Graduate Education Reform in Europe, Asia and the Americas

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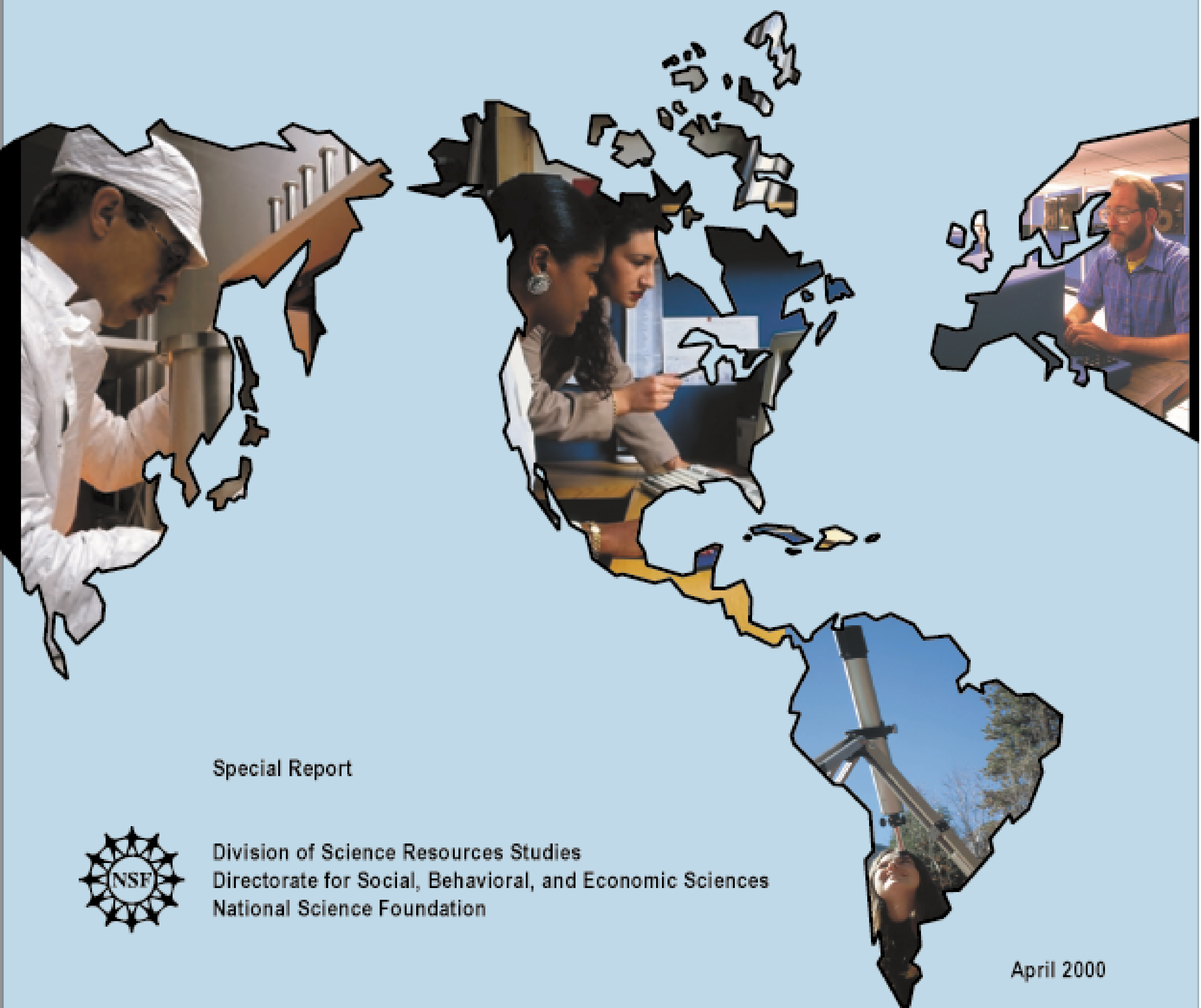
Proceedings of an NSF Workshop



Special Report

Division of Science Resources Studies
Directorate for Social, Behavioral, and Economic Sciences
National Science Foundation

April 2000

Graduate Education Reform in Europe, Asia and The Americas

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Proceedings of an NSF Workshop

Special Report

Jean M. Johnson, Project Officer

Division of Science Resources Studies
Directorate for Social, Behavioral, and Economic Sciences
National Science Foundation

April 2000

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Any opinions, findings, conclusions, or recommendations expressed in this report are those of the participants, and do not necessarily represent the official views, opinions, or policy of the National Science Foundation.

Foreword

The Division of Science Resources Studies (SRS) supported the workshop on "Graduate Education Reform in Europe, Asia, and the Americas and International Mobility of Scientists and Engineers," held at the National Science Foundation (NSF) November 17-18, 1998. The objective of this workshop was to provide NSF, SRS, and the National Science Board with analyses of recent changes in graduate science and engineering education and international mobility of scientists and engineers among these regions.

The information generated by this effort is intended to assist NSF in its continuing efforts to promote the education of scientists and engineers in a changing global environment. Recent changes in that environment have included the reported expansion of graduate S&E programs abroad, as well as changes in patterns of international mobility of scientists and engineers. An understanding of the nature and magnitude of these changes is needed to inform program and policy deliberations and assist in planning NSF graduate education initiatives.

The information presented here complements and augments the international coverage in the *Science and Engineering Indicators* report (Chapter on Higher Education in Science and Engineering) of the National Science Board.

Lynda T. Carlson
Division Director

Mary J. Frase
Deputy Division Director

Division of Science Resources Studies
Directorate for Social, Behavioral, and Economic Sciences

April 2000

AUTHOR'S ACKNOWLEDGMENTS

This workshop was made possible by the contributions of a dozen international experts who agreed to prepare country papers under tight time constraints covering the main workshop topics: expansion of graduate capacity, educational reforms, the role of government and industry in supporting and employing S&E graduates, and the patterns of international mobility of scientists and engineers. Among the experts who agreed to prepare papers and attend the workshop were Peter Maassen, Director of the Center for Higher Education Policy Studies (CHEPS) in The Netherlands; his research associate Jeroen Bartelse, who has recently completed his dissertation research on institutional reform in European higher education; Dominique Martin Rovet, author of mobility studies on French scientists and head of the Washington liaison office of the French national research system; Shinichi Yamamoto, Director of the Research Center for University Studies in Tsukuba, Japan; Yugui Guo, who has recently completed his dissertation on graduate education in China; Atul Wad, president of a technology-transfer firm; Jacqueline Leta, of the Biomedical Sciences Institute of the Federal University of Rio de Janeiro; Hebe Vessuri, of the Venezuelan Institute of Scientific Investigations; Manuel Mari, of the Institute of Social Studies of Science and Technology in Argentina; and Sergio Marshall, graduate dean of the Catholic University of Valparaiso and head of the Council of Rectors of Chilean universities. Mario Albornoz, head of the Institute of Social Studies of Science and Technology was the lead author of the country paper on Argentina, but was unable to attend the workshop. Similarly Beatriz Santana, of the Latin American Studies Center of the University of Los Angeles headed the team that prepared the Brazilian paper, but was unable to attend the workshop.

Through a contract with Stanford Research Institute (SRI), H. Robert Coward assisted SRS in preparations and follow-up for this workshop, including locating some country experts, reviewing several authors' drafts and suggesting changes, and providing international travel, per diem and honoraria for all international attendees. In addition, Dr. Coward participated in the workshop, prepared the highlights of discussion which appear in the summary of proceedings, and assisted SRS in iterating with several authors on the edits of their papers. Alan I. Rapoport, Senior Analyst in SRS, and I read the edits of several country papers and iterated with the authors on the resolution of editor queries.

Jennifer Sue Bond, Program Director of the Science and Engineering Indicators Program, gave guidance and encouragement for the workshop, both for potential participants and for a follow-up publication of the papers. Colleagues within SRS, Alan I. Rapoport and Mark C. Regets, assisted in the preparation of the U.S. country paper. Jeanne Griffith, then Division Director of SRS, reviewed the U.S. paper, along with Mary J. Golladay, Program Director, Human Resources Statistics Program; Rolf F. Lehming, Program Director, Integrated Studies Program; Susan T. Hill, Director, Doctorate Data Project; and Joan S. Burrelli, Senior Analyst in SRS. These reviewers provided additional source material on U.S. and international graduate education and improved the presentation of the U.S. data. In addition, Paul W. Jennings of the NSF Graduate Education Program provided useful suggestions.

Several program directors within the Division of International Programs (INT) reviewed individual country papers: Richard R. Ries, Christine Galitzine, Mark Suskin, Jeanne E. Hudson, Larry H. Weber, Harold J. Stolberg and Laura Noto (INT Intern). Additional reviews were provided by program directors from the NSF research directorates: Norbert M. Bikales and Carmen I. Huber. External peer reviewers in the United States, who reviewed individual country papers, included Richard P. Suttmeier, Paul B. Pedersen, A.K. Jain, Maresi Nerad, Bernard Stein and Yii-Der Chuang. External peer reviewers from abroad included Cheng Kai-ming, Mark Bray, Nora Narvaez, Jean-Baptiste Meyer, Nick Jagger, Britt Marie Bertilsson, Gonzalo Ordonez, Heloisa Vilhena de Araujo, and Jacques Guillard. These external reviewers provided useful suggestions and in some cases significant national source material that improved the education indicators presented.

Jeanne Griffith introduced the workshop and highlighted international trends in graduate education in science and engineering. I chaired the Asian session, Bennett I. Bertenthal, Assistant Director for

Social, Behavioral and Economic Sciences (SBE) chaired the European session and Jennifer Sue Bond chaired the Latin American session. Dorothy S. Zinberg of Harvard University served as a discussant at the end of the workshop presentations.

Anne Houghton, Publications Manager for SRS, generously assisted in all phases of preparation for publication, arranging for external copyediting, formatting and composition of this report. Julia Harriston and Tanya Gore also assisted in the copyediting of the report. Nita Congress edited all the papers for publication to establish more uniformity across country presentations. Phillip Coons, Krista Bruno, and Shawn Bryan of ROH Incorporated formatted the text tables, appendix tables and figures for all papers and provided composition services.

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Summary of Proceedings

Jean M. Johnson and H. Robert Coward

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

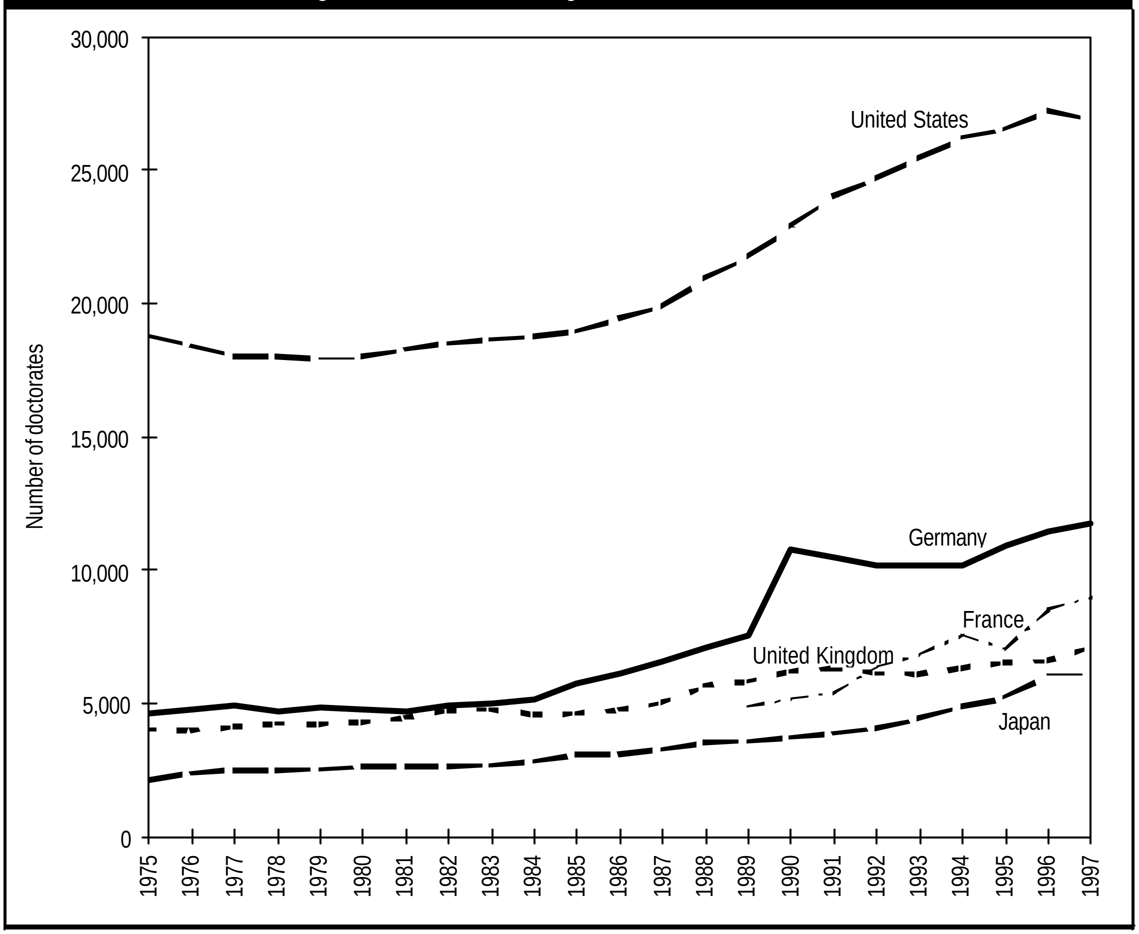
By individual country, the United States leads in the number of doctoral degrees earned in S&E fields. In 1997, U.S. universities awarded about 27,000 S&E doctoral degrees—more than twice the number of S&E degrees awarded in any of the other major industrial countries. (See figure 1.)

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).

