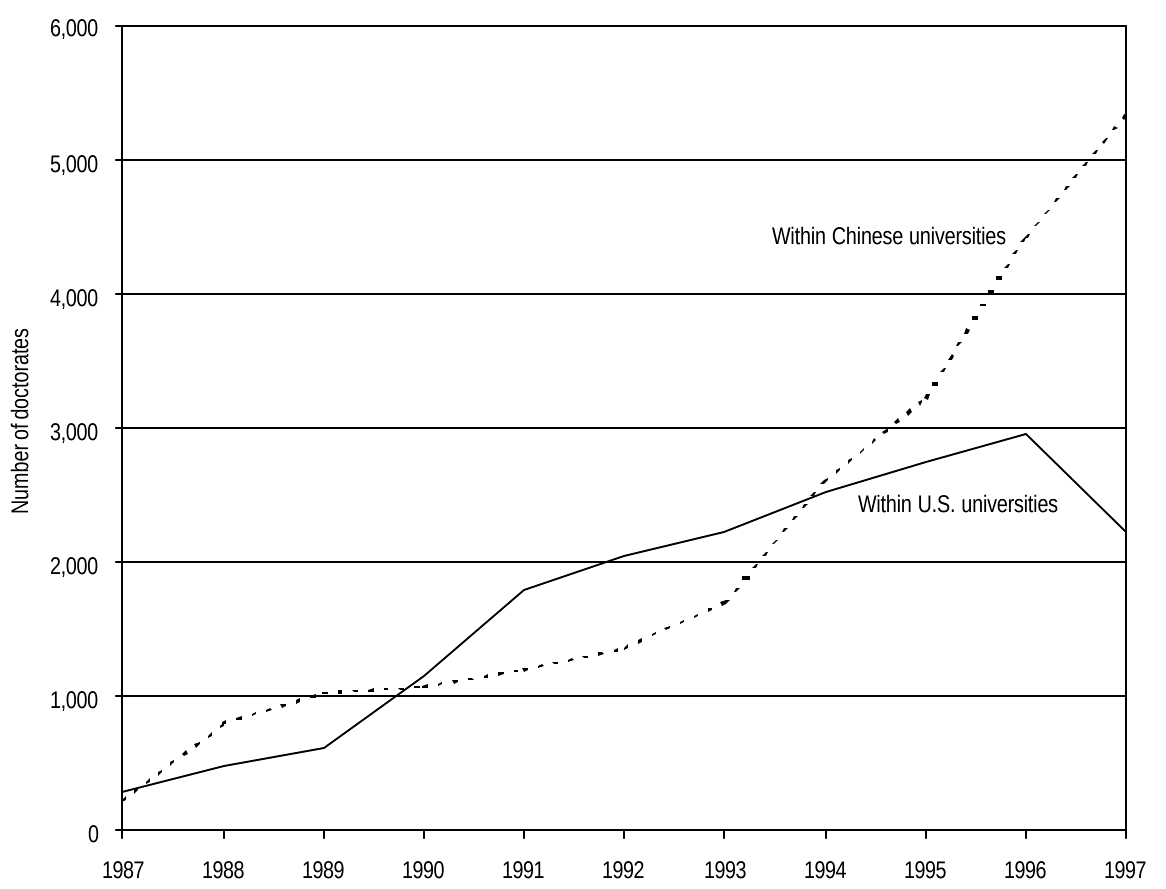
## Forces for Change

Forces for graduate education expansion and reform include demographic, economic, technological, and social changes. These forces are altering the nature of—and the very students who enroll in—graduate programs; they mandate cross-disciplinary knowledge.

### Demographic

Recruitment pools for graduate education are rising from the so-called "massification" (i.e., the enlargement of the proportion of the population that undertake a university degree) of bachelor-level programs in industrialized countries. Across Europe, participation rates of the college-age cohort in first university degrees have more than doubled in the last 20 years, from 7 to 17 percent. Japan has over a quarter of its young people completing bachelor degrees, and the United States about one-third. In addition, in the United States, improvement in K-12 programs and undergraduate programs are increasing the graduate recruitment pools for women and minorities.

Figure 4. S&E doctoral degrees earned by Chinese students within Chinese and U.S. universities




**SOURCE:** See appendix table 6.

## Economic

Several economic forces are influencing change in graduate education. The cost of education, increasing faster than the cost of living, requires collaboration between and among research centers. Among economic forces for reform in the United States and Europe are the pressures from national and state funding sources to produce graduate students who will contribute to economic development. Asian countries—given their conviction that economic growth is dependent on science and technology (S&T) knowledge and its connection to production—are accelerating their within-country capacity to educate scientists and engineers at the doctoral level.

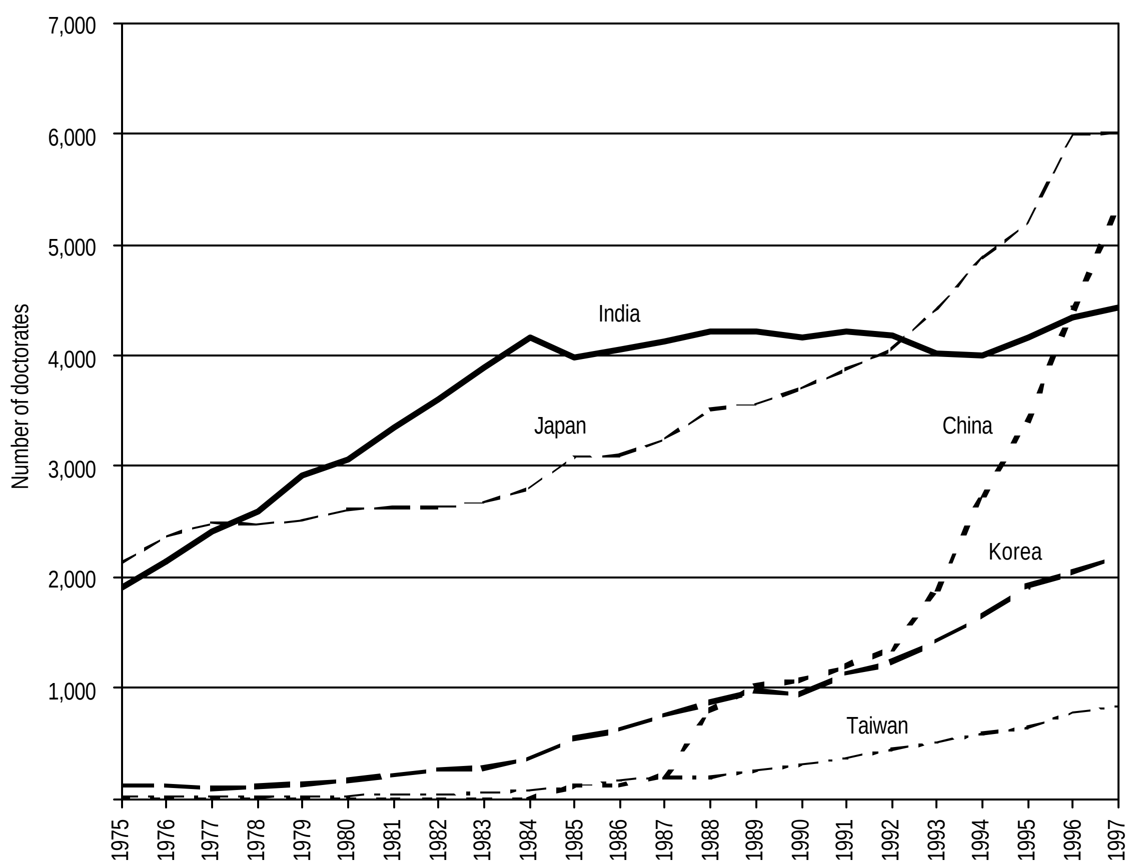
## Technological

The pace of technological change is diminishing the life-span, the so-called industrial half-life, of products. Traditional industrial R&D for incremental improvement of products and processes (a particularly strong suit of Japanese industrial labs) are rendered ineffective by breakthrough innovations creating new commercial products. As current products become obsolete more quickly, industries are motivated to partner with graduate research programs that augment their innovation capacity. New inventions are increasingly linked to public science (conducted in universities and national laboratories), and industry is increasing its investment in basic research performed in universities.

## Social

The growing demand for public accountability of academic institutions is forcing a reexamination of the balance between faculty research and teaching, and the role of graduate students as research assistants. Students are demanding career information and broader skills for non-academic employment.

**Figure 5. Doctoral S&E degrees in selected Asian countries**




**SOURCE:** See appendix table 3.

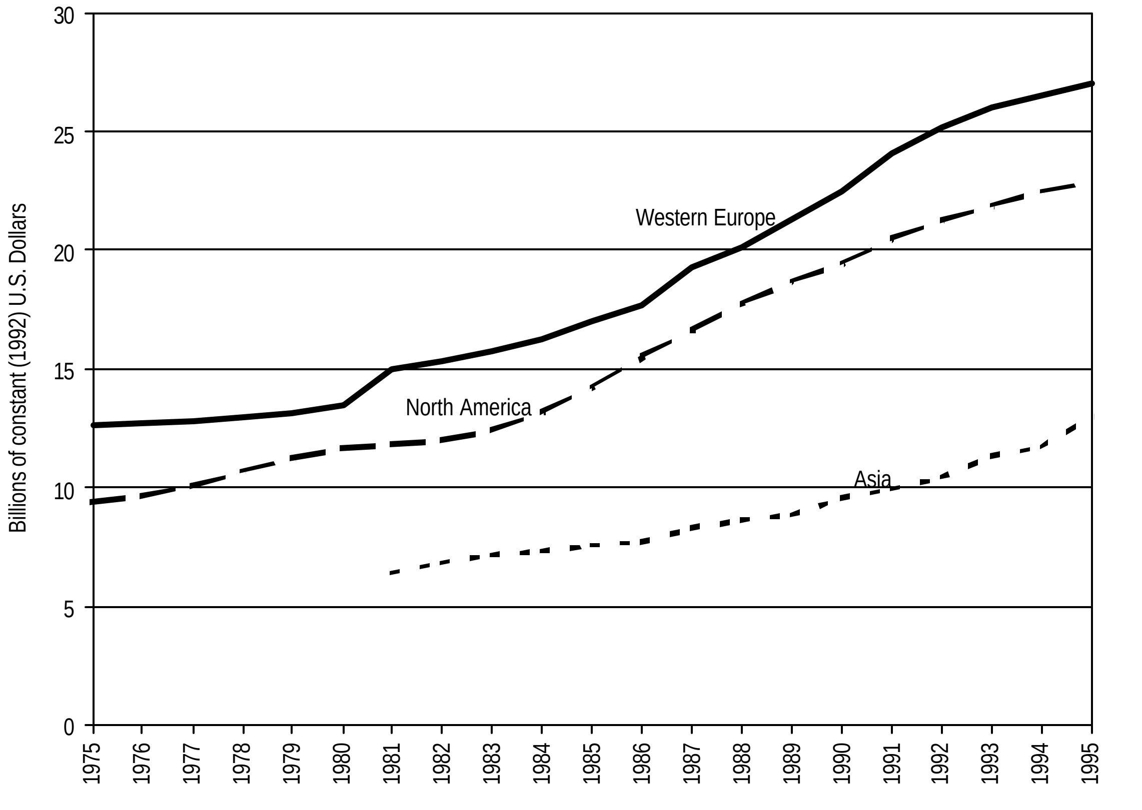
## Different Emphases in Reforms Across Countries

These underlying forces for change, while ubiquitous across regions, show different emphases and reform strategies in different countries. Reforms being discussed naturally differ according to the scale and maturity of graduate programs, and often reflect stages of economic development within different countries and regions. Several Latin American and Asian developing countries are attempting to expand and strengthen their modest graduate programs to increase the percentage of faculty in higher education with doctoral training. The United States and European countries, with large graduate programs and excellent university research capacity, are mainly focused on broadening the training of graduate students for careers outside academia.

### Latin America

Within Latin America, countries such as Mexico, Chile, and Argentina have only recently begun to expand the scale of their doctoral programs. (Brazil greatly expanded the scale of its graduate programs in the 1980s to foster graduate S&T programs as an essential instrument for knowledge creation and dissemination.) These developing Latin American countries are motivated by a desire to have more of their university faculty trained at the doctoral level. For example, within Mexico, about 80 percent of the higher education faculty have only the first university degree (*licenciatura*). Government policies in Mexico are particularly aimed at upgrading the qualifications of the teaching staff in the *licenciaturas*, and thereby improving the quality of the *licenciatura* degree.

Figure 6. R&D performed in universities, by region




**SOURCE:** See appendix table 8.

## Europe and the United States

The criticism by industry of traditional graduate programs as too long, too narrow, and too campus-centered is particularly expressed in the United States, France, and Germany. With the expansion of graduate education and an ever-greater percentage of students who enter careers outside academia, the larger labor market is demanding broader training. For example, Germany is discussing shortening time to degree and orienting doctoral recipients to industrial research, since doctoral recipients are considered too old to begin working in industry. Full preparation of scientists and engineers in Germany requires about 20 years of higher education (including a 7-year first-university degree, a 10-year doctoral program, and a 3-year *habilitation*: experience in independently running a research lab).

Within these advanced industrialized countries, discussions of reform call for doctoral training (previously focused on specialized research) to be broadened in a variety of ways. These include doctoral programs providing off-campus internships, opportunities for interdisciplinary research experience, teaching and mentoring skills, complementary course work, and awareness of changing career opportunities and emerging employment categories. In addition, higher education institutions within the European Union are promoting transnational cooperation in graduate education. For example, Nordic countries are experimenting with a "European Ph.D." in which one-year of doctoral research will be conducted in another Nordic country.

Reforms discussed in advanced countries also relate to lessening time-to-degree, and to restraining costs from public funding sources of enlarged graduate programs. In European countries, with centralized systems of higher education and government financial support to graduate students, shortening time to degree is required to cut costs, although high unemployment rates (10-14 percent) encourage long graduate programs. Within the United States, lessening time to degree is discussed more in terms of institutional accountability: students should not be kept for years within an overspecialized doctoral program because of their value as a research assistant to their major professor.

## Asian Countries

Within Asian developing countries, as in Brazil, reforms are motivated by the belief that universities could be the engines of economic growth through research and innovation leading to high technology products. Reforms are focused on establishing quality graduate schools, building university facilities and research infrastructure, and acquiring highly trained S&E professors, either at home or abroad. This effort at expansion of graduate education is more accelerated in Asia than in Latin America, and involves the building of whole new science and technology universities. In now Chinese Hong Kong and in South Korea, the establishment of S&T universities has been supported by private industry. Chinese research universities are expanding through more self-support from close alliances with, or ownership of, high-technology industries, and through international loans. In Japan, the government is funding the upgrading of graduate programs.

Among advanced countries, Japan's current reform efforts are unique. Japan had previously evolved a close match between graduate education and industry; industry for the most part trained its own doctorate-level researchers. Japan is now concerned that such industrially-formed scientists and engineers are not contributing breakthrough research for new and emerging industries. With a long-run recession in Japan, competitive pressures domestically and internationally demand that R&D funding build up the national capacity for breakthrough research and innovation. Japan is convinced that industries of the 21st century will require within-country innovation capacity. As part of its efforts to support future innovation through basic science, Japan is greatly expanding and reforming graduate education within its universities. The doubling of the government budget for science will go mainly to universities to improve the environment for basic research. Japan is greatly augmenting fellowships and traineeships for graduate students, and funding top level foreign researchers to come to Japanese universities to upgrade basic research.

# Workshop Discussion Highlights

## Involvement of graduate education with industry

The relationships being developed between universities and industry were a major topic of discussion during the workshop. The degree to which these relationships represent ties to graduate education varies among different countries and levels of economic development and depends partly upon the degree to which graduate education is tied into university-based research as well. In China, for example, ties are developing between factories and both university- and Science Academy-based education and research. There are few countries that are not grappling with some aspect of the problem, but, while this is a reflection of the force of increasing technological complexity in the industrial sector, there are many contrasting trends.

Particularly in developing countries, many have little tradition of industry involvement in research at all. This may limit the degree to which the country's firms see the need to hire individuals with advanced degrees, as well as representing a barrier to interaction with university-based research. Chile and South Korea were cited as examples, but such industrialized countries as France and Japan share the problem. Countries such as Brazil are seeking to encourage increased interaction with mechanisms such as tax incentives and shared support for research projects. Thus, in some countries, industry does not represent a significant stimulus for the reform or expansion of graduate education in science and engineering and the major spur comes from government or international programs, such as support from international development banks.