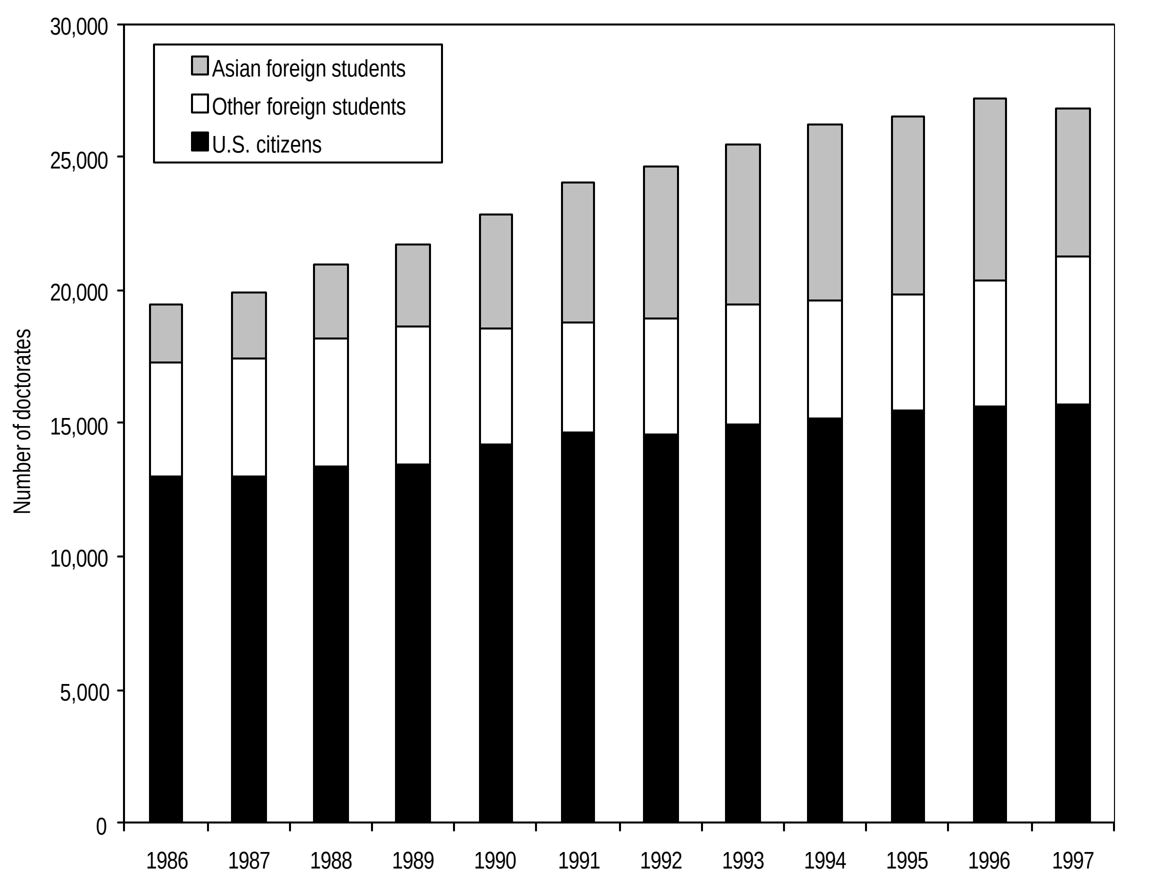
The scale of graduate education in Japan has been small by international standards. Until recently, most doctorates in the natural sciences and engineering in Japan were earned by industrial researchers after many years of research within Japanese companies. Doctoral reforms of 1989 called for the expansion 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.

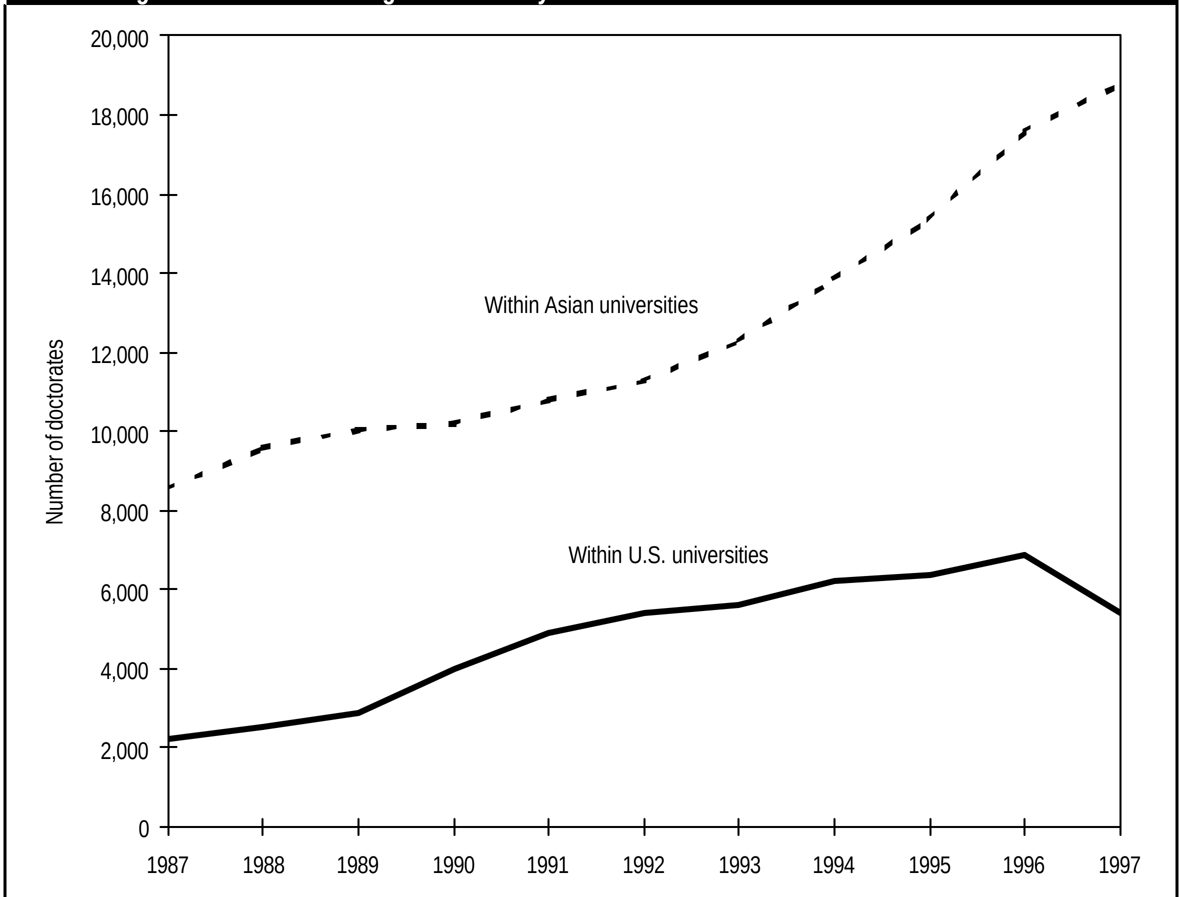
Ministry of Education began increasing support to universities to improve facilities and greatly accelerate doctoral programs in natural science and engineering fields. In 1994, Japanese engineers earned more doctoral degrees for research within university laboratories than within industrial research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

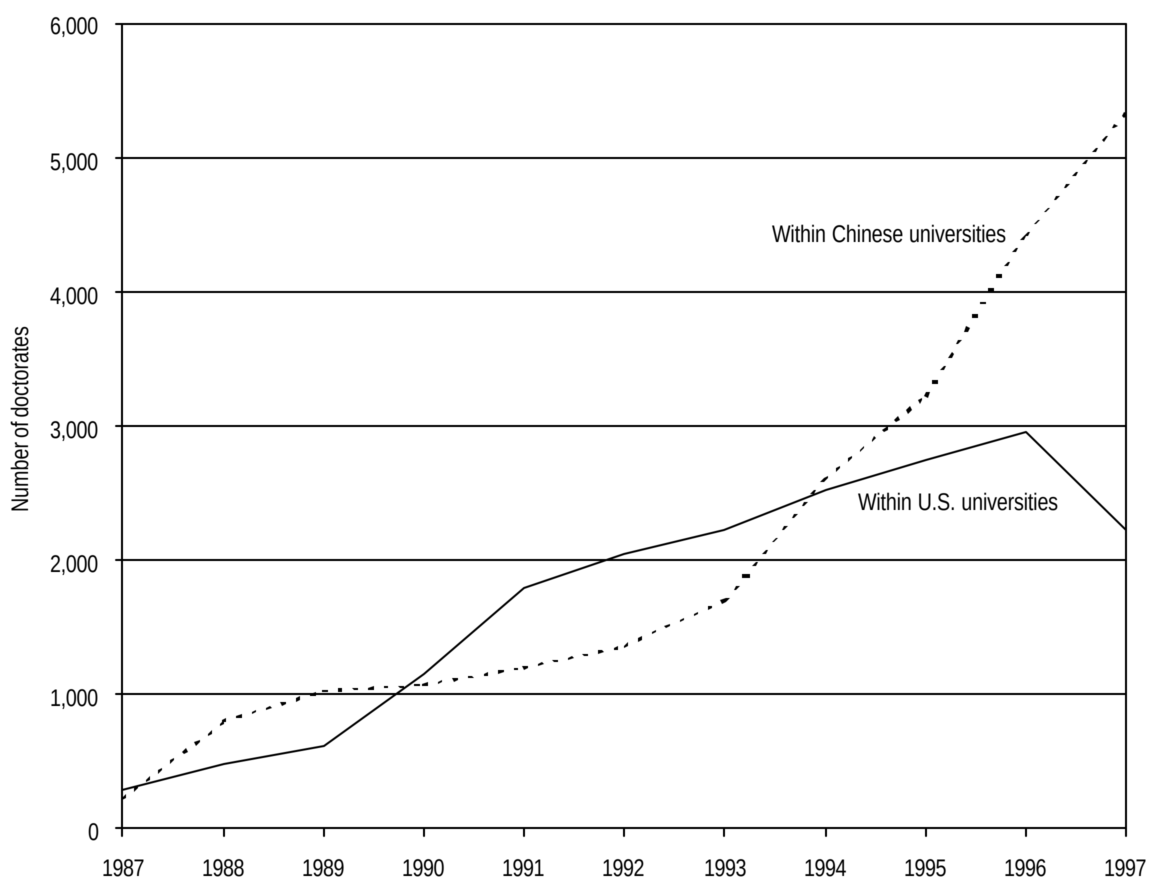
Forces for Change

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.

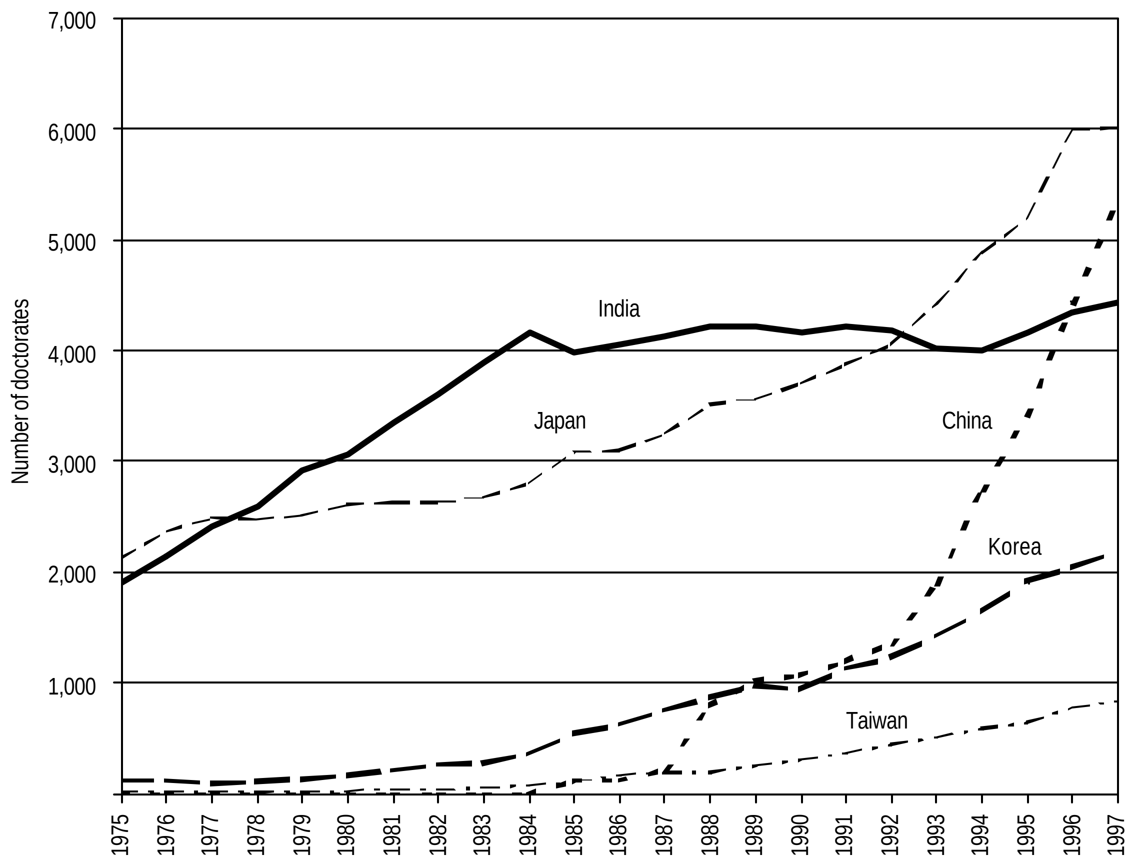
Technological

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.