Overall, however, the trend is one of growing interest on the part of the industrial sector. As efforts to develop knowledge-based economies and an increasingly high tech industrial base are pursued, the market for technically trained people with advanced degrees increases. Growing numbers of such graduates are going into industry in countries such as China and Taiwan. In Germany, ways of reshaping graduate education to serve industry's needs more adequately has been a major subject of debate and research. Particularly in the case of doctoral degrees, the German educational system takes so long that graduates are generally too old to be easily recruited and assimilated by industry. In other countries, such as Japan and Brazil, industry's growing interest in graduate education takes the form of increasing support for university-based research. Changing education practices in Japan that places greater emphasis on course-based doctoral degrees as opposed to career-based degrees means that such support is increasingly related to graduate education.

In addition to various incentives for cooperation, as noted above, a number of countries have introduced special programs aimed at strengthening the links between universities and industry. Sweden, for example, where nearly all government supported research is performed in universities, has established special research companies attached to universities and introduced special postgraduate programs for industry. Chalmers University, Sweden's most technologically oriented institution, has, in fact, been privatized.

The development of ties between industry and university- or Science Academy-based education is not a smooth process. One of the most important and widespread problems is the matter of intellectual property rights distribution. It is particularly a source of debate in Europe, where industry claims a relational equality that is not apparent to other observers. There are also tensions concerning the setting of research agendas—especially between the industrial interest in applied research and the basic research interests of the universities. The cultural differences between research institutions and industry represent a serious barrier and limitation on the rapidity with which such ties can be developed.

Within countries, the situations may vary from field to field. Thus, for certain disciplines there is a strong tradition of producing trained people for the private sector—e.g., the biological sciences in Argentina; the information technology (IT) industry in India; and engineering in Japan. There can be a downside of imbalanced industrial demand for employees with graduate degrees, however. A voracious appetite on the part of certain industries for particular specialties may result in the concentration of the most talented students in a select number of narrow fields and deprive other industries their needs for enhanced human resources.

The desire to foster partnerships and produce graduates that are more oriented toward and have an education more suitable for careers in industry provides a very mixed picture. It was an ubiquitous theme in the papers and workshop discussion. A variety of experimental mechanisms are being tried, some of which are based on U.S. models. Both China and Sweden, for example, have established systems modeled on NSF's Engineering Research Centers Program. The program supports topically focused interdisciplinary research centers at U.S. universities for up to 11 years with block (as opposed to project) funding, specifically to enhance U.S. competitiveness in each Center's field, with the requirement of industrial involvement and co-support. Many countries are pushing universities and other research institutions—which may be involved in graduate education—to become more engaged with and derive greater financial support from industry. France's perceived surplus of degrees is pushing toward development of courses more oriented to the "real world." Europe, in general, is grappling with the fact that more than half of graduate degree S&Es will not go into academic careers. Most efforts involving the interaction between graduate education and industry are experimental, in the early stages of development, small in number and in scale, and their ultimate impact cannot be assessed at this time.

## INVESTMENTS BEING MADE IN GRADUATE EDUCATION

There were not a great deal of quantitative time-series data concerning trends in the financing of graduate education available for the workshop papers, although rising enrollments in most countries implies increased investment. Like the involvement of industry with graduate education, there were a number of common themes concerning the funding of graduate education. However, countries have devised such a variety of methods to meet their individual challenges in this area that it is difficult to discern any pattern. Depending upon a country's constitutional structure, there are variations in the patterns of national, regional or local, industrial, and self-support for graduate education. The rising cost of research-based education and the impact of the enlarging pool of university graduates resulting from "massification" that seek access to graduate degrees has placed particular stress on government support of education. Consequently, the most common theme is the effort to reduce the burden on public funding, whether by cutting government support for graduate education—especially in terms of individual scholarships, imposing student fees and tuition, or seeking industrial support. In the more developed countries, "massification" is probably the most widespread motive for governments to seek reductions in the cost of education, but countries such as Argentina are also grappling with its implications.

There is also a widespread trend toward greater selectivity and relevance to economic development. Factories are contributing to both academy and university efforts in China. Japan has made university funding more competitive and selective. Chile is trying to make public support more mission-oriented and contract-based. Most of the European countries, beginning with Britain, have undertaken efforts to make research and graduate training more relevant to socio-economic objectives. In the European Union (EU), there is an interest in more structural financial input on part of industry. There are limits to what various agencies can do, however. In France, for example, the fact that about 30 percent of graduate students are self-funded limits the government's ability to deal with what is perceived to be excess production of graduate degrees. In recent years, Mexico has gone through periods of expanding and contracting programs due to varying perceptions of the market for advanced degrees.

Overall, the trend in funding of graduate S&E education appears to be upward. Especially in developing countries, such as Argentina, Chile, Brazil, China, and South Korea, but in Japan as well, government investment is increasing, although not necessarily in the same forms. In Argentina, for example, there has been an increase in the number of fellowships available for graduate work from a variety of new programs, but a decrease in the number from the traditional CONICET source.

In other countries, too, the mix of funding is shifting. In China, more funds are going to the universities than to academy-based education. Japan's increasing investment in graduate education includes substantial emphasis on the support of basic research in the universities and there is a strong initiative for the selective allocation of resources. In Chile and Argentina, there has been a growth in the number of private universities, which means an increased number of self-supported, tuition paying students. Although public funding is increasing, the proportion of public funding appears to be decreasing, with a growth in industrial support representing the primary countervailing factor. The impact of this should not be exaggerated, however—non-governmental funding of graduate education remains a small part of the picture overall.

Internationally, the changing economics of graduate education is evident through the interest of international organizations. The OECD is funding a study examining the costs per student versus the cost of research. The World Bank is increasingly involved in supporting programs that do not just support, but try to reform higher education in countries such as Chile, Brazil, China, and Thailand. Other regional development banks in Latin America, Africa, and Asia are becoming increasingly involved in efforts to reform higher education and promote R&D.

Investment in human resources in higher education raises other important issues. The increase of private institutions in countries like Chile and Argentina, as well as a number of other developing countries, generally means an increase in institutions staffed by faculty lacking advanced degrees. On the one hand, developing countries typically are in the position of needing to channel new graduate degrees into their higher education systems in order to raise faculty credentials, often hampered by the need to wait for current faculty to retire. At the same time, many private universities face neither legal nor economic incentives to provide a large proportion of faculty with graduate degrees. Demand for more advanced training creates a highly profitable market in Chile for the so-called "postitulu" programs—so financially profitable that they can attract faculty away from traditional graduate education programs. These "postitulo" programs refer to professional education for jobs such as engineer, teacher, or lawyer.

## MOBILITY

The mobility of trained scientists and engineers is a topic of great interest on which data are quite limited. Host countries often have good information concerning the foreign students to whom degrees were granted, as was shown in several of the papers, but the whereabouts of nationals studying abroad is limited. Even countries where support for study abroad is concentrated in the hands of the central government do not know how many privately supported students are abroad, much less where. Even U.S. data, which is quite good on foreign students in the United States, provide but limited information on U.S. students abroad.

Perspectives within individual countries derive primarily from two factors—whether the country is advanced or developing, and whether the direction of flow represents a "brain drain" or a "brain gain." The direction of flow is usually from the developing to the more advanced countries. In France, however, an excess of graduate degrees and lack of post-doctoral support for French nationals (it is concentrated on foreign candidates) as a temporary holding position results in a brain drain, much of it to the United States. On the other hand, Taiwan and South Korea have achieved notable success in reversing the flow and attracting their nationals back home.

The flow from developing countries is usually due to a lack of opportunities at home. Few jobs for individuals with advanced degrees may be available, and those that exist represent poor financial rewards and inferior working conditions and facilities. In some countries, domestic training is viewed as a means of escape from these. The paper on India notes that many students select their field of study based on those that offer the best opportunities of finding opportunities to study and then work abroad. (One countervailing factor can be that success abroad affords the opportunity to return home for family or other reasons with a financial cushion.) With an undergraduate degree in a marketable field, foreign graduate training becomes attractive and often leads to job opportunities in the country involved. U.S. universities are particularly attractive, and students benefit from opportunities in both the academic and industrial sectors upon receiving their advanced degree.