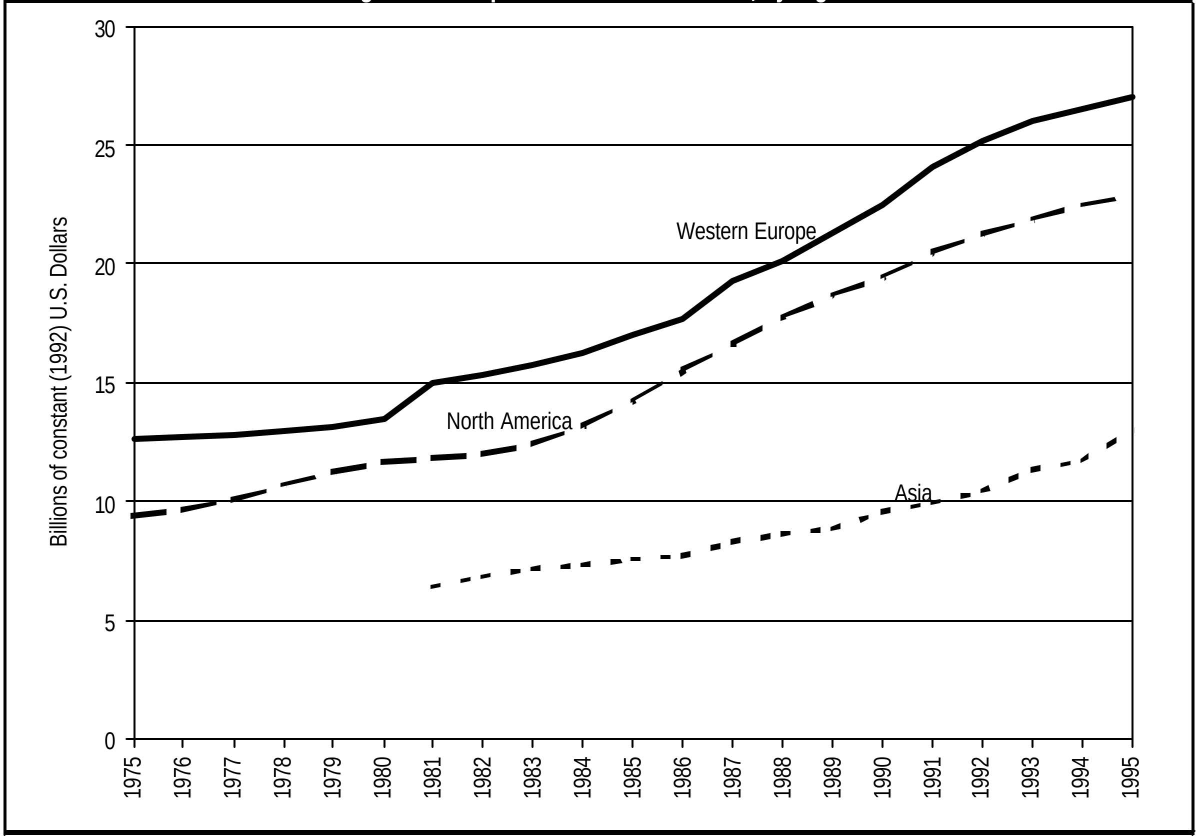
Different Emphases in Reforms Across Countries

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.

ASIAN REGION

Graduate Education Reforms and International Mobility of Scientists and Engineers in China

Yugui Guo

Historical Sketch

China is a nation with a long history of an ancient higher education system, and a shorter period with a more modern one. Compared with the leading Western nations, the process of development of Chinese graduate education has been convoluted. Its modern stage can be traced to 1902, when the Qing Dynasty government issued the first official regulations for a modern educational system, which stipulated the establishment of a Grand School (graduate school) above the existing undergraduate education system. During the period 1911-34, the government made numerous efforts to establish the academic degree system, which finally came into being as a result of these efforts in 1935. However, due to World War II and the Japanese intervention of 1937-45, the Regulations on Degree Conferment, aimed at improving education and science in China, were not fully implemented. For the 14-year period between 1935-49, only baccalaureate degrees and 200 master's degrees were granted—not a single doctoral degree was awarded (B. Wu 1993). The training of graduate students took place largely in foreign countries.

After the founding of the People's Republic of China (PRC) in 1949, the communist government abolished the academic degree system; it was not reestablished until 1981. During the period from 1949-65, before the Cultural Revolution occurred in 1966, only about 20,900 students graduated from the Soviet-pattern graduate schools that had been established (Guo 1998). As the old academic degree system had been abolished earlier, not one of these students was actually granted a graduate degree.

The Cultural Revolution led to a 12-year suspension of graduate enrollment. This resulted in a great loss to higher education institutions. When the Cultural Revolution ended in 1976, the number of full professors had decreased by 25 percent as compared with 1965, associate professors by 19 percent, and lecturers by 6 percent (MOE 1985). In the first years after graduate education was resumed in 1978, the shortage of high-level scientific and educational personnel and the low quality of teachers was evident everywhere in China. During the Cultural Revolution alone, China had lost 1.5 million specialists (Chen 1992). It has been estimated that the Cultural Revolution set China's socioeconomic and scientific development back about 20 years (Min 1997).

Subsequently, Chinese leaders became aware of the correlation between high-level specialized personnel and the realization of their ambitious "Four Modernizations" (of industry, agriculture, science and technology, and national defense). With the new national policies for reform, as well as the opening up of the country to the outside world in 1978, the Chinese government resumed graduate education in China and gave priority to its development. Within a short period, Chinese graduate education experienced notable development, which has attracted international attention. In terms of enrollment and output, between 1978-94, 460,000 graduate students had been admitted—nearly 20 times the number (23,400) for the 17-year period between 1949 and the beginning of the Cultural Revolution in 1965 (Z. Wu 1995). Between 1978-97, 430,000 graduate students (including 390,000 master's degree and 34,000 doctoral degree) had graduated, over 20 times the number (20,900) graduated prior to the Cultural Revolution (Zhang 1998).

Current System

The existing higher education system in China basically derived from the Soviet model, and its pattern of governance is still a prominent force in its impact on the universities. In recent years, however, Chinese higher education has been shifting from a rigid model of state control to a model of state supervision that is more in accord with the transformation from a planned to a market economy.

Before focusing on the administrative structure of graduate education, two important features that are derived from the Soviet model and that characterize Chinese higher and graduate education need to be understood.

- **Within and Without Research Institutions.** Unlike undergraduate education, which is exclusively carried out in institutions of higher learning, graduate education in China is undertaken by both institutions of higher learning and research institutes outside universities. This is due to the traditional division of teaching and research between universities and research institutes. Currently, these institutions of graduate learning can be divided into four categories in terms of type of control and sources of funding.

- Thirty-six key comprehensive, polytechnic, and normal institutions are administered directly by the State Education Commission (SEdC),[1] which is also responsible for the overall guidance of the higher and graduate education system in China by formulating policies, decrees, and plans. Many of them are prestigious, pace-setting institutions, with broad scope in both undergraduate and graduate education.

- Over 400 specialized institutions and research institutes are under the control of central ministries like the Ministry of Agriculture, Ministry of Public Health, etc., and specialize in training personnel for their sponsoring ministries, with emphasis on national needs.

- About 100 provincial-level institutions and research institutes are governed by provincial educational commissions (or bureaus) and commissions for science and technology. Most have a relatively small number of graduate students.

- There are also 130-odd research institutes and a few other institutions of higher learning affiliated with the Chinese Academy of Sciences (CAS) and the Chinese Academy of Social Sciences (CASS); these are traditionally focused on basic research.

To maintain standards in degree courses, only selected universities and research institutes have been authorized to grant degrees. According to 1996 statistics, there were a total of 1,054 institutions of higher education in China (DFA 1996), of which only 471 institutions of higher education and 315 research institutes were authorized to grant graduate degrees. The majority of these were under the jurisdiction of the SEdC, the central ministries, or the CAS/CASS.

- **Division of Authority for Academic Matters.** American universities generally operate under the authority of state governments to grant accredited degrees and enjoy substantial autonomy (Johnstone 1993). In China, authority for graduate admissions, training, management, and the formulation of degree standards is shared by two state administrative organs—the SEdC and the Academic Degrees Committee (ADC) under the State Council[2]—operating in parallel. Both have their own corresponding vertical administrative structures and exercise somewhat different responsibilities and authorities. Generally speaking, the former has a more executive function, while the latter has a more legislative function. A brief description of their respective structures and functions follows.

Administration of Graduate Education

China has a three-level graduate education administrative system, with the SEdC at the top; the education commissions and bureaus of higher education under the central ministries, provinces, and the CAS at the middle level; and the training institutions and research institutes at the base.

- The SEdC exercises unified leadership over graduate education in the country and is responsible for macro-level guidance and administration.

- The middle-level administrative entities are responsible for administering graduate education in the institutions of higher learning under their respective jurisdictions.

- At the micro-level, the president/director, or one of the vice presidents/directors, of the university or research institute takes charge of the work of graduate education. An administering body, such as a graduate school, graduate department or di-

[1]Before 1985, this institution was called the Ministry of Education, and recently—in March 1998—it reverted back to this title.

[2]The State Council in China is comparable to the U.S. cabinet or to a council of ministers.

vision, or graduate section, can be set up to do the daily administrative work in accordance with the scope of graduate education and actual needs.

Administration of Academic Degrees

Similar and parallel to the administrative system of graduate education, a three-tiered administrative structure has been applied in the management of academic degrees: the ADC is at the top; the central ministries and commissions, CAS/CASS, and provinces are at the middle; and the degree-granting institutions (including both universities and research institutes) are at the bottom of the system.

- The ADC was set up under the State Council in December 1980 to supervise the conferring of academic degrees all over the country. Its main duties include formulating national guiding principles and policies for academic degree work, examining and approving graduate degree-granting universities and research institutes, and certifying disciplines and specialties as well as doctoral supervisors.

- The ministry- and provincial-level degree administrative agencies take charge of the degree work under their own jurisdictions. Their main responsibility is to coordinate work within the scope of their own authority and to provide additional funding for key and urgently needed degree programs.

- An academic degree evaluation committee is established in each degree-granting institution as a leading agency responsible for the quality of degree work and granting of degrees.

By the middle of 1998, the ADC system had accredited 633 institutions to confer master's degrees in 8,248 disciplines and specialties, 229 institutions to confer doctoral degrees in 2,292 disciplines and specialties, and more than 10,000 doctoral supervisors (Chisa 1998).[3]

Thus, the SEdC takes charge of developing the basics of graduate education, graduate teaching, and research training, while the ADC has responsibility for checking and accepting the resulting "products"—the graduate programs and graduates—in accordance with ADC standards.

[3]In Chinese universities and research institutes, only disciplines (somewhat similar to disciplinary programs) and specialties of relatively high quality in terms of teachers, research facilities, and reputation are authorized by the ADC system to offer graduate courses and grant graduate degrees.

Finance

There are two major sources of funding for higher education in China: state appropriations, the major source, accounting for more than 80 percent of the total; and income generated by higher education institutions and research institutes themselves, which has been increasing in recent years. The allocation for the 36 national universities administered by the SEdC and the specialized institutions and research institutes under the control of central ministries and the CAS comes from the budget of the Ministry of Finance. The local universities and research institutes receive funds mainly from provincial finance departments.

There are other funding sources for graduate training and research activity. One fund allocation is from the Ministry of Finance and is based on a head-count enrollment. Another is from a variety of research foundations, such as the Chinese National Science Foundation. A third source is from contract projects.

Since the late 1970s, China has increased its allocation to higher education both in absolute terms and relative to government expenditure and gross national product (GNP). Total public expenditure increased 4.76 times, from 111.10 billion yuan in 1978 to 528.74 billion yuan in 1993; expenditure on higher education increased 10.0 times, from 1.50 billion yuan to 15.05 billion yuan, during the same time period (Min 1997). This reflects the high priority given to higher education in the country's modernization process.

Degree Structure

As in America, the levels of academic degrees in China are connected to different phases of higher education. There are three categories of official degrees: bachelor's degrees, master's degrees, and doctoral degrees.

Bachelor's Degree

Precollege education in China consists of 12 years. By taking national entrance examinations, senior high school graduates are enrolled for their college studies.

The average length of an undergraduate program is 4 years, with 5-year programs offered in a number of specialties in science universities. Medical universities provide 5- or 6-year undergraduate programs. Students who complete all requirements of the curriculum receive a bachelor's degree.

Graduate-Level Degrees

China's graduate education has two official levels—the master's degree and the doctoral degree. At each academic level, two kinds of people are trained to meet the country's different needs: academic personnel and applied science personnel. There are full-time and part-time graduate programs; the latter require from 1 to 3 years of additional study.

The Master's Degree. By passing graduate entrance examinations, those who hold bachelor's degrees or equivalent academic qualifications can pursue 2- or 3-year master's programs.[4] Master's degrees are conferred upon those who have passed certain prescribed courses, including written examinations; written and defended orally a thesis presenting original views on a designated research theme; have a firm grasp of basic theories and systematic knowledge of the relevant field; exhibit good command of a foreign language; and are able to conduct scientific research or specialized technical work independently.

In recent years, in addition to this regular path of earning a master's degree, five other alternative channels have been developed, mainly for employed professionals and self-study applicants (ADC and SEdC 1995, Qin 1994).

The Doctoral Degree. By passing entrance examinations, those who hold a master's degree or equivalent academic qualifications can pursue 3- to 4-year doctoral programs. In addition, a small number of outstanding newly graduated bachelor's degree-holders can directly enter doctoral programs upon special recommendation. To receive a doctorate, students must pass written examinations in prescribed courses (usually including political theory, two foreign languages, and two to three specialized subjects) and conduct an oral defense of a dissertation. This must be accompanied by qualified records demonstrating that the student has a firm and comprehensive grasp of basic theories, systematic and profound knowledge in the branch of learning concerned, good command of two foreign languages, the ability to undertake scientific research independently, and the capacity to turn out creative achievements in science or specialized technology.

As with the master's degree, there is an alternative way for employed professionals to obtain a doctoral degree. This route is similar to the Japanese *Ronbun hakase*—earning a doctoral degree by submitting a dissertation without enrolling at a university. Matriculation and coursework are not necessary; submission of the dissertation suffices for the degree.

In terms of administrative structure and degree structure, the current Chinese degree system is something of a hybrid of the old Soviet system and the American system, combined with elements indigenous to China itself. Its administrative structure is more like the Soviet model, while its degree structure resembles that common in America.

Expansion of Graduate Education

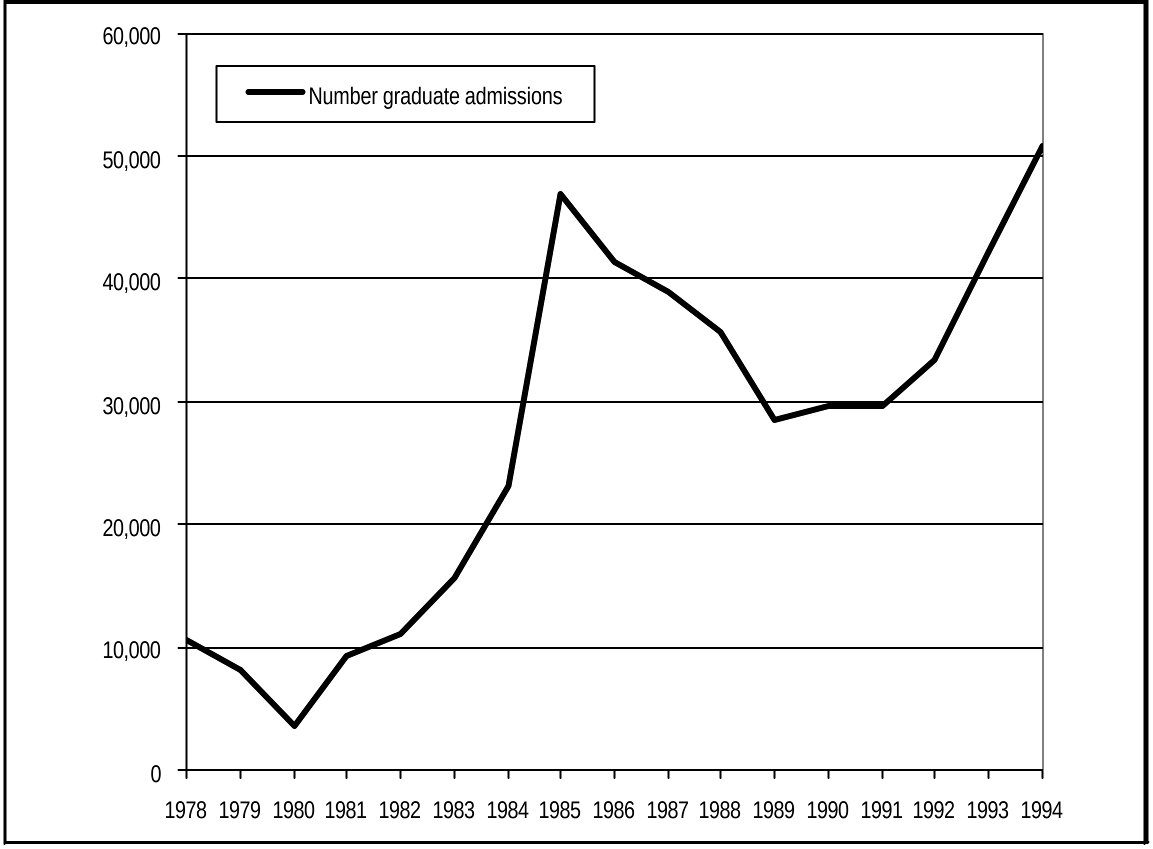
Since its resumption in China in 1978, graduate education has experienced a development that merits particular attention because it is not only unprecedented in China in terms of its speed and scale, but also rare in the history of graduate education internationally. According to available statistics, China spent 17 years increasing its graduate enrollment from 10,900 to 128,000 during the 1978-94 period; concurrently, America, Britain, Japan, and the former Soviet Union respectively spent 20, 29, 34, and 31 years reaching the same or similar developmental scale in their respective histories (Z. Wu 1995).

Figure 1 shows a number of significant fluctuations in Chinese graduate admissions. The admission decrease in graduate students from 1978-80 was related to the resumption of 4-year undergraduate education in China in 1977, following its suspension for 11 years. Before 1981, the main source of eligible applicants was from among those who had been admitted into 4-year undergraduate programs prior to the Cultural Revolution. As a great number of these students had matriculated in 1978-79, the number of qualified applicants in 1980 remained limited.

Between 1981-85, graduate education in China experienced a very rapid expansion due to a number of social, economic, educational, and scientific and techno-

[4]Usually the length for engineering and science programs is 2 to 2.5 years, while that for social science and humanities programs is 3 years.

Figure 1. Graduate recruitment in China, 1978-94



SOURCE: *Academic Degrees and Graduate Education,* 71 (6): 17, 1996. *Academic Degrees and Graduate Education,* 72 (1): 51, 1997.

logical factors. These changes occurred during a period when the Chinese government extended its new policy of reform and of opening its doors to the outside world beyond the economy and into many domains of society. The reflection of this first reform wave was clearly evident in the expansion of graduate education.

The total number of admitted graduate students in 1981 was 9,363—2.6 times as many as in 1980. This increase in admissions was due to two primary reasons: first, the establishment and implementation of the academic degree system in 1981 encouraged and attracted more people to pursue graduate studies; second, the first 4-year undergraduate program students who had entered college in 1977 graduated in 1981, thus adding to the pool of eligible and qualified graduate candidates.

Another big jump in graduate admissions occurred in 1984 and 1985. In 1985, 46,871 students were recruited, twice as many as in 1984. In turn, the accepted total in 1984 was 23,181, or 1.5 times as many as in 1983. This rapid growth was driven by landmark reforms in the economy, science and technology, and education:

- In 1984, a major reform document modifying the Chinese economic system was adopted—the "Resolution of the CPC [Communist Party of China] on the Reform of the Economic Structure," whose central argument was that the economy is activated only by relying on scientific and technological progress. Needless to say, a mammoth force of high-level specialized personnel would be needed to fulfill this task.

- The National Science Conference was held in March 1985, which advocated the promotion of strong linkages between research and teaching and led to the establishment of a new science fund—the National Fund of Natural Sciences—for which researchers in both universities and research institutes of the national academies are eligible to apply and with award decisions based on peer review. This reform legally and, to a certain degree, financially guaranteed higher education institutions a new role in research.

- In May 1985, the document "Decision on the Reform of the Education System" was approved by the CPC at the National Education Conference. Among the many policy changes set out in this document, the following two are of special importance concerning the development of graduate education: first, institutions were to be allowed to admit additional students on the basis of contracts with enterprises and other employers, and also to enroll fee-paying students; second, the credit system and double-degree studies were to be introduced.

- Starting in 1981, the World Bank undertook a 5-year program under which it would offer a loan of US$200 million, together with US$95 million from the Chinese government, to "strengthen science and engineering programs in 28 key higher education institutions by increasing graduate and undergraduate enrollments, improving the quality of graduate and undergraduate education and the ability to do university based research." This program played a significant role in improving the conditions and quality of both teaching and research and, especially, in expanding graduate enrollment in that period, for these key universities enrolled a large share of China's graduate students.

With strategic priority being given to education and research and relatively more financial investment coming in from the government and the World Bank in this period, approximately 379 new institutions of higher education were created between 1980-86—from 675 to 1,054; undergraduate student enrollment increased from 1,140,000 to 1,880,000. Graduate enrollment increased more than fivefold during the same period, rising from 21,600 to 110,371 (IAP and CRC 1991, DFA 1994).

With little experience in conducting graduate education, the Chinese government was confronted with a number of issues after 8 years of rapid development (1978-85). The phase between 1986-91 was characterized by frequent readjustment and various reforms in policies concerning the developmental scale and quality of Chinese graduate education. The total enrollment of 120,191 in 1987 transcended the capacity and resources available. Starting in 1986, following the SEdC's new directive on stabilizing scale, graduate admissions were gradually reduced to 35,645 in 1988, with a further large decline in graduate admissions in 1989, when only 28,569 were accepted—20 percent less than in 1988. This admission stabilization policy was continued by the SEdC in the subsequent 2 years. The reasons for the decline in graduate recruitment were complex. According to World Bank research findings, students' changing career goal patterns (more and more students wanted to go abroad or into joint ventures), the economic retrenchment policies of 1988, and the aftermath of the June 1989 events all had negative effects on graduate recruitment (IAP and CRC 1991).

Distribution Across Graduate Degree Levels

In general, the distribution of levels of graduate degrees in a nation is determined and affected by a variety of societal factors. An ideal distribution of graduate degrees—the ratio between doctoral and master's degrees—should remain in accordance with the level of the country's national economic, scientific, and cultural development; population density; degree of universal schooling; and developmental status of its national education system. The appropriate ratio between these two degrees varies from nation to nation and from time to time. Some countries deliberately plan their ratio; others let market demand drive it.

In China, the government sets an annual ratio between doctoral and master's degree enrollment. During the 14-year period from 1982-95, China granted only 22,162 doctoral degrees, which is not commensurate with the country's vast population and the demands of rapid economic development. During this period, the number of doctoral degrees accounted for a very small share of the total graduate degrees awarded (table 1); the average ratio between master's and doctoral degrees over the period is about 14:1.

The rapid national economic development and the competition and challenge of science and technology in the 21st century call for high-level scientific and technical personnel. It is imperative that China pay more attention to doctoral education in the future. In view of China's current situation and future development, the ratio between master's and doctoral degrees should be raised to around 5:1 for a time. Such a ratio would seem reasonable given the existing circumstances in China, i.e.:

- In 1994, only 2.2 percent of full-time teachers in regular higher education institutions in China had earned doctor's degrees (Guo 1998).

Table 1. Doctoral and master's degrees awarded and their ratio, 1982-94			
Year	Master's	Doctorate	Ratio
1981	8,665	0	0
1982	5,773	13	444.0:1
1983	3,548	19	187.0:1
1984	7,798	91	85.7:1
1985	12,618	234	53.9:1
1986	14,938	307	48.7:1
1987	20,831	622	33.5:1
1988	36,501	1,682	21.7:1
1989	35,442	1,904	18.6:1
1990	32,557	2,127	15.3:1
1991	30,675	2,556	12.0:1
1992	25,276	2,540	10.0:1
1993	24,129	2,114	11.4:1
1994	26,166	3,590	7.3:1
1995	28,098	4,363	6.4:1

SOURCE: *Academic Degrees and Graduate Education,* 71 (6): 73, 1996. *Academic Degrees and Graduate Education,* 72 (1): 51, 1997.

- The former vice minister of the SEdC pointed out that as early as 1993 China had about 1 million senior specialized personnel; 80 percent of them will be retired by the year 2000, and the vacancies left by them will require a younger generation with advanced degrees.

- Due to the Cultural Revolution, China lost 1.5 million specialists. This resulted in an "inverse peak" in the 40- to 50-year range in the age structure of the faculty of higher education institutions. Those in their 40s are the smallest group, constituting only 14 percent of faculty members (Guo 1998).

- The rapid national economic development and competition and challenge of science and technology in the 21st century will doubtless require a mammoth force of high-level scientific and technical personnel.

- In China's ambitious development plan of higher education, a number of universities are to be transformed into world-class universities in the next century. One important feature of world-class universities is that they annually grant a large number of doctorate degrees and that the percentage of their faculty members with doctorates is very high—in some universities, as high as 100 percent. This can be clearly seen in a recent issue of *Asiaweek* (1997) which, based on its own evaluation, ranks Asia's top 50 universities. One important lesson from the ranking is that the relatively low percentage of faculty members with graduate degrees holds Chinese universities back.

Given these circumstances, it is imperative to pay more attention to doctoral education in the future. According to the Chinese development plan of graduate education, in the year 2000, graduate enrollment will be around 200,000. If 70,000 of these students graduate annually, given a ratio of 5:1 between master's and doctoral degrees, only about 14,000 will be doctorate recipients. In view of the current Chinese situation and the country's future development—as well as in comparison with the United States, where the corresponding ratio between annual master's and doctoral degrees is around 3:1—this number of doctoral degrees is far from what is really needed. China, aware of this situation, has already begun a "self-reliant" effort to generate doctoral degrees at home since the early 1990s.

Field Distribution of Graduate Education

The current disciplinary distribution of graduate education in China is basically a reflection of the existing base, including graduate supervisors' academic specialties and expertise (Z. Wu 1997). One of its deficiencies is an asymmetry in major fields of study, primarily characterized by two features (tables 2 and 3). First, the proportion of traditional and basic disciplines such as history, literature, natural science, engineering, and medicine is too large—combined, these fields account for 82.2 percent and 78.9 percent of all doctoral and master's degree programs, respectively. Moreover, the master's and doctoral degrees awarded in these major fields of study from 1981-95 account for as much as 82.7 percent and 88.1 percent, respectively, of degree awards. Second, the proportion of newly emerging and applied disciplines, such as economics and law, which are badly needed in a market economy is too small—combined, these account for only 7.3 percent and 8.8 percent, respectively, of total doctorate and master's degree programs. Between 1981 and 1995, degree awards in these fields accounted for only 9.3 percent and 5.9 percent, respectively, of all master's and doctoral degrees awarded. This structure of major fields of study is aimed to serve the centrally planned economy; it by no means can respond to the growing demands for various types of high-level specialized personnel from a market economy. Thus, the Chinese government should strive to readjust the structure of major fields of study in its graduate education so as to develop a structure that is both internally coherent as well as externally responsive to labor market changes in the transition from a planned economy to a market economy.

Table 2. Percent distribution of graduate programs by field of study, 1995

Field	Doctorate granting programs	Percent	Master's degree granting programs	Percent
Total	2,398	100.0	8,467	100.0
Philosophy	41	1.7	170	2.0
Economics	109	4.5	374	4.4
Law	67	2.8	374	4.4
Education	40	1.7	214	2.5
Literature	115	4.8	599	7.1
History	75	3.1	224	2.7
Sciences	465	19.4	1,345	15.9
Engineering	863	36.0	2,906	34.3
Agriculture	161	6.7	598	7.1
Medicine	454	18.9	1,571	18.9
Military science	8	0.3	92	1.1

SOURCE: *Academic Degrees and Graduate Education,* 72 (1): 50, 1997.

Future Trends in Graduate Expansion: 1995-2020

Graduate enrollment is affected primarily by the growth rate of both the national economy and the relevant age cohort. In China, to a great extent, it is also affected by public policy determinations to either set enrollment quotas to restrict growth or to let enrollment be driven by demand. The projection here is mainly based on the first two factors: the growth rate of the economy and the relevant age group.

The demand for high-level educated personnel depends to a large extent on how fast the economy grows. According to the newly issued long-term development target for the year 2010, the Chinese government's target for gross domestic produce (GDP) in 2000 is to quadruple that of 1980, and for GDP in 2010 to double that of 2000. This requires an average annual growth rate of 8 percent between 1995 and 2000, and of over 7 percent between 2000 and 2010.

Given the momentum of China's economic growth rate in the period between 1978 and 1994, it is realistic to expect GDP to continue to grow at an average annual rate of 7 to 9 percent in real terms over the next 25 years.