Programs intended to attract S&E nationals home abound. In Taiwan, efforts such as the establishment of technology parks have been rewarded and the return rate can be documented, and Korea has had similar success. In many cases, the return represents an opportunity afforded by a multinational corporation seeking a bilingual individual to manage a local manufacturing facility or laboratory. China has provided special positions—some provided with extra funding from the provincial or local government—intended to induce expatriate S&Es to return or to recruit foreign faculty, and Taiwan is particularly open to the recruitment of foreign faculty. Colombia is attempting to identify its expatriate community and keep members in touch with their homebound counterparts in a network that does not necessarily aim at bringing them home. One anecdote quoted a high Chinese official as being unconcerned about the number of overseas S&Es: modern transportation would make it easy enough for them to return when China developed the jobs for them, and globalization would eventually make the issue moot!

It was suggested that there might be some sort of metric involved in bringing about the turn-around from drain to gain. Although it may be necessary that some particular level of per capita GDP be achieved for this, incentive programs, political factors, and other factors were seen as entering into the equation. The role of small and medium enterprises (SMEs) in the economy, their recognition (or lack thereof) of the need for employees with advanced training, and ability to attract the venture capital to hire them and initiate projects using their talents, was considered a potentially important aspect of a country's ability to reverse brain drains—both from developing and advanced countries. SMEs represent a large potential market for graduate trainees, if the financial and cultural climates are accommodating.

Most developing countries recognize the need for extensive graduate training abroad and provide fellowships, loans, or other subsidies to assist their nationals in achieving this. Some countries, such as China and Malaysia, attach stringent conditions and obligations to such funds, although their success at enforcing requirements is less than complete. Latin American countries appear to take a more laissez-faire approach in providing funds for overseas support and, since the decline of authoritarian government in the region, seem to be gaining increased rates of return, although no quantitative data were presented at the workshop to document this.

A relatively recent phenomenon in international mobility relates to globalization of the economy and to European integration. In Asia, efforts to attract foreign students are being made by China, Hong Kong, and Taiwan. Spain is increasingly attractive as a place for Latin Americans to do graduate study. Within Europe, the Nordic countries have established an initiative with some 6,000 grants that support study within another Nordic country as a required part of an advanced degree, a program intended to promote their regional identity and have education deal with regional problems.

The European Union (EU) has become influential in policies on higher education, largely to the extent of default by the national governments. Originally charged with providing Europe-wide standards for technical training and certification, EU proposals, such as one for a "European doctorate," have not been received with great enthusiasm, but such proposals do tend to lead to incremental changes. The European Commission's budget, especially for research, provides a certain amount of leverage, too. Several European graduate research centers have been established.

Finally, as the discussion above of the involvement of graduate education with industry implies, there are emerging patterns of mobility between graduate education and industry. This may take the form of increased recruitment of students with advanced degrees by industry, interactive modes such as seminars, personnel exchange, and cooperative research, and industrial involvement in various types of advisory mechanisms.

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# APPENDIX

## Appendix table 1. Earned doctoral degrees in science and engineering, by region/country: 1997 or most recent year

| Region/country | All doctoral degrees | All S&E doctoral degrees | Degree field: Natural sciences [a] | Math and computer sciences | Agriculture | Social sciences [b] | Engineering | Non S&E |
|---|---|---|---|---|---|---|---|---|
| Total, three world regions.............. | **159,239** | **90,577** | **38,367** | **6,048** | **6,176** | **15,417** | **24,239** | **68,658** |
| | | | | **Asia** | | | | |
| **Total...............................................** | 35,219 | 18,513 | 6,533 | 609 | 2,363 | 1,029 | 7,979 | 16,706 |
| China......................................... | 6,042 | 5,328 | 1,678 | 334 | 348 | 325 | 2,643 | 714 |
| India.......................................... | 9,070 | 4,000 | 2,950 | NA | 715 | NA | 335 | 5,070 |
| Japan [c]...................................... | 13,921 | 6,157 | 1,315 | NA | 1,043 | 388 | 3,411 | 7,764 |
| South Korea.............................. | 4,999 | 2,189 | 427 | 187 | 178 | 240 | 1,157 | 2,810 |
| Taiwan...................................... | 1,187 | 839 | 163 | 88 | 79 | 76 | 433 | 348 |
| | | | | **Western Europe** | | | | |
| **Total...............................................** | 73,306 | 40,454 | 19,953 | 3,248 | 2,275 | 5,718 | 9,260 | 32,852 |
| European Union......................... | 69,006 | 38,167 | 18,863 | 3,065 | 2,141 | 5,337 | 8,761 | 30,839 |
| Austria.................................... | 2,144 | 1,184 | 316 | 139 | 245 | 137 | 347 | 960 |
| Belgium.................................. | 602 | 373 | 191 | 19 | 66 | NA | 97 | 229 |
| Denmark................................ | 365 | 177 | 103 | 0 | 34 | 10 | 30 | 188 |
| Finland................................... | 1,422 | 598 | 168 | 74 | 54 | 118 | 184 | 824 |
| France.................................... | 11,073 | 8,962 | 4,394 | 869 | 207 | 1,629 | 1,863 | 2,111 |
| Germany................................. | 24,174 | 11,728 | 6,418 | 785 | 521 | 1,775 | 2,229 | 12,446 |
| Greece................................... | 932 | 367 | 128 | 44 | 36 | 66 | 93 | 565 |
| Ireland.................................... | 423 | 307 | 234 | 13 | 14 | 10 | 36 | 116 |
| Italy......................................... | 3,463 | 1,643 | 770 | 22 | 156 | 85 | 610 | 1,820 |
| The Netherlands.................... | 5,014 | 1,567 | 594 | 0 | 311 | 261 | 401 | 3,447 |
| Spain...................................... | 5,852 | 2,550 | 1,449 | 331 | 107 | 249 | 414 | 3,302 |
| Sweden................................... | 2,549 | 1,580 | 473 | 204 | 102 | 181 | 620 | 969 |
| United Kingdom..................... | 10,993 | 7,131 | 3,625 | 565 | 288 | 816 | 1,837 | 3,862 |
| European Free Trade Assoc...... | 4,300 | 2,287 | 1,090 | 183 | 134 | 381 | 499 | 2,013 |
| Norway.................................. | 643 | 425 | 145 | 32 | 32 | 88 | 128 | 218 |
| Switzerland............................ | 3,657 | 1,862 | 945 | 151 | 102 | 293 | 371 | 1,795 |
| | | | | **The Americas** | | | | |
| **Total...............................................** | 50,710 | 31,610 | 12,157 | 2,191 | 1,538 | 8,670 | 7,054 | 19,100 |
| North America............................ | 47,273 | 29,408 | 11,032 | 2,183 | 1,130 | 8,467 | 6,596 | 17,865 |
| Canada.................................. | 3,834 | 2,165 | 629 | 171 | 116 | 759 | 490 | 1,669 |
| Mexico................................... | 734 | 396 | 113 | 11 | 48 | 170 | 54 | 338 |
| United States......................... | 42,705 | 26,847 | 10,290 | 2,001 | 966 | 7,538 | 6,052 | 15,858 |
| South America........................... | 3,437 | 2,202 | 1,125 | 8 | 408 | 203 | 458 | 1,235 |
| Argentina............................... | 408 | 382 | 218 | 8 | 97 | 18 | 41 | 26 |
| Brazil...................................... | 2,972 | 1,775 | 862 | NA | 311 | 185 | 417 | 1,197 |
| Chile....................................... | 57 | 45 | 45 | NA | 0 | 0 | 0 | 12 |

[a] Natural sciences here include physical, earth, atmospheric, oceanographic, and biological sciences.

[b] Social sciences include psychology, sociology, and other social sciences.

[c] Japanese data include "thesis" doctorates called Ronbun Hakase, earned by employees in industry.

**KEY:** NA = not available

**NOTES:** Data are compiled from numerous national and international sources, and degree fields may not be strictly comparable. Data for Austria, Canada, China, Denmark, Finland, France, Germany, Ireland, Italy, Japan, the Netherlands, Norway, South Korea, Sweden, Taiwan, the United Kingdom and the United States are for 1997. Data for Argentina, Belgium, Brazil, Chile, Mexico, Spain and Switzerland are for 1996. Data for India and Greece are for 1994.