Table 3. Percent distribution of master's and doctoral degrees awarded by field of study (1981-95)

Number and Percent	Total	Philosophy	Economics	Law	Education	Literature	History	Sciences	Engineering	Agriculture	Medicine	Military science
Master's degree	313,006	5,681	17,731	11,701	5,166	15,914	6,669	60,527	141,119	13,115	34,690	693
Percent	100.0	1.8	5.6	3.7	1.7	5.1	2.1	19.3	45.1	4.2	11.1	0.2
1981	8,665	178	163	56	21	530	209	2,387	3,949	198	974	0
1985	12,618	207	575	336	158	648	390	3,204	5,188	834	1,708	0
Percent	100.0	1.6	4.6	2.7	1.3	5.1	3.1	25.4	41.1	6.6	8.5	0.0
1986	14,938	260	654	607	133	611	316	3,104	6,609	798	1,846	0
1990	32,557	686	1,850	1,165	585	1,374	793	6,157	14,396	1,406	4,093	52
Percent	100.0	2.1	5.7	3.6	1.8	4.2	2.4	18.9	44.2	4.3	12.6	0.2
1994	26,166	418	2,024	1,321	517	1,477	437	4,592	11,672	884	2,689	135
1995	28,098	384	2,207	1,390	547	1,484	499	4,653	13,174	903	2,723	134
Percent	100.0	1.4	7.8	5.0	2.0	5.3	1.8	16.6	46.9	3.2	9.7	0.5
Doctorate degree	22,162	345	891	428	211	523	503	6,192	8,725	773	3,560	0
Percent	100.0	1.6	4.0	1.9	1.0	2.4	2.3	27.9	39.4	3.5	16.1	0.0
1981	13	0	0	0	0	0	0	12	1	0	0	0
1985	234	5	0	0	0	6	10	94	87	0	32	0
Percent	100.0	2.1	0.0	0.0	0.0	2.6	4.3	40.2	37.2	0.0	13.6	0.0
1986	307	7	3	1	1	10	7	119	122	2	35	0
1990	2,127	29	137	34	16	45	36	590	828	88	324	0
Percent	100.0	1.4	6.4	1.6	0.8	2.1	1.7	27.7	38.9	4.1	15.2	0.0
1994	3,590	53	170	98	43	92	68	918	1,389	125	634	0
1995	4,364	60	198	102	52	116	76	1,191	1,659	182	728	0
Percent	100.0	1.4	4.5	2.3	1.2	2.7	1.7	27.3	38.0	4.2	16.7	0.0

SOURCE: *Academic Degrees and Graduate Education,* 72 (1): 51, 1997. *Academic Degrees and Graduate Education,* 71 (6): 73, 1997.

Table 4 provides estimates per capita GDP based on three scenarios of average annual GDP growth rate: (1) slow growth at 7 percent, (2) medium growth at 8 percent, and (3) fast growth at 9 percent. According to these projections, China's per capita GDP would be US$600 to US$700 by 2000, US$1,100 to US$1,600 by 2010, and US$2,100 to US$3,500 by 2020.[5]

Table 4. Expansion trends of graduate education, 1994-2020 (in constant 1994 yuan)

Rate of Growth	1994	2000	2010	2020
	GDP per capita in yuan			
Slow growth (r=7%)........................	3,800	5,400	9,900	18,300
Medium growth (r=8%)....................	3,800	5,700	11,500	23,300
Fast growth (r=9%).........................	3,800	6,000	13,300	29,600
	In dollars (8. 5 Yuan=$1)			
Slow growth (r=7%)........................	447	630	1,200	2,200
Medium growth (r=8%)....................	447	670	1,300	2,700
Fast growth (r=9%).........................	447	710	1,600	3,500
	Enrollment ratio (%)			
r=7. 6%..	0.11	0.15	0.43	0.81
r=9. 8%..	0.11	0.19	0.64	1.47
	Enrollment (thousand students)			
r=7. 6%..	128	186	387	805
r=9. 8%..	128	224	571	1,455
Country income level......................	Low	Becoming lower-middle	Lower-middle	Becoming upper-middle

NOTE: The numbers are rounded.

SOURCE: The World Bank Report No.15573-CHA, pp. 61-62 and pp. 148-151. China Statistical Yearbook 1995, China Statistical Publishing House, 1995, p 62.

The population for graduate education in China is here referred to as the 25- to 29-year-old age cohort. The reason for choosing this age group is mainly that the average age of all recipients of master's degrees awarded between 1991 and 1994 is 27.5 years (table 5). Given the current system of Chinese graduate education, the time span for master's degree studies is between 2.5 and 3 years. That means that when they entered graduate school, students were around 25 years old. Though the average age of doctoral degree recipients for this period is 31, the real average time span for doctoral studies in China is about 3.5 years (ADC and SEdC 1995), which means these students entered doctoral programs at the age of 27.5.

The population of 25- to 29-year-olds in China is projected by the World Bank to decline gradually from 1994 to around 2005, when the generation born after the implementation of China's 1979 one-child policy comes of age. The size of the 25- to 29-year-old age cohort is projected to fluctuate between 90 million at the lowest point in 2010 and 115 million at the highest in 2015, and then to go down to 99 million in 2020.

Table 5. Average age of doctoral and master's degrees awarded through full-time studies, 1991-94 (number of persons)

Year	Doctoral degree		Master's degree	
	Total	Average age	Total	Average age
1991.........	2,519	31	29,112	27
1992.........	2,503	31	23,572	27
1993.........	2,082	31	23,029	28
1994.........	3,523	32	24,780	28

SOURCE: *Data of Academic Degrees and Graduate Education Statistics to 1991-1994,* China Archives Press, 1995.

Projected graduate enrollment is based on two different enrollment growth rates (table 4):

- **Gradual Growth.** If graduate enrollment follows the historical average annual undergraduate enrollment growth rate of 7.6 percent up to 2020, China would reach an enrollment ratio of 0.15 percent of the 25- to 29-year-old age cohort by 2000, 0.43 percent by 2010, and 0.81 percent by 2020. This growth rate lags behind historical GDP growth rates, but keeps pace with undergraduate enrollment—if the latter maintains its established

[5]The World Bank's definition of country income level is as follows: low-income countries are those with a per capita GNP of US$695 or less, lower middle-income countries are those with a per capita GNP between US$696 and US$2,784, and upper middle-income countries are those with a per capita GNP between US$2,784 and US$8,626 (World Bank 1995).

growth rate over the next 25 years. If both undergraduate and graduate enrollments grow at the same rate of 7.6 percent in the next 25 years, the ratio between them will be at the 1994 level: 100:4.57.

- **Fast Growth.** If graduate enrollment growth is to catch up with the historical average annual GDP growth rate of 9.8 percent, the enrollment ratio would reach 0.19 percent by 2000, 0.64 percent in 2010, and 1.47 percent in 2020. Although total enrollment by 2020 would be 1,455,000, the enrollment ratio would still only be 1.47. However, this enrollment could be considered enormous because, if 25 to 30 percent of the students graduate annually (the majority of graduate students in China study full time, so it is entirely possible for them to complete their studies within the prescribed 3-year time span), the number of graduate degrees awarded would be about 400,000. This is similar in scale to the United States—which has the largest graduate system in the world—where advanced degrees awarded annually number about 300,000 master's degrees; 35,000 Ph.D. degrees; and 70,000 first professional degrees (e.g., M.D., Ed.D., J.D., etc.).

Beyond the two principal factors discussed above—growth rate of the national economy and population of the relevant age cohort—are two other considerations.

Projection of GDP

To estimate the public resources available in the future, three scenarios are projected of average annual GDP growth rates between 1995 and 2020 at 7 percent, 8 percent, and 9 percent. The reason for choosing these average annual growth rates is that 7 and 8 percent fall within the Chinese government's own target, and 9 percent is close to the historical growth rate of 9.8 percent between 1978-94. Projected GDP forms the basis for projection of the Chinese government's expenditure on higher education.

Projection of Government Expenditure on Higher Education

The projection of government expenditure on higher education assumes that future government expenditure remains at 12.9 percent of GDP (the ratio in 1994), and that the government expenditure on higher education is about 2.6 percent of total government spending (the ratio of 1992). The reason for choosing the 1992 ratio instead of the 1994 ratio is that the government expenditure on higher education in 1994 increased considerably over previous years; this level might conflict with the overall objective of deficit reduction. The projection is based on a pessimistic assumption that the future growth of revenue remains unchanged and that the future growth of public spending on higher education will be constrained by the need to reduce the consolidated government deficit. Using these ratios for projection, total government expenditure on higher education would increase from about Y19 to 79 billion (in constant 1994 rates), if the GDP grows at 7 percent per year between 1994 and 2020; it would grow to Y100 billion if the GDP grows at 8 percent, and to Y128 billion if the GDP grows at 9 percent (World Bank 1996).

Overseas Study and International Mobility of Scientists and Engineers

Overseas Study

The Chinese government's decision to send thousands of students for overseas study represents a historical continuity rather than a radical departure in modern China's cultural policy. For over a century, with the sole exception of the period from 1967-74, Chinese students have been studying abroad, frequently in large numbers. The roles played by the generations of returned Chinese students educated abroad in social, economic, scientific, and political modernization in general, and educational modernization in particular, have been important historically. In fact, the modern higher education system in China is a direct result of China's contact with the outside world, both West and East, brought back by returned foreign-trained students. In contrast to earlier periods, today's overseas student situation has three striking features.

First is its vast scale and scope. During the period 1978-98, about 300,000 students—50 times as much as the figure (11,900) for the 28-year period 1950-77—went to more than 100 countries and areas for overseas study; the United States was the major host country (*China Spectrum* 1998). More than half of these students were enrolled in American universities. Table 6 clearly shows the dramatically increasing enrollment and ratio of Chinese students among total foreign students in American universities from 1980-96: enrollment increased 14.3 times from 2,770 to 39,613, while the proportion rose from 0.9 percent to 8.7 percent. In comparison, the total number of foreign students in the United States increased from 311,880 to 453,787, or only 45.5 percent, in the same period. Therefore, students from China became by far the fastest growing community on American campuses. Although Chinese students have, during recent years, been the second largest foreign student population after Japanese students, during the period 1989-94, they took the lead in total foreign student enrollment in the United States. The relative decline of Chinese student enrollment after 1994 was affected by the situation in China, where the second reform tide after 1992 led to more opportunities in both the job market and graduate studies at home. As a result, the wave of overseas students slowed to some extent in recent years.

Table 6. Foreign students enrolled in American universities, 1980-81 to 1995-96

	Total foreign students	Country of origin: China	Country of origin: Japan
	1980-81		
Number..............	311,880	2,770	13,500
Percent..............	100.0	0.9	4.3
	1985-86		
Number..............	343,780	13,980	13,360
Percent..............	100.0	4.1	3.9
	1989-90		
Number..............	386,850	33,390	29,840
Percent..............	100.0	8.6	7.7
	1990-91		
Number..............	407,530	39,600	36,610
Percent..............	100.0	9.7	9.0
	1991-92		
Number..............	419,590	42,940	40,700
Percent..............	100.0	10.0	9.7
	1992-93		
Number..............	438,620	45,130	42,840
Percent..............	100.0	10.0	9.8
	1993-94		
Number..............	449,704	44,381	43,770
Percent..............	100.0	9.9	9.7
	1994-95		
Number..............	452,635	39,403	45,276
Percent..............	100.0	8.7	10.0
	1995-96		
Number..............	453,787	39,613	45,531
Percent..............	100.0	8.7	10.0

SOURCE: U.S. Department of Education, *Digest of Education Statistics 1996 and 1997,* p. 450 and p. 456.

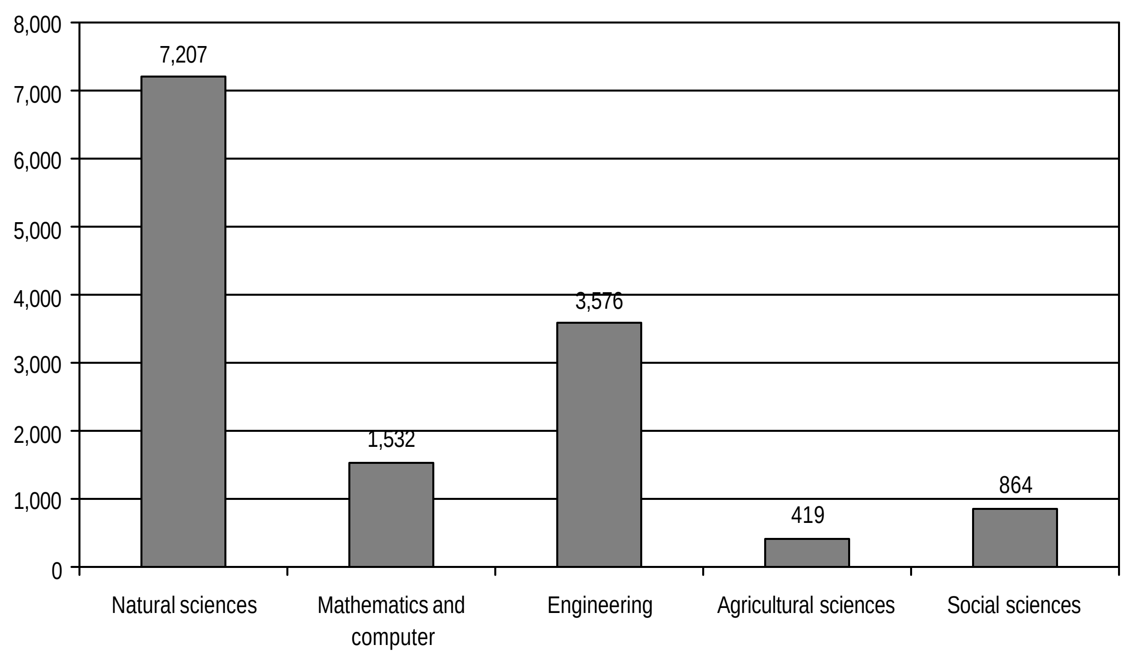
The second characteristic of the current situation is its advanced educational level. The majority of Chinese students go abroad for graduate rather than undergraduate studies. For example, among those Chinese students who were enrolled in American universities in the 1995-96 academic year, graduate students accounted for more than 80 percent (NSB 1998). Graduate training, especially at the doctoral level, is associated with research. The data in figure 2 show that, from 1988-95, American universities granted Chinese students 14,705 doctoral degrees; of these, 92.5 percent (13,598) were in science and engineering (S&E) fields. Many Chinese graduates continued their research activities as postdoctoral students after earning their Ph.D.s.