**SOURCES: ASIA: China**—National Research Center for Science and Technology for Development, unpublished tabulations; **India**—Department of Science and Technology, *Research and Development Statistics 1994-95* (New Delhi:1966); **Japan**—Ministry of Education, Science, and Culture (Monbusho), *Monbusho Survey of Education* (Tokyo: annual series); **South Korea**—Ministry of Education, *Statistical Yearbook of Education* (Seoul:1998); **Taiwan**— Ministry of Education, *Educational Statistics of the Republic of China: 1998* (Taipei:1998); **EUROPEAN UNION: Austria; Denmark; Finland; Ireland; Italy; Spain; The Netherlands; Switzerland**—OECD/CERI; **France**—Ministère de l'Éducation Nationale, de la Recherche et de la Technologie, *Rapport sur les Études Doctorales,* (Paris, 1998); **Germany**—Statistisches Bundesamt, *Prüfungen an Hochschulen* (Wiesbaden); **Greece**—National Statistica; (1997); **Sweden**—Statistics Sweden, unpublished tabulations (1997) and OECD/CERI; **United Kingdom**—Higher Education Statistical Agency, *Students in Higher Education Institutions, 97/98* (Cheltenham:1999); **EUROPEAN FREE TRADE ASSOCIATION: Norway**—Institute for Studies in Research and Higher Education, the Norwegian Research Council, unpublished tabulations (1997); **The Americas: Argentina**—Ministry of Education and Culture, unpublished tabulations, 1999; **Brazil**—Ministério da Educação e Cultura, Coordenação de Aperfeiçoamento de Pessoal de Nivel Superior (CAPES), Brasilia; **Canada**—tabulations from Association of Universities and Colleges of Canada, based on *Statistics Canada;* **Chile**—Consejo de Rectores Universidades Chilenas, unpublished tabulations; **Mexico**—Asociación Nacional de Universidades e Instituciones de Educación Superior, *Anuario Estadistico 1995 Posgrado* (Mexico:1996); and **United States**—National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards: 1997,* NSF 99-323 (Arlington, VA, 1999).

**Appendix table 2. Doctoral degrees in science and engineering in selected Western industrialized countries, by field: 1975-97**



| Country/degree field | 1975 | 1977 | 1979 | 1981 | 1983 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **France** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | NA | NA | NA | NA | NA | NA | NA | NA | NA | 5,963 | 6,782 | 7,198 | 8,585 | 9,295 | 10,602 | 9,801 | 10,963 | 11,073 |
| Total S&E | NA | NA | NA | NA | NA | NA | NA | NA | NA | 4,888 | 5,158 | 5,384 | 6,377 | 6,820 | 7,555 | 7,027 | 8,511 | 8,962 |
| Natural sciences | NA | NA | NA | NA | NA | NA | NA | NA | NA | 2,615 | 2,841 | 2,883 | 3,525 | 3,631 | 3,866 | 3,572 | 4,052 | 4,394 |
| Mathematics/computer sciences | NA | NA | NA | NA | NA | NA | NA | NA | NA | 722 | 795 | 831 | 976 | 1,065 | 1,203 | 1,129 | 1,241 | 869 |
| Agricultural sciences | NA | NA | NA | NA | NA | NA | NA | NA | NA | 37 | 53 | 38 | 38 | 52 | 94 | 84 | 194 | 207 |
| Social sciences | NA | NA | NA | NA | NA | NA | NA | NA | NA | 672 | 488 | 539 | 663 | 797 | 1,018 | 815 | 1,285 | 1,629 |
| Engineering | NA | NA | NA | NA | NA | NA | NA | NA | NA | 842 | 981 | 1,093 | 1,175 | 1,275 | 1,374 | 1,427 | 1,739 | 1,863 |
| Non-S&E | NA | NA | NA | NA | NA | NA | NA | NA | NA | 1,075 | 1,624 | 1,814 | 2,208 | 2,475 | 3,047 | 2,774 | 2,452 | 2,111 |
| **Germany** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 11,418 | 11,386 | 11,939 | 12,283 | 13,637 | 14,951 | 15,530 | 16,064 | 17,321 | 17,901 | 22,372 | 22,462 | 21,438 | 22,000 | 22,000 | 22,387 | 22,849 | 24,174 |
| Total S&E | 4,588 | 4,922 | 4,821 | 4,710 | 4,978 | 5,738 | 6,091 | 6,576 | 7,101 | 7,568 | 10,762 | 10,465 | 10,148 | 10,200 | 10,200 | 10,889 | 11,472 | 11,728 |
| Natural sciences | 2,238 | 2,443 | 2,380 | 2,444 | 2,404 | 2,986 | 3,184 | 3,440 | 3,844 | 4,095 | 5,319 | 5,326 | 5,638 | 5,700 | 5,700 | 5,868 | 6,078 | 6,418 |
| Mathematics/computer sciences | 242 | 294 | 273 | 213 | 274 | 274 | 278 | 294 | 332 | 383 | 429 | 418 | 464 | 500 | 500 | 663 | 810 | 785 |
| Agricultural sciences | 338 | 323 | 281 | 317 | 361 | 414 | 406 | 468 | 450 | 518 | 997 | 709 | 602 | 500 | 500 | 507 | 512 | 521 |
| Social sciences | 1,015 | 1,024 | 959 | 913 | 966 | 968 | 1,064 | 1,068 | 1,150 | 1,200 | 1,544 | 1,483 | 1,344 | 1,400 | 1,400 | 1,741 | 1,803 | 1,775 |
| Engineering | 755 | 838 | 928 | 823 | 973 | 1,096 | 1,159 | 1,306 | 1,325 | 1,372 | 2,473 | 2,529 | 2,100 | 2,100 | 2,100 | 2,110 | 2,269 | 2,229 |
| Non-S&E | 6,830 | 6,464 | 7,118 | 7,573 | 8,659 | 9,213 | 9,439 | 9,488 | 10,220 | 10,333 | 11,610 | 11,997 | 11,290 | 11,800 | 11,800 | 11,498 | 11,377 | 12,446 |
| **United Kingdom** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 5,341 | 5,331 | 5,700 | 5,983 | 6,528 | 6,208 | 6,492 | 6,835 | 7,588 | 7,845 | 8,242 | 8,387 | 8,396 | 8,717 | 9,000 | 9,761 | 9,974 | 10,993 |
| Total S&E | 4,023 | 4,115 | 4,222 | 4,463 | 4,759 | 4,608 | 4,759 | 5,016 | 5,663 | 5,816 | 6,207 | 6,302 | 6,112 | 6,098 | 6,325 | 6,512 | 6,583 | 7,131 |
| Natural sciences | 2,082 | 2,155 | 2,303 | 2,389 | 2,426 | 2,409 | 2,495 | 2,583 | 2,787 | 2,937 | 3,113 | 3,151 | 3,054 | 3,034 | 3,200 | 3,356 | 3,373 | 3,625 |
| Mathematics/computer sciences | 242 | 282 | 273 | 311 | 289 | 282 | 290 | 321 | 374 | 415 | 471 | 535 | 519 | 528 | 600 | 602 | 581 | 565 |
| Agricultural sciences | 209 | 208 | 185 | 195 | 183 | 159 | 260 | 192 | 244 | 238 | 241 | 248 | 279 | 275 | 325 | 351 | 299 | 288 |
| Social sciences | 431 | 513 | 495 | 541 | 663 | 687 | 686 | 732 | 899 | 878 | 916 | 914 | 935 | 739 | 700 | 646 | 674 | 816 |
| Engineering | 1,059 | 957 | 966 | 1,027 | 1,198 | 1,071 | 1,028 | 1,188 | 1,359 | 1,348 | 1,466 | 1,454 | 1,325 | 1,522 | 1,500 | 1,557 | 1,656 | 1,837 |
| Non-S&E | 1,318 | 1,216 | 1,478 | 1,520 | 1,769 | 1,600 | 1,733 | 1,819 | 1,925 | 2,029 | 2,035 | 2,085 | 2,284 | 2,619 | 2,675 | 3,249 | 3,391 | 3,862 |

See explanatory information and SOURCE at end of table.

**Appendix table 2. Doctoral degrees in science and engineering in selected Western industrialized countries, by field: 1975-97 (Continued)**



| Country/degree field | 1975 | 1977 | 1979 | 1981 | 1983 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **United States** | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 32,952 | 31,716 | 31,239 | 31,356 | 31,282 | 31,298 | 31,899 | 32,367 | 33,499 | 34,324 | 36,068 | 37,517 | 38,853 | 39,754 | 41,011 | 41,743 | 42,415 | 42,705 |
| Total S&E | 18,799 | 18,008 | 17,872 | 18,257 | 18,635 | 18,935 | 19,437 | 19,894 | 20,932 | 21,731 | 22,868 | 24,023 | 24,675 | 25,443 | 26,205 | 26,535 | 27,230 | 26,847 |
| Natural sciences | 8,103 | 7,676 | 7,817 | 7,995 | 8,195 | 7,326 | 7,486 | 7,679 | 8,157 | 8,099 | 8,589 | 9,086 | 9,372 | 9,562 | 9,996 | 9,997 | 10,355 | 10,290 |
| Mathematics/computer sciences | 1,147 | 964 | 979 | 960 | 987 | 998 | 1,128 | 1,190 | 1,264 | 1,471 | 1,597 | 1,839 | 1,927 | 2,024 | 2,022 | 2,188 | 2,043 | 2,001 |
| Agricultural sciences | 905 | 782 | 855 | 982 | 1,015 | 1,111 | 998 | 977 | 1,015 | 1,086 | 1,176 | 1,074 | 1,063 | 969 | 1,078 | 1,036 | 1,037 | 966 |
| Social sciences | 6,538 | 6,720 | 6,582 | 6,774 | 6,672 | 6,335 | 6,450 | 6,337 | 6,310 | 6,532 | 6,614 | 6,806 | 6,873 | 7,190 | 7,289 | 7,307 | 7,490 | 7,538 |
| Engineering | 3,011 | 2,648 | 2,494 | 2,528 | 2,781 | 3,166 | 3,376 | 3,712 | 4,187 | 4,543 | 4,894 | 5,215 | 5,439 | 5,696 | 5,822 | 6,008 | 6,305 | 6,052 |
| Non-S&E | 14,153 | 13,708 | 13,367 | 13,099 | 12,647 | 12,363 | 12,462 | 12,473 | 12,567 | 12,593 | 13,200 | 13,494 | 14,178 | 14,311 | 14,806 | 15,208 | 15,185 | 15,858 |
| | **Summary, S&E doctoral degrees, by country** | | | | | | | | | | | | | | | | | |
| Total S&E Ph.D. degrees | NA | NA | NA | NA | NA | NA | NA | NA | NA | 40,003 | 44,995 | 46,174 | 47,312 | 48,561 | 50,285 | 50,963 | 53,796 | 54,668 |
| France | NA | NA | NA | NA | NA | NA | NA | NA | NA | 4,888 | 5,158 | 5,384 | 6,377 | 6,820 | 7,555 | 7,027 | 8,511 | 8,962 |
| Germany | 4,588 | 4,922 | 4,821 | 4,710 | 4,978 | 5,738 | 6,091 | 6,576 | 7,101 | 7,568 | 10,762 | 10,465 | 10,148 | 10,200 | 10,200 | 10,889 | 11,472 | 11,728 |
| United Kingdom | 4,023 | 4,115 | 4,222 | 4,463 | 4,759 | 4,608 | 4,759 | 5,016 | 5,663 | 5,816 | 6,207 | 6,302 | 6,112 | 6,098 | 6,325 | 6,512 | 6,583 | 7,131 |
| United States | 18,799 | 18,008 | 17,872 | 18,257 | 18,635 | 18,935 | 19,437 | 19,894 | 20,932 | 21,731 | 22,868 | 24,023 | 24,675 | 25,443 | 26,205 | 26,535 | 27,230 | 26,847 |

**KEY:** NA = not available

**NOTES:** French doctoral degree data not available before 1989 (in the same data series). Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences.

**SOURCES:** **France:** Ministere de l'Education Nationale, de la Recherche et de la Technologie, *Rapport sur les Etudes Doctorales* (Paris,1998); **Germany:** Statistisches Bundesamt, *Prufungen an Hochschulen* (Wiesbaden, 1998); **United Kingdom:** Higher Education Statistical Agency, *Students in Higher Education Institutions 97/98* (Cheltenham: 1997); **United States:** National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards: 1997, NSF 99-323* (Arlington, VA: 1999).

## Appendix table 3. Doctoral degrees in science and engineering in selected Asia countries, by field: 1975-97



| Country/degree field | 1975 | 1977 | 1979 | 1981 | 1983 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **China** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 0 | 0 | 0 | 0 | 19 | 234 | 307 | 622 | 1,682 | 1,904 | 2,127 | 2,556 | 2,540 | 2,114 | 3,590 | 4,364 | 4,950 | 6,042 |
| Total S&E | 0 | 0 | 0 | 0 | NA | 125 | 127 | 218 | 797 | 1,024 | 1,069 | 1,198 | 1,357 | 1,895 | 2,741 | 3,417 | 4,428 | 5,328 |
| Natural sciences | 0 | 0 | 0 | 0 | NA | 33 | 27 | 52 | 165 | 141 | 209 | 252 | 304 | 528 | 918 | 1,191 | 1,479 | 1,678 |
| Mathematics/computer sciences | 0 | 0 | 0 | 0 | NA | 23 | 10 | 31 | 75 | 78 | 89 | 95 | 101 | 103 | 139 | 187 | 264 | 334 |
| Agricultural sciences | 0 | 0 | 0 | 0 | NA | 1 | 0 | 8 | 55 | 56 | 20 | 37 | 68 | 92 | 125 | 182 | 256 | 348 |
| Social sciences | 0 | 0 | 0 | 0 | NA | 0 | 1 | 0 | 26 | 23 | 36 | 47 | 61 | 102 | 170 | 198 | 234 | 325 |
| Engineering | 0 | 0 | 0 | 0 | NA | 68 | 89 | 127 | 476 | 726 | 715 | 767 | 823 | 1,069 | 1,389 | 1,659 | 2,195 | 2,643 |
| Non-S&E | 0 | 0 | 0 | 0 | NA | 109 | 180 | 404 | 885 | 880 | 1,058 | 1,358 | 1,183 | 219 | 849 | 947 | 522 | 714 |
| **India** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 2,015 | 2,710 | 3,646 | 4,904 | 6,597 | 7,139 | 7,346 | 7,603 | 7,598 | 8,284 | 8,586 | 8,374 | 8,383 | 8,720 | 9,070 | 9,070 | 9,070 | 9,070 |
| Total S&E | 1,909 | 2,408 | 2,917 | 3,356 | 3,886 | 3,976 | 4,052 | 4,123 | 4,208 | 4,209 | 4,166 | 4,212 | 4,183 | 4,021 | 4,000 | 4,000 | 4,000 | 4,000 |
| Natural sciences | 1,484 | 1,837 | 2,261 | 2,516 | 2,800 | 2,892 | 2,922 | 2,937 | 3,038 | 3,044 | 2,976 | 2,950 | 3,044 | 2,997 | 2,950 | 2,950 | 2,950 | 2,950 |
| Mathematics/computer sciences | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Agricultural sciences | 289 | 317 | 480 | 558 | 575 | 575 | 576 | 583 | 576 | 579 | 583 | 633 | 688 | 701 | 715 | 715 | 715 | 715 |
| Social sciences | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Engineering | 136 | 174 | 176 | 282 | 511 | 509 | 554 | 603 | 594 | 586 | 607 | 629 | 451 | 323 | 335 | 335 | 335 | 335 |
| Non-S&E | 106 | 302 | 729 | 1,548 | 2,711 | 3,163 | 3,294 | 3,480 | 3,390 | 4,075 | 4,420 | 4,162 | 4,200 | 4,699 | 5,070 | 5,070 | 5,070 | 5,070 |
| **Japan** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 4,592 | 5,322 | 5,812 | 6,599 | 7,233 | 7,978 | 8,533 | 9,157 | 9,602 | 10,036 | 10,633 | 10,758 | 10,885 | 11,576 | 12,160 | 12,645 | 13,820 | 13,921 |
| Total S&E | 2,127 | 2,492 | 2,515 | 2,632 | 2,676 | 3,088 | 3,095 | 3,248 | 3,511 | 3,561 | 3,704 | 3,874 | 4,056 | 4,438 | 4,877 | 5,205 | 6,006 | 6,157 |
| Natural sciences | 676 | 843 | 814 | 791 | 774 | 860 | 820 | 837 | 881 | 876 | 835 | 863 | 892 | 1,009 | 1,132 | 1,182 | 1,243 | 1,315 |
| Mathematics/computer sciences | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Agricultural sciences | 381 | 518 | 430 | 529 | 515 | 697 | 646 | 715 | 746 | 734 | 719 | 791 | 870 | 824 | 894 | 956 | 1,108 | 1,043 |
| Social sciences | 84 | 88 | 76 | 76 | 97 | 127 | 136 | 149 | 167 | 177 | 183 | 191 | 200 | 243 | 241 | 276 | 358 | 388 |
| Engineering | 986 | 1,043 | 1,195 | 1,236 | 1,290 | 1,404 | 1,493 | 1,547 | 1,717 | 1,774 | 1,967 | 2,029 | 2,094 | 2,362 | 2,610 | 2,791 | 3,297 | 3,411 |
| Non-S&E | 2,465 | 2,830 | 3,297 | 3,967 | 4,557 | 4,890 | 5,438 | 5,909 | 6,091 | 6,475 | 6,929 | 6,884 | 6,829 | 7,138 | 7,283 | 7,440 | 7,814 | 7,764 |
| **Korea** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 557 | 566 | 583 | 601 | 845 | 1,400 | 1,645 | 1,906 | 2,125 | 2,458 | 2,481 | 2,984 | 3,211 | 3,583 | 3,999 | 4,462 | 4,723 | 4,999 |
| Total S&E | 128 | 99 | 139 | 212 | 281 | 548 | 631 | 759 | 871 | 984 | 945 | 1,135 | 1,228 | 1,421 | 1,650 | 1,920 | 2,046 | 2,189 |
| Natural sciences | 29 | 22 | 41 | 75 | 83 | 212 | 201 | 277 | 207 | 192 | 170 | 225 | 202 | 244 | 296 | 358 | 391 | 427 |
| Mathematics/computer sciences | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 73 | 105 | 75 | 99 | 106 | 124 | 145 | 169 | 178 | 187 |
| Agricultural sciences | 48 | 40 | 45 | 52 | 60 | 89 | 105 | 110 | 155 | 175 | 154 | 156 | 151 | 172 | 196 | 223 | 199 | 178 |
| Social sciences | 31 | 23 | 24 | 25 | 41 | 50 | 52 | 102 | 90 | 97 | 107 | 189 | 217 | 222 | 227 | 232 | 236 | 240 |
| Engineering | 20 | 14 | 29 | 60 | 97 | 197 | 273 | 270 | 346 | 415 | 439 | 466 | 552 | 659 | 786 | 938 | 1,042 | 1,157 |
| Non-S&E | 429 | 467 | 444 | 389 | 564 | 852 | 1,014 | 1,147 | 1,254 | 1,474 | 1,536 | 1,849 | 1,983 | 2,162 | 2,349 | 2,542 | 2,677 | 2,810 |