The third issue concerning overseas study is the serious problem of "brain drain": at least half of Chinese students are extending their stays or trying to seek permanent residency in foreign countries. According to incomplete statistics from the Chinese Embassy in the United States, in the past 20 years, about 160,000 Chinese students came to the United States to study; by 1998, only 30,000 of them had returned home. According to data from the U.S. National Science Foundation for the period 1990-96, the percentages of foreign S&E doctoral recipients planning to remain in the United States increased. Over 68 percent planned to locate in the United States, and nearly 44 percent had firm offers to do so. The data in table 7 show that, in 1990, 41 percent of over 1,000 Chinese S&E doctoral recipients in U.S. universities had firm plans to remain in the United States. By 1996, about 56 percent of the nearly 3,000 Chinese S&E doctoral recipients from U.S. universities had firm plans to remain in the United States. The underlying cause for this shift is the large number of Chinese students granted permanent residence status in the United States in 1992 following China's response to student demonstrations (NSB 1998).

Beyond clearly political factors, the reasons behind the rapidly growing number of nonreturning Chinese students include the relatively poor working and living conditions in China. This whole phenomenon of overseas students who do not return has severely damaged domestic teaching, research, and research and development. Given the scarcity of human resources in the country and its ambitious economic development program, such a large outflow of high-level specialized personnel represents a severe brain drain problem for China (Cao 1996).

The Chinese government has made efforts to reduce brain drain in the past 20 years. These efforts have varied over time. In general, before the mid-1980s, the

Figure 2. Chinese S&E Ph.D. degrees recipients from U.S. universities, by major field, 1988-95



SOURCE: National Science Foundation, Division of Science Resources Studies (SRS), Survey of Earned Doctorates, 1998.

Table 7. Chinese Ph.D. recipients from U.S. universities who plan to stay in the U.S. (1990-96)

Year	All fields				
	Total Ph.D. recipients	Plan to stay in U.S.		Firm plans to stay in U.S.	
	Number	Number	Percent	Number	Percent
1990..........	1,225	725	59.2	502	41.0
1991..........	1,919	1,523	79.4	920	47.9
1992..........	2,238	1,980	88.5	1,080	48.3
1993..........	2,416	2,134	88.3	1,077	44.6
1994..........	2,772	2,548	91.9	1,223	44.1
1995..........	2,979	2,744	92.1	1,341	45.0
1996..........	3,201	2,896	90.5	1,788	55.9

SOURCE: National Science Board, *Science and Engineering Indicators 1998,* (NSB 98-1), pp. A-89-A90, Arlington, VA, 1998.

policies on study abroad were considered “fairly liberal” by foreign experts (Altbach 1991). For example, in 1984, the State Council announced: “All Chinese citizens who are able to secure financial support in foreign currency or foreign scholarships through proper means and who have gained admission to foreign educational institutions can apply for undergraduate or graduate studies at their own expense regardless of former education, age, or length of employment” (Du 1992). After the mid-1980s, the Chinese government became conscious of the fact that over 95 percent of the students sponsored by the government did not show any sign of coming back (Zhao 1996). As a result, the state gradually limited the number of government-sponsored students and set more and more rules to restrict their numbers.

Two important rules aimed to reduce the ratio of those going abroad and those not returning. According to the first rule, a bachelor’s degree-holder had to work in China for at least 5 years, and a master’s or doctoral degree-holder for at least 2 years, before going abroad. Since the majority of Chinese students were seeking their permanent residency in the United States, the second rule was set to reduce the ratio of emigration. The Chinese government planned to send the majority of students to countries that were capable of accepting more, but that had taken few so far. Of the government-sponsored students, about 20 percent would be sent to the United States, 50 percent to Europe, 20 percent to Australia, and 10 percent to Japan (Reed 1988).[6] After the June 4 event in 1989, due to some restrictions, the number of going abroad was further reduced. However, this picture has begun to change since 1992, when more relaxed and liberal policies on overseas study were formulated.

[6]The real intention of the Chinese government was to send more students to European countries whose immigration laws are very strict.

International Mobility of Scientists and Engineers

In 1996, the Chinese government strategy started to shift from concentrating on the return of overseas Chinese students and professionals, as well as blocking the outflow of scholars and students, to tolerating their migration, optimizing their contributions, and improving the home environment (Cao 1996). A new policy of supporting study abroad, encouraging return and free movement in and out of the country was introduced in 1992; and the government made a clear connection between supporting study abroad and the nation's strategic development in the next century. This new policy represents the most relaxed policy on study abroad in China since 1978. To some degree, this has encouraged China's high-level specialized personnel to join in the international scientific community, generating greater international mobility of scientists and engineers in and out of China. This is demonstrated in several ways, including the following.

Reform in Overseas Study Policies. In 1996, the State Overseas Study Foundation was established to select and sponsor qualified scholars nationwide for overseas study. Most of them are visiting scholars, and the length of stay is usually 1 year. Each candidate has to sign a contract with the foundation, along with a guarantor. If the candidate fails to return on schedule, the guarantor has to help the foundation get the candidate to return or pay fines stipulated in the contract. In 1998 alone, 1,709 scholars were selected and sponsored for overseas study. The data show that the return ratio of those sponsored by the foundation since 1996 is 85.7 percent. All those who remained have paid off the fines (*Chisa* 1998).

New Policies on Attracting Students. Since 1992, many educational and research institutions and organizations in China have formed career delegations that have visited the United States, Britain, Germany, Japan, and other developed countries to recruit overseas Chinese students and professionals. Since then, an increasing number of Chinese students and professionals are going back to China for either long-term work assignments or short-term academic and business visits. For example, between 1993-94, more than 10,000 overseas Chinese students and scholars made such visits. In 1994, 65 Ph.D.s returned to China from France alone.

Many institutions in China have taken measures to improve the home environment in attempts to attract overseas Chinese students and professionals. The Chinese Academy of Sciences is seeking an extra Y2 billion (US$240 million) a year for recruiting 600 bright young researchers from overseas in 1998 to 2000 (*Nature* 1998). The Ministry of Education announced in August 1998 that it would establish a special professorship system. Within the next 3 to 5 years, 300 to 500 outstanding young researchers would be selected from both home and abroad and granted the rank of specially appointed professors by key Chinese universities (*Chisa* 1998).

Many local governments in China also have established special policies to attract overseas Chinese students. In Shanghai alone, according to a recent report, 16,000 students have returned as of August 1998. In addition, several thousand overseas Chinese scholars have arranged business visits with the municipal government, and 557 have registered and opened businesses. Most of these represent high-tech companies and consulting firms (*Chisa* 1998).

With their newly acquired knowledge and expertise, these returned students and scholars have been playing key roles in China's higher education, scientific research, and production management. For example, of the 36 institutions of higher learning directly administered by the SEdC, more than half were headed by returned scholars. In many universities, over 80 percent of the academic leaders and chairpersons have some overseas experience.

Acceptance of Foreign Students for Study in China. From 1978-97, more than 258,000 foreign students came from over 160 countries and regions to China for study at different levels, including baccalaureate, master's, and doctoral programs as well as short-term programs. In 1997 alone, over 43,000 foreign students—35.8 times as many as the number (1,200) in 1978—were studying in China. Of the 4,569 foreign students sponsored by the Chinese government in 1997, 4.9 percent were enrolled in doctoral programs, 14.5 percent in master's degree programs, and 33 percent in bachelor's degree programs. In addition, in the same year, 39,035 were self-financed, of which 2 percent were pursuing doctoral degrees, 4.6 percent master's degrees, 28 percent bachelor's degrees, and 0.3 percent short-term diplomas (*Chisa* 1998).

In addition to the foreign students studying in China, there are also more students from overseas regions of Hong Kong, Macao, and Taiwan coming to study in mainland China. During the 10-year period 1988-97, 403 students from these three regions were enrolled in Chinese universities. Most were graduate students (*Chisa* 1998).

International Exchange Activities. From 1979-96, according to incomplete statistics, the cumulative number of foreign scientists and engineers invited for various types of visits by China reached 570,000. In 1997 alone, more than 80,000 foreign experts and scholars were working in China (*Chinanews* 1998). In 1996, about 7,000 Chinese teachers and experts working in various fields were sent abroad to teach or give short-term lectures. During the period 1978-97, the number of Chinese scholars going abroad to attend international conferences and the number of foreign participants coming to China to attend international conferences hosted by Chinese institutions both exceeded 11,000 (Liu 1998).

Jointly Run Institutions. In addition to these international exchanges, some forms of international cooperation also took shape. An example of inter-institutional collaboration is the Nanjing-Johns Hopkins Center for Chinese and American Studies. Opened in the fall of 1986, it is jointly run by Nanjing University of China and Johns Hopkins University of the United States. The center offers a two-semester graduate-level curriculum in culture, economics, politics, foreign policy, international relations and law, modern history, and U.S.-China relations. The American students make up half of the total student body; Chinese students make up the other half. The author's personal experience in meeting American graduates from this center has been that they demonstrate substantial expertise on Chinese affairs and make contributions to the promotion of mutual understanding and friendship between China and America.

As early as 1993, some top Chinese universities, such as Beijing University, Shanghai Jiaotong University, and Nanjing University, started to offer 3-year Chinese master of business administration programs for Mandarin-speaking managers; these were offered first in Singapore and then in Malaysia. Xiamen University began offering a 6-year degree correspondence course in Chinese language and literature in Singapore in 1994 in collaboration with local institutions. This is the first time Chinese universities have offered Chinese degrees to individuals outside the country (Meng 1994).

CONCLUSION

It has been 20 years since graduate education was resumed in China in 1978. During this period, while Chinese graduate education has experienced remarkable development, many deficiencies remain in a course characterized by uneven development. Graduate education was resumed in a planned economy context and is being developed in a transition period toward a market economy. Thus, Chinese graduate education inevitably bears the dual imprints of the two periods. The current Chinese graduate education system is somewhat of a hybrid of the Soviet system and the American system, but it is tending to move toward the later. One of the main challenges faced by the Chinese government is to keep an appropriate growth rate for graduate education in accordance with future economic development and to readjust the disciplinary structure to meet the needs of a transition from an extensive-type (labor-type) economic growth to an intensive-type (knowledge-type) economic growth.

Chinese policies on overseas study have not been entirely successful. Although the situation in China has been improving, there are still many Chinese students and scholars going and remaining abroad. In recent years, China has started to participate in the international scientific community, but the scale is still limited in comparison to some other countries and regions. Of the many factors affecting the movement of overseas students and scholars, economics always plays a critical role. South Korea and Taiwan had a similar problem of brain drain before the mid-1980s. However, when their per capita GNP reached about US$4,000, their overseas students and scholars started to flow back home. Currently, China has a per capita GNP of nearly US$700. If the country continues to reform its economic structure, relying on scientific and technological progress in its transition to a market economy, the demand for specialized personnel will be high. Considering China's special circumstances, it seems likely that, when it has a per capita GNP of US$2,500 to US$3,000, China will turn brain drain to brain gain and benefit from the reverse flow of overseas Chinese students and scholars.

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GRADUATE EDUCATION REFORMS AND INTERNATIONAL MOBILITY OF SCIENTISTS AND ENGINEERS IN HONG KONG

Yugui Guo

As of July 1, 1997, Hong Kong ceased to be a colony of the United Kingdom and became a special administrative region (SAR) of the People's Republic of China under a "one country-two systems" arrangement. According to this arrangement, Hong Kong has been promised self-rule; it has also been promised that its higher education system can retain its unique characteristics rather than having to align with the mainland Chinese system. This paper explores higher education issues in Hong Kong.

GENERAL REVIEW

Hong Kong has been a Chinese territory since ancient times, except for the period 1842-1997 when it was a British colony. Situated at the southeastern tip of China, Hong Kong has a total land mass of only 1,092 square kilometers. Though it ranks 90th in terms of population, Hong Kong is the world's 8th largest trading economy. Its 6.3 million inhabitants (97 percent Chinese) enjoy the second highest living standard in Asia.

Higher education in Hong Kong has existed for more than 80 years. The oldest current institution is the University of Hong Kong (HKU) which was founded in 1911. As the governors were not always interested in making decisions on Hong Kong education (Ip 1998), it was not until 1963 that a second university, Chinese University of Hong Kong (CUHK), was established. However, as Hong Kong industry and commerce moved from low-skilled, low-wage production toward more sophisticated markets and outputs, employers needed a better educated workforce; they also needed more people educated at the highest level. The pressure for wider access to higher education was met in part by expanding existing institutions and in part by founding new ones. At present, there are eight institutions of higher education that receive funds from the University Grants Committee (UGC):

- HKU,
- CUHK,
- City University of Hong Kong (CityU),
- Hong Kong Baptist University (HKBU),
- Lingan College (LC),
- Hong Kong Polytechnic University (PolyU),
- Hong Kong University of Science and Technology (HKUST), and
- Hong Kong Institute of Education (HKIEd).

These institutions fulfill different roles in accordance with their size, tradition, and level; this information is summarized (with some simplification) in table 1.

CityU and PolyU, until recently polytechnics, emphasize the application of knowledge and vocational training. HKBU and LC stem from a liberal arts tradition, which regards breadth of education as important. CUHK,

Table 1. Current roles of UGC institutions

Institution	Sub-degree work	First degree work	Graduate degrees	Research	Professional schools	Links with industry or community
CityU and PolyU	substantial	substantial	some	some areas	some	strong
HKBU	-	predominant	some	some areas	-	strong
LC	-	predominant	minimal	some areas	-	strong
CUHK and HKU	-	substantial	substantial	all areas	many	high level
HKUST	-	substantial	substantial	all relevant areas	some	high level
HKIEd	substantial	-	-	-	-	strong

KEY: (-) indicates not applicable.

SOURCES: University Grants Committee (UGC), *Higher Education in Hong Kong,* Hong Kong, 1996; and UGC, *Roles and Operations,* Hong Kong, 1998.

HKU, and HKUST have major professional schools and substantial research programs. CUHK and HKU are full-scale universities, and both have medical schools. HKIEd, which joined the UGC July 1, 1996, currently offers predominantly subdegree programs (similar to the U.S. associate degree) of teacher education and continuing professional education so as to serve teachers and help maintain strong links with both schools and the teaching profession.

Levels and Qualifications of Higher Education

Hong Kong's children are required to remain in school until the age of 15 or the end of secondary 3,[1] whichever is earlier. They thus all receive a minimum of about 3 years of secondary education. After secondary 3, some children drop out of formal education, while others join craft and technician courses, but about 91 percent choose to stay at school for a further 2 years. They take curricula leading to the Hong Kong Certificate of Education Examination (HKCEE). Some of the learning opportunities after the HKCEE lie within Hong Kong's broad structure of higher education. These include 2- to 3-year subdegree courses, usually vocational in nature; and 3-year courses of teacher education.

At present, 38 percent of children remain in school after secondary 5 (HKCEE) and take 2-year sixth form courses leading to the Hong Kong Advanced Level Examination (HKALE). Students with appropriate grades in the HKALE may then enter 3-year diploma or first degree courses or 2-year courses of teacher education. To enter a full-time undergraduate program, a student must meet general educational qualifications, usually including proficiency in English and Chinese; and have passed the HKALE at least once. For science, technology, and medical programs, there are also specific HKALE or HKCEE subject requirements; similar requirements are less common in the arts and social sciences.

In general, a full-time undergraduate course lasts 3 years. Some courses are of 2 years' duration because they build on an earlier qualification such as a diploma in the same subject area. Additionally, students may be admitted to the second year of a 3-year course if they possess "advanced standing" by virtue of previous study or experience. On the other hand, some undergraduate courses are extended to 4 years because they contain one or more periods of professional experience. Examples include the courses in language education and the bachelor of science degree in speech and hearing sciences at HKU.

Those gaining first degrees or equivalent qualifications may subsequently be admitted to taught higher degrees or may undertake research for a master's degree or doctorate.[2] Full-time postgraduate courses leading to master's degrees or doctorates are restricted to the UGC institutions, but part-time provision is more widespread. Some non-UGC institutions offer part-time programs leading to postgraduate diplomas, certificates, or degrees. Postgraduate certificate and diploma courses usually take 1 year of full-time study or 1 to 2 years part time. Master's courses take 1 to 2 years full time or 2 to 3 years part time. The purposes of taught postgraduate courses are diverse. The diploma and certificate in education courses run by HKBU, CUHK, HKU, and HKIEd qualify successful participants to teach in secondary schools. The postgraduate certificate in law offered by CityU and HKU enables successful students to enter the legal profession as student barristers or solicitor trainees. Other postgraduate courses take specialist knowledge in a particular field beyond that acquired in undergraduate courses: an example is the M.A. degree in arbitration and dispute resolution offered at CityU.

Taught postgraduate courses are the principal means by which higher education institutions can respond swiftly to changing situations and the changing needs of both students and society. The various UGC institutions choose different ways to organize their taught courses and different nomenclature to describe them. For example, HKU's nine faculties offer about 60 taught postgraduate courses under specific degrees such as the master of science in urban planning or advanced diploma in orthodontics. CUHK has 35 graduate divisions which offer 15 master of arts, science, or social science courses and 2 diploma programs. HKUST has about 14 taught postgradu-

[1]In Hong Kong, compulsory education lasts for 9 years. Primary schooling begins at the age of 6 and lasts for 6 years, and secondary junior schools offer a 3-year course in a broad range of academic subjects.

[2]In both the United Kingdom and Hong Kong, postgraduate education falls into two categories. The first category is programs based mainly on systematically taught courses that characteristically lead to a master of arts or master of science degree. These programs have only coursework, with no research or thesis requirements. The second type of program leads to a master of philosophy or doctor of philosophy (Ph.D.) degree. These degrees are largely awarded on production of a thesis or dissertation through research training (Henkel and Kogan 1993, p. 72).

ate courses, including some interdisciplinary ones, under fairly general titles. CityU's four faculties have some courses with specific titles. PolyU's taught graduate courses, mostly part time and on a credit accumulation basis, are offered by individual departments: there are about 50 in all, but many are based on a modular scheme incorporating common units. HKBU has a small number of courses of recent origin. In all, there are about 170 taught postgraduate courses available, with a typical class size of 10 to 20 full-time-equivalent students.

Many of the taught master's degrees can be extended to a master's of philosophy (M.Phil.) by the incorporation or addition of a substantial piece of research and presentation of a thesis; the M.Phil. is well-regarded in Hong Kong. The additional work is usually expected to take from a few months to a year. Other M.Phil. programs stand alone or are structured as the preliminary stages of a Ph.D. degree. The Ph.D. supposedly takes 3 to 4 years full time (the UGC has recommended support for up to 4 years), or about 5 to 6 years part time. Approximately 60 percent of students pursuing an advanced research degree take the M.Phil.; 40 percent take the Ph.D.

In an endeavor to reduce the costs of preliminary training for Ph.D. research, the science faculties in the institutions have recently introduced a scheme for joint courses. In some scientific and technological areas, because of the need for specialized and expensive equipment, work for an M.Phil. or Ph.D., although original, forms part of a team effort on a particular research topic. In other areas—most usually in the arts and social sciences—the research student works alone. Until quite recently, motivation for research in many Hong Kong universities was low. These attitudes have changed very markedly in the last few years. Thus, although research students have an important role to play in the conduct of research in some disciplines, it is difficult to pursue research degrees without an existing academic staff with both the motivation and means to search for new knowledge.

Governance and Finance

Following United Kingdom tradition, universities in Hong Kong are permitted to operate with a high degree of autonomy. Individual institutions determine their own policies for recruitment of staff and students, for the nature and length of courses, and for the balance between subject disciplines (Bray 1992).

However, the government does exercise some influence through its control of finance. The most influential body on higher education in Hong Kong is the UGC, which was founded in 1965 on the model of the UK body of the same name. Its main role is "to advise government on the funding of new institutions and the upgrading of existing ones, on major subject developments to meet community needs, on employment matters, and many other subjects relevant to tertiary education in Hong Kong" (UGC 1996, p. 9). In 1972, the committee was renamed the University and Polytechnic Grants Committee (UPGC), to reflect the inclusion of the then-titled Hong Kong Polytechnic within its purview. Following the adoption of university titles by the two polytechnics and the Hong Kong Baptist College, the committee reverted to its original title—i.e., UGC—in 1994.

UGC members are appointed by the chief executive of the SAR (before July 1, 1997, by the governor), and are all prominent in their fields. The membership comprises eminent academicians, businessmen, and administrators. No government officer sits on the committee, but its secretariat is staffed by civil servants. The nationalities of its members reflect the sources of influence from abroad. In 1998, the committee included nine local Hong Kong Chinese, four British, three American (one a professor of Hong Kong Chinese origin), and two Australian members. The remaining three members are from the Netherlands, Singapore, and mainland China (UGC 1998).

As chancellor, the chief executive of the SAR (before July 1, 1997, the governor) is the nominal head of all UGC-funded institutions. The executive head of each is its vice chancellor, who is assisted by pro-vice chancellors. The senate oversees the academic affairs of a university. Each university is subdivided into faculties and departments.

The UGC is an administrative device to ensure that institutions of higher learning can be adequately financed without misuse of large sums of money while maintaining autonomy (Mak and Postiglione 1997). The key word in the title is "grants." The UGC recommends a triennial block grant for each institution. Its funding methodology is based upon two major activities: the quantity of teaching, primarily related to number of students; and the quantity of research, largely determined by the number of academic staff. Although there is much discussion between the UGC and the institutions based upon academic and other plans and opportunities, and much discussion between the government and the UGC about available finance and community needs, once the block grant is settled, each institution has very wide latitude as to its use.

In the 1997-98 academic year, the Hong Kong government spent 1.23 percent of its gross domestic product on UGC institutions. The total amount of approved grants for these institutions was HK$13,218 million (including recurrent grants of HK$11,808 million and capital grants of HK$1,410 million), accounting for 5.4 percent of total public expenditures and 27.2 percent of total public expenditures on education (UGC 1998).

Students in UGC institutions are heavily subsidized. In 1987, the government announced plans to reduce the subsidy, but projected that by 1993-94 fees would still cover only 12 percent of the total real cost. This was revised in 1991, but the new projection is still only 18 percent by 1997-98. Moreover, the government also runs a grants and loans scheme to ensure that no one will be deprived of the opportunity for higher education because of financial difficulties (Cheng 1995). The scheme seems to achieve this objective, and the high salaries for graduates make it easy for the majority of students to repay their loans.

Expansion and Level Structure

In the 1980s, the growing demand for a more highly qualified workforce and the loss of graduates through emigration resulted in the Hong Kong government's adoption of an ambitious tertiary education development policy. The expansion of this sector was first announced by the governor in 1988. It was revised in 1989 to set an even more ambitious pace of development, with the aim of doubling the number of first-year first-degree (FYFD) places from 7,000 in 1990 to 15,000 in 1995. By then, 6 out of 10 sixth form completers would be able to participate in some form of higher education in Hong Kong. This would be 18 percent of the age group, compared with around 8 percent in 1990 (Sensicle 1992).

The expansion of FYFD places and the consequent growth in total undergraduate numbers are shown in table 2. From 1991-92 to 1997-98, FYFD places increased by 37.2 percent—from 10,665 to 14,632—and undergraduate enrollment rose by 56.9 percent—from 29,199 to 45,823. Due partly to the undergraduate expansion, postgraduate enrollment witnessed a corresponding expansion (table 2 and figure 1). During the same period, total postgraduate enrollment more than doubled, rising from 4,279 to 9,010. Of this, taught postgraduate enrollment increased by 86.4 percent—from 2,931 to 5,465—and research postgraduate enrollment rose by 163 percent—from 1,348 to 3,545.

If the government had very clear views on desirable undergraduate numbers, the issues were more complex and sometimes conflicting regarding postgraduate development. Hong Kong has been, in fact, remarkably reluctant to become involved in research. Until quite recently, there had only been a limited "research culture" in Hong Kong's higher education institutions (in 1994-95, only 50 percent of the academic staff themselves held doctorates). Partly because the recent major expansion of the system has led to the recruitment of many new staff members from outside Hong Kong, and partly due to the government's financial encouragement—including the 1991 establishment of the Research Grants Council as a support mechanism—that situation is changing. Research activity has recently grown very markedly and so has the number of postgraduate students. Table 3 shows this expansion: from 1991-92 to 1997-98, postgraduate

Table 2. Student enrollment of UCG-funded programs, 1991-92 to 1997-98

Number of full-time equivalent students enrolled [a]	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98 [b]
Total	47,480	51,190	54,574	57,935	62,014	69,022	69,723
Subdegree	14,001	12,332	10,214	9,370	9,436	14,540	14,890
Undergraduate	29,199	33,351	38,150	41,782	44,701	45,965	45,823
Taught postgraduate	2,931	3,565	3,904	4,236	4,924	5,163	5,465
Research postgraduate [c]	1,348	1,943	2,306	2,547	2,953	3,353	3,545
First-year first-degree places	10,665	12,090	12,726	14,253	15,070	14,779	14,632

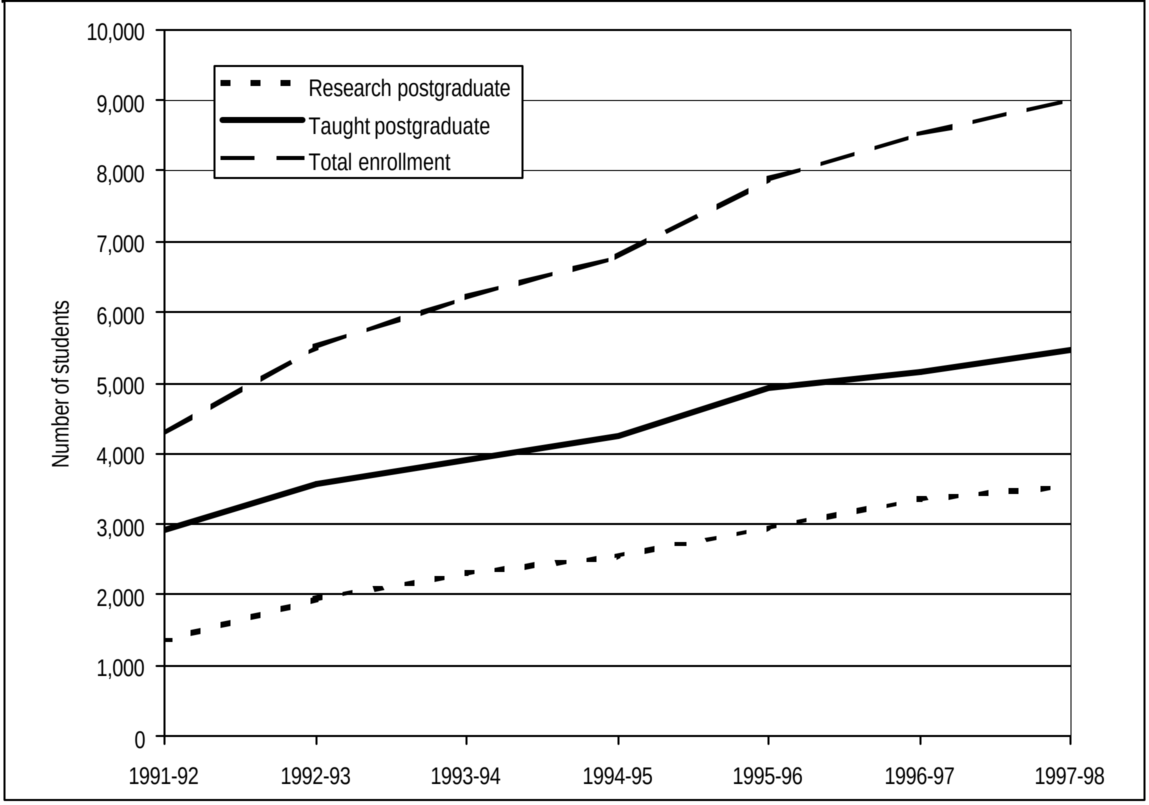
[a] Enrollment figures include blister students and nonlocal students.

[b] The Hong Kong Institute of Education came under the aegis of the UGC as of July 1, 1996.

[c] Research postgraduate figures refer to student enrollment numbers counted within UGC target.

SOURCE: University Grants Committee (UGC), *Higher Education in Hong Kong,* Hong Kong, 1998.

Figure 1. Postgraduate enrollment in UGC institutions, 1991-92 to 1997-98



SOURCE: University Grants Committee (UGC), *Higher Education in Hong Kong,* Hong Kong, 1998.

education output increased by 139.6 percent (graduates of taught postgraduates and research postgraduates increased by 98 percent and 485.5 percent, respectively).