See explanatory information and SOURCE at end of table.

## Appendix table 3. Doctoral degrees in science and engineering in selected Asia countries, by field: 1975-97



| Country/degree field | 1975 | 1977 | 1979 | 1981 | 1983 | 1985 | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Taiwan** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 37 | 45 | 43 | 64 | 86 | 115 | 200 | 225 | 249 | 314 | 410 | 410 | 608 | 701 | 808 | 848 | 1,053 | 1,187 |
| Total S&E | 21 | 24 | 26 | 49 | 58 | 109 | 172 | 197 | 197 | 257 | 312 | 370 | 450 | 513 | 592 | 650 | 783 | 839 |
| Natural sciences | 2 | 4 | 4 | 8 | 8 | 20 | 22 | 35 | 35 | 42 | 47 | 62 | 82 | 97 | 115 | 115 | 154 | 163 |
| Mathematics/computer sciences | 0 | 0 | 1 | 1 | 4 | 4 | 13 | 14 | 14 | 18 | 24 | 32 | 42 | 45 | 49 | 55 | 63 | 88 |
| Agricultural sciences | 4 | 4 | 7 | 15 | 17 | 10 | 28 | 28 | 28 | 36 | 33 | 36 | 39 | 48 | 60 | 63 | 65 | 79 |
| Social sciences | 7 | 13 | 6 | 10 | 15 | 16 | 26 | 22 | 22 | 41 | 43 | 31 | 23 | 36 | 56 | 44 | 66 | 76 |
| Engineering | 8 | 3 | 8 | 15 | 14 | 59 | 83 | 98 | 98 | 120 | 165 | 209 | 264 | 287 | 312 | 373 | 435 | 433 |
| Non-S&E | 16 | 21 | 17 | 15 | 28 | 6 | 28 | 28 | 52 | 57 | 98 | 40 | 158 | 188 | 216 | 198 | 270 | 348 |
| **Total Asia, by S&E field** | | | | | | | | | | | | | | | | | | |
| Total Ph.D. | 7,201 | 8,643 | 10,084 | 12,168 | 14,780 | 16,866 | 18,031 | 19,513 | 21,256 | 22,996 | 24,237 | 25,082 | 25,627 | 26,694 | 29,627 | 31,389 | 33,616 | 35,219 |
| Total S&E | 4,185 | 5,023 | 5,597 | 6,249 | 6,901 | 7,846 | 8,077 | 8,545 | 9,584 | 10,035 | 10,196 | 10,789 | 11,274 | 12,288 | 13,860 | 15,192 | 17,263 | 18,513 |
| Natural sciences | 2,191 | 2,706 | 3,120 | 3,390 | 3,665 | 4,017 | 3,992 | 4,138 | 4,326 | 4,295 | 4,237 | 4,352 | 4,524 | 4,875 | 5,411 | 5,796 | 6,217 | 6,533 |
| Mathematics/computer sciences | 0 | 0 | 1 | 1 | 4 | 27 | 23 | 45 | 162 | 201 | 188 | 226 | 249 | 272 | 333 | 411 | 505 | 609 |
| Agricultural sciences | 722 | 879 | 962 | 1,154 | 1,167 | 1,372 | 1,355 | 1,444 | 1,560 | 1,580 | 1,509 | 1,653 | 1,816 | 1,838 | 1,990 | 2,139 | 2,343 | 2,363 |
| Social sciences | 122 | 124 | 106 | 111 | 153 | 193 | 215 | 273 | 305 | 338 | 369 | 458 | 501 | 603 | 694 | 750 | 894 | 1,029 |
| Engineering | 1,150 | 1,234 | 1,408 | 1,593 | 1,912 | 2,237 | 2,492 | 2,645 | 3,231 | 3,621 | 3,893 | 4,100 | 4,184 | 4,700 | 5,432 | 6,096 | 7,304 | 7,979 |
| Non-S&E | 3,016 | 3,620 | 4,487 | 5,919 | 7,860 | 9,020 | 9,954 | 10,968 | 11,672 | 12,961 | 14,041 | 14,293 | 14,353 | 14,406 | 15,767 | 16,197 | 16,353 | 16,706 |
| **Summary, S&E doctoral degrees, by country** | | | | | | | | | | | | | | | | | | |
| Total Asia | 4,185 | 5,023 | 5,597 | 6,249 | NA | 7,846 | 8,077 | 8,545 | 9,584 | 10,035 | 10,196 | 10,789 | 11,274 | 12,288 | 13,860 | 15,192 | 17,263 | 18,513 |
| China | 0 | 0 | 0 | 0 | NA | 125 | 127 | 218 | 797 | 1,024 | 1,069 | 1,198 | 1,357 | 1,895 | 2,741 | 3,417 | 4,428 | 5,328 |
| India | 1,909 | 2,408 | 2,917 | 3,356 | 3,886 | 3,976 | 4,052 | 4,123 | 4,208 | 4,209 | 4,166 | 4,212 | 4,183 | 4,021 | 4,000 | 4,000 | 4,000 | 4,000 |
| Japan | 2,127 | 2,492 | 2,515 | 2,632 | 2,676 | 3,088 | 3,095 | 3,248 | 3,511 | 3,561 | 3,704 | 3,874 | 4,056 | 4,438 | 4,877 | 5,205 | 6,006 | 6,157 |
| Korea | 128 | 99 | 139 | 212 | 281 | 548 | 631 | 759 | 871 | 984 | 945 | 1,135 | 1,228 | 1,421 | 1,650 | 1,920 | 2,046 | 2,189 |
| Taiwan | 21 | 24 | 26 | 49 | 58 | 109 | 172 | 197 | 197 | 257 | 312 | 370 | 450 | 513 | 592 | 650 | 783 | 839 |

**NA =** not available

**NOTES:** Natural sciences include physical, biological, earth, atmospheric, and oceanographic sciences. Japanese data include "thesis" doctorates, called Ronbun Hakase, earned by employees in industry. In Japanese higher education data, mathematics is included in natural sciences; computer science is included in engineering.

**SOURCES:** **China**—National Research Center for Science and Technology for Development, unpublished tabulations; **India**—Department of Science and Technology, *Research and Development Statistics 1994-95* (New Delhi:1966); **Japan**—Ministry of Education, Science, and Culture (Monbusho), *Monbusho Survey of Education* (Tokyo: annual series); **South Korea**—Ministry of Education, *Statistical Yearbook of Education* (Seoul:1998); **Taiwan**—Ministry of Education, *Educational Statistics of the Republic of China: 1998* (Taipei:1998).

**Appendix table 4. U.S. doctoral degrees in S&E fields earned by U.S. and foreign citizens: 1986-97**

| Year | U.S. citizens | Other foreign students | Asian foreign students[a] |
|---|---|---|---|
| 1986 | 13,022 | 4,276 | 2,139 |
| 1987 | 12,966 | 4,455 | 2,473 |
| 1988 | 13,369 | 4,802 | 2,762 |
| 1989 | 13,467 | 5,165 | 3,099 |
| 1990 | 14,166 | 4,386 | 4,315 |
| 1991 | 14,624 | 4,156 | 5,239 |
| 1992 | 14,558 | 4,390 | 5,725 |
| 1993 | 14,929 | 4,569 | 5,943 |
| 1994 | 15,162 | 4,491 | 6,549 |
| 1995 | 15,460 | 4,368 | 6,687 |
| 1996 | 15,621 | 4,757 | 6,852 |
| 1997 | 15,744 | 5,528 | 5,575 |

[a] Includes students from all Asian countries on either temporary or permanent visas.

**SOURCE:** National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards: 1997,* NSF 99-323 (Arlington, VA: 1999).

**Appendix table 5. Total S&E doctoral degrees earned by Asian students from Asian and U.S. universities: 1975-97**

| Year | Asian universities | U.S. universities |
|---|---|---|
| 1975 | 4,185 | NA |
| 1976 | 4,663 | NA |
| 1977 | 5,023 | NA |
| 1978 | 5,211 | NA |
| 1979 | 5,597 | NA |
| 1980 | 5,871 | 991 |
| 1981 | 6,249 | 1,031 |
| 1982 | 6,544 | 1,168 |
| 1983 | 6,901 | 1,339 |
| 1984 | 7,409 | 1,531 |
| 1985 | 7,846 | 1,761 |
| 1986 | 8,077 | 1,889 |
| 1987 | 8,545 | 2,218 |
| 1988 | 9,584 | 2,511 |
| 1989 | 10,035 | 2,872 |
| 1990 | 10,196 | 3,999 |
| 1991 | 10,789 | 4,911 |
| 1992 | 11,274 | 5,407 |
| 1993 | 12,288 | 5,628 |
| 1994 | 13,860 | 6,229 |
| 1995 | 15,361 | 6,359 |
| 1996 | 17,594 | 6,505 |
| 1997 | 18,787 | 5,340 |

**KEY:** NA = not available

**NOTES:** Asian universities include those in China, India, Japan, South Korea, and Taiwan. Asian students in U.S. universities include those on either temporary or permanent visas from these five countries.

**SOURCES:** **China**—National Center for Science and Technology for Development, unpublished tabulations, 1997; **India**—Department of Science and Technology, *Research and Development Statistics 1994-95* (New Delhi:1996); **Japan**—Ministry of Education, Science and Culture, *Monbusho Survey of Education,* (Tokyo: annual series); **South Korea**—Ministry of Education, *Statistical Yearbook of Education Se*oul:1998); **Taiwan**—Ministry of Education, *Education Statistics of the Republic of China, 1998* (Taipei:1998); **United States**—National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards: 1960-84;* and *Science and Engineering Doctorate Awards: 1997 Advanced Release.*

## Appendix table 6. Doctoral S&E degrees earned by Chinese students within Chinese and U.S. universities: 1987-97

| Year | Within U.S. universities | Within Chinese universities |
|---|---|---|
| 1987 | 293 | 218 |
| 1988 | 480 | 797 |
| 1989 | 620 | 1,024 |
| 1990 | 1,150 | 1,069 |
| 1991 | 1,793 | 1,198 |
| 1992 | 2,045 | 1,357 |
| 1993 | 2,227 | 1,704 |
| 1994 | 2,531 | 2,602 |
| 1995 | 2,752 | 3,230 |
| 1996 | 2,952 | 4,428 |
| 1997 | 2,223 | 5,328 |

**SOURCES:** National Science Foundation, Division of Science Resources Studies, *Science and Engineering Doctorate Awards* : 1997, Advanced Release; and China: National Research Center for Science and Technology for Development, unpublished tabulations.

## Appendix table 7. Proportion of NS&E doctoral degrees earned by foreign students in selected countries: 1995

| Country | Foreign doctoral recipients | |
|---|---|---|
| | Natural sciences | Engineering |
| France | 29.1 | 34.2 |
| Germany | 7.9 | 15.8 |
| Japan | 22.1 | 32.2 |
| United Kingdom | 28.5 | 49.1 |
| United States | 40.5 | 57.9 |

**KEY:** NS&E = Natural sciences and engineering

**SOURCES:** **France—**Ministere de l'Education Nationale de la Recherche et de la Technologie, *Rapport sur les Études Doctorales* (Paris: 1996); **Germany**—Statistisches Bundesamt, *Prufungen an Hochschulen* (Wiesbaden); **Japan—** Ministry of Education, Science, and Culture (Monbusho), *Monbusho Survey of Education* (Tokyo: annual series); **United Kingdom—** Higher Education Statistical Agency, unpublished tabulations; **United States—** National Science Foundation, Division of Science Resources Studies, *Selected Data on Science and Engineering Doctorate Awards 1995:* NSF 96-303 (Arlington, VA: 1996).

## Appendix table 8. R&D performed in universities by region

| Year | Millions of constant (1992) U.S. dollars | | |
|---|---|---|---|
| | Western Europe | North America | Asia |
| 1975 | 12,642 | 9,382 | NA |
| 1976 | 12,706 | 9,657 | NA |
| 1977 | 12,769 | 10,073 | NA |
| 1978 | 12,969 | 10,688 | NA |
| 1979 | 13,151 | 11,266 | NA |
| 1980 | 13,510 | 11,640 | NA |
| 1981 | 15,032 | 11,822 | 6,412 |
| 1982 | 15,350 | 12,010 | 6,837 |
| 1983 | 15,729 | 12,415 | 7,159 |
| 1984 | 16,223 | 13,161 | 7,330 |
| 1985 | 17,012 | 14,245 | 7,571 |
| 1986 | 17,719 | 15,536 | 7,699 |
| 1987 | 19,287 | 16,616 | 8,292 |
| 1988 | 20,107 | 17,767 | 8,635 |
| 1989 | 21,299 | 18,700 | 8,855 |
| 1990 | 22,443 | 19,432 | 9,579 |
| 1991 | 24,109 | 20,486 | 9,937 |
| 1992 | 25,211 | 21,247 | 10,424 |
| 1993 | 26,010 | 21,881 | 11,326 |
| 1994 | 26,549 | 22,493 | 11,716 |
| 1995 | 27,011 | 22,906 | 13,013 |

**KEY:** NA = not available

**NOTES:** North America includes Canada and United States; Asia includes China, India, Japan, South Korea and Taiwan. Western Europe includes all Western European countries. See appendix table 1.

**SOURCES:** **Western Europe—**Organization for Economic Co-operation and Development, Main Science and Technology Indicators database, OECD/MSTI (Paris:1997); **Canada—** OECD/MSTI; **United States—**National Science Foundation, Division of Science Resources Studies, *National Patterns of R&D Resources: 1998* (Arlington, VA: 1998); **Asia—**National Science Foundation, Division of Science Resources Studies, *Human Resources for Science and Technology: The Asian Region,* NSF 93-303.