Distribution of Enrollment by Broad Field

The expansion of the UGC component of the higher education system did not occur uniformly across disciplines. Rather, it has largely reflected economic development and the shift of the industrial structure in Hong Kong. As the economy shifted from relying on entrepot trade in the 1950s to manufacturing in the 1960s and 1970s, skilled and semiskilled labor of more diverse sorts were in demand. With competition from neighboring newly industrialized countries, Hong Kong had to shift from labor-intensive to technology-intensive industries; this in turn meant that Hong Kong would have to function as a service center rather than a manufacturing center and that its manpower needs would be changing accordingly.

In 1993, Hong Kong had a workforce of 2.8 million. Of this, 28 percent were engaged in wholesale, retail, import and export trades, and restaurants and hotels; 11.2 percent in transport, storage, and communications services; 9.4 percent in financing, insurance, real estate, and business services; 20.2 percent in community, social, and personal services; and 21.1 percent in manufacturing. The Hong Kong Statistics Department reported that the share of the labor force employed by the manufacturing sector had declined from 47 percent in 1971 to 41.2 percent in

Table 3. Graduates of postgraduate education in UGC institutions, 1991-92 to 1997-98

Level	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97[a]	1997-98[b]
Total	2,372	2,599	3,183	3,519	4,109	4,568	5,684
Taught postgraduate	2,117	2,274	2,668	2,924	3,386	3,694	4,191
Research postgraduate	255	325	515	595	723	874	1,493

[a] The Hong Kong Institute of Education (HKIEd) came under the aegis of the University Grants Committee (UGC) as of July 1, 1996.

[b] Graduate numbers for the academic year 1997-98 are projected.

SOURCE: University Grants Committee (UGC), *Higher Education in Hong Kong,* Hong Kong, 1998.

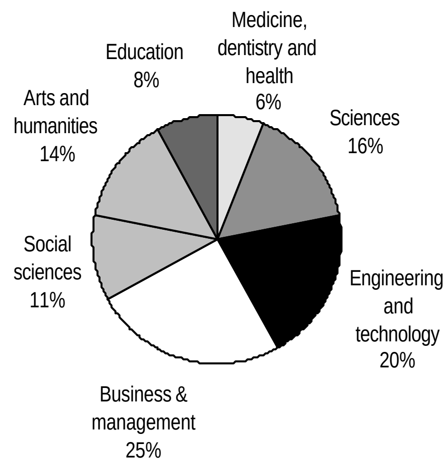
1981 and 28.2 percent in 1991 (Cheng 1995). It is obvious that education has become an increasingly important asset for a labor force that seeks to improve its remuneration and opportunities in the expanding service industries.

Table 4 demonstrates corresponding trends in disciplinary development. From 1993-94 to 1997-98, enrollment in engineering and the sciences declined from 26 percent to 20 percent and from 19 percent to 16 percent, respectively; enrollment in business and education increased from 22 to 25 percent and from 4 to 8 percent, respectively; enrollment in medicine and the social sciences remain essentially stagnant.

The largest field in higher education in 1997-98 was business studies, which accounted for a quarter of all tertiary enrollment in Hong Kong (figure 2). Engineering and the sciences are also important (accounting for 20 percent and 16 percent, respectively); with the arts and humanities marginally behind (14 percent). The social sciences and education follow (11 percent and 8 percent); together with medicine (6 percent), these occupy smaller, but important, niches.

As far as the disciplinary structure of postgraduate enrollment is concerned, the UGC report of 1996 provides a slightly different picture. Business studies (particularly toward an MBA) and education accounted for about a quarter each of taught postgraduate students. The next largest disciplines were engineering and the social sciences, a few taught postgraduates were in the sciences or humanities. Two-thirds of research students were in scientific or technological areas.

Figure 2. Distribution of enrollment by broad disciplines in UGC institutions, 1997-98



SOURCE: University Grants Committee (UGC), *Higher Education in Hong Kong,* Hong Kong, 1998.

In 1994-95, funding for new research projects through the Research Grants Council (RGC) was HK$245.6 million, as compared with HK$217.7 million through the UGC. Of RGC grants, 32 percent were awarded in engineering; 26 percent in biological science and medicine; 19 percent in physical science; and 23 percent in social science, business studies, and the humanities. The disciplinary structure of higher and graduate education to a great extent matches the current economic structure in Hong Kong, in its dual role as a leading metropolis and business hub of South China and as a regional and international financial and service center.

Table 4. Student enrollment by broad disciplines, 1993-94 to 1997-98

Discipline	1993-94	1994-95	1995-96	1996-97 [a]	1997-98 [b]
Headcount (total enrollment)	70,241	72,154	75,557	85,550	86,202
	Percentages				
Medicine, dentistry and health	6	6	6	6	6
Sciences	19	20	18	16	16
Engineering and technology	26	24	22	20	20
Business and management	22	22	27	25	25
Social sciences	12	11	12	11	11
Arts and humanities	11	12	11	14	14
Education	4	5	4	8	8

[a] The Hong Kong Institute of Education (HKIEd) came under the aegis of the University Grants Committee (UGC) as of July 1, 1996.

[b] Graduate numbers for the academic year 1997-98 are projected.

SOURCE: University Grants Committee (UGC), *Higher Education in Hong Kong,* Hong Kong, 1998.

Overseas Study and International Mobility of Scientists and Engineers

Overseas Study

In 1992, owing to long-standing restrictions on higher education in Hong Kong, large numbers of students went overseas, generally for three major reasons: limited educational opportunities in tertiary education, job discrimination against graduates of local institutions, and political uncertainty. Since World War II, there have been three waves of student migration. The first wave was from the late 1940s to the late 1960s; this saw students leave primarily because of discrimination at home. In general, students from mainland China universities, Hong Kong private colleges, and even from CUHK did not have equal opportunity in the job market in Hong Kong as compared to graduates from HKU. Thus they went "overseas for further studies in order to obtain qualifications recognized within the British Commonwealth or to seek opportunities elsewhere" (Wu 1992, pp. 47-48).

The second wave was caused by the student and nationalist movements of the 1960s, which culminated in the riots of 1967, and by the growth of wealth within the territory. The main push to leave Hong Kong during this phase came from both increasing affluence and political uncertainty caused by the events within China. The students who left were primarily from relatively wealthy families. Unlike their predecessors who left to pursue graduate studies, most of these second-wave students were in pursuit of undergraduate studies.

In the third wave, stimulated by political uncertainty due to the impending transfer of sovereignty to China in 1997, overseas education combined with the migration of entire families to create a major outflow of population to North America, Britain, and Australia. The majority went for university studies, but many went for secondary education as well.

Because the Hong Kong government guarded against rapid expansion of higher education before the 1980s, the supply of university places was very limited. In the mid-1970s, the proportion of those in the 17- to 20-year-old age group who had access to FYFD places never exceeded 2.5 percent (Mak and Postiglione 1997). Although the higher education sector expanded dramatically later, competition to enter higher education remained intense throughout the 1980s. In the middle of the decade, less than 3 percent of the age group in Hong Kong was able to study in local universities, a figure that compared unfavorably with 5 percent in Singapore and 10 percent in the United Kingdom (Bray 1992). As late as 1994, only three institutions in Hong Kong enjoyed university status. Because of the intense competition, many people were forced to study abroad; in the mid-1980s, Hong Kong had as many students abroad as at home. Table 5 shows that the number of students leaving in the peak year of 1990 amounted to more than half of the 41,301 students in UGC-funded institutions in 1990-91. Their intake of first-year students in the same year was 8,575. Unfortunately, just as universities in Hong Kong had achieved a respectable international standard, middle-class parents were sending their children abroad because they wanted to provide them the option of remaining overseas in preparation for 1997 (Cheng 1995).

In 1994-95, 56,000 undergraduate students were enrolled in Hong Kong universities, and 28,000 were in overseas universities, resulting in a ratio of 1:0.5. At the postgraduate level, the numbers were, respectively, 7,000 and 12,000, for a ratio of 1:1.7. Of the estimated 40,000 Hong Kong students in higher education who were studying outside the territory, about 70 percent were undergraduates. Almost all of these took full-time courses.

There are only limited data available regarding subject breakdown for these students. In the United States, 35 percent took business studies and 16 percent engineering. In the United Kingdom, the proportions were, respectively, 35 and 13 percent. In Australia, half of all Hong Kong students were taking business studies, and only 9 percent were in engineering (UGC 1996).

The relative popularity of the host countries has changed somewhat (see table 5). Traditionally, the United Kingdom received the most students from Hong Kong. In recent years, the United States has taken over. For example, in 1994-95, the United States had about 13,000 Hong Kong students in higher education;[3] the United Kingdom, 10,000; Australia, 9,000; and Canada, about 6,500. Numbers for other places of study, such as mainland China and Taiwan, were smaller, but may amount to another 2,000 in all (UGC 1996). Extensive overseas study is a drain on the economy, but helps make Hong Kong an international society.

[3]Between 1986 and 1995, American universities awarded 952 doctoral degrees to Hong Kong students (NSB 1998, p. 2-31).

Table 5. Number of Hong Kong students leaving for overseas study, 1988-91					
Year	United States	Canada	United Kingdom	Australia	Total
Total..........	20,776	19,126	17,172	16,673	73,747
1988......	4,215	3,808	3,856	3,147	15,026
1989......	4,855	5,096	4,539	4,678	19,168
1990......	5,840	5,681	4,349	5,258	21,128
1991......	5,866	4,541	4,428	3,590	18,425

SOURCE: Cheng, Joseph Y.S. Higher Education in Hong Kong-The Approach to 1997 and the China Factor. *Higher Education* 30(3): 257-71, 1995.

In addition to studying abroad, students have increasingly had the opportunity of gaining access to higher education through courses offered by overseas institutions of higher education in Hong Kong. The territory has always imported some education in response to demand for subjects related to service industries such as hotel management, business administration, accounting, international trade, and financial management. As recently as 1993, it was estimated that the demand for these and similar courses largely exceeded local supply; government projections forecast a continuing shortfall in 2001 (Chan and Drover 1997). Overseas institutions are beginning to compete with local institutions for students in an expanding array of courses to help meet this need. This new trend toward the globalization of educational institutions may well make this the hub of its educational exchange with the rest of the world. The influx of overseas institutions may reflect a trend of educational institutions going in search of international students instead of international students coming to them.

International Mobility

The rapid increase in the development of higher education in Hong Kong made the government realize that continued reliance on an overseas organization was no longer appropriate and that it would be desirable to consider the establishment of a Hong Kong system. Large numbers of students were still going abroad, but this tendency was likely to become less pronounced when more local opportunities became available in the 1990s. After 1994, the number of students at local universities surpassed that going overseas (Postiglione 1998). There has been a reverse movement in recent years. Consulates-general of Western countries in Hong Kong have reported a decline in the numbers of emigration visas granted. For example, the U.S. consulate-general indicated that only 13,142 people were granted emigration visas in 1993, down from 14,882 in 1992 and 18,880 in 1991. There are also signs that an increasing number of people who had emigrated are returning to Hong Kong. The Hong Kong government estimated in 1995 that at least 12 percent of the people who had emigrated in the 10 years prior to 1992 had returned to Hong Kong (Cheng 1995).

Besides bringing its own students back home, Hong Kong is beginning to compete with established universities abroad in attracting overseas students. The numbers are at present small, but they are growing, particularly at the postgraduate level. Chan and Drover (1997) identified three reasons for moving in that direction. First is the extent that newly created wealth has enabled Hong Kong to develop university quality equivalent to other developed economies of the world. Second, this policy recognizes the value of diversifying the Hong Kong student body and welcoming students from other cultures to enhance the intellectual and research environment for students who cannot study abroad. Third, faced with potential “brain drain” in the form of increased competition from recognized universities and newly emerging private universities, all of which are using increasingly sophisticated marketing strategies to attract a rapidly expanding cohort of university aspirants whose families are able to fund their education, the best defense is for Hong Kong to take the offense by internationalizing its own student body.

The international character of Hong Kong’s universities is underscored by the composition of its academic staff. In the past, chiefly because of shortages of qualified local applicants, Hong Kong institutions of higher learning employed a significant number of expatriates. The percentage has been reduced, but it remains prominent. This international influence in higher education continues, as shown in the country of origin of faculty. For example, in 1993-94, 33 percent of all faculty in nine tertiary institutions were registered as nonlocals. Comparable figures by institution show different degrees of internationalization (Mak and Postiglione 1997):

- HKUST—55 percent,
- HKU—51 percent,
- the Academy of Performing Arts—51 percent,
- CUHK—37 percent,
- LC—30 percent,
- CityU—28 percent,

- HKBU—22 percent,
- Open Learning Institute—22 percent, and
- PolyU—18 percent.

Despite the transfer of sovereignty, the academic profession in Hong Kong has maintained its staff, including a high proportion of international faculty. In fact, the 1997 transfer actually attracted many top-notch academics to Hong Kong, some of whom stayed longer than planned.

The meaning of "international" has changed somewhat. While it still refers mostly to expatriates from English-speaking countries like Britain, the United States, and Australia, an increase has been registered among Chinese from the People's Republic of China, Chinese from Taiwan, and Chinese already living in Hong Kong who hold valid passports to the latter two areas. Due to the large number of overseas appointees, the academic qualifications of faculty have been rising: about 90 percent of all doctorates of Hong Kong faculty were earned overseas, usually in Australia, Canada, the United Kingdom, or the United States (Postiglione 1997 and 1998).

Future Trends and Concluding Remarks

Since Hong Kong became an SAR on July 1, 1997, "Hong Kong's universities have not been greatly affected" (Postiglione 1998); Ip (1998) notes that "Hong Kong seems to be the same as before." Despite this seemingly stagnant picture, Hong Kong is, in fact, changing—and change in education may serve as the best illustration.

Enhancing Internationalization

There is a much greater sense of commitment on the part of the new government to education as compared to the old colonial regime. In his first policy address made in October 1997, the new chief executive, Tung Chee-hwa, made education a high priority and promised to make a real change in education. Two major policy initiatives on tertiary education are key in making Hong Kong's universities stronger. First, from 1998 to 2001, the new Hong Kong government will invest heavily in higher education so as to enable Hong Kong universities to achieve and maintain recognition as world-class researchers in the international academic community, keep pace with rising standards, and serve the future economic and social needs of Hong Kong. During the same period, the number of nonlocal undergraduates and taught postgraduates will be doubled from 2 to 4 percent, and the ratio of nonlocal research postgraduate students in tertiary institutions will be increased substantially from one-fifth to one-third.

Raising Research Status

Until recently, the primary function of tertiary institutions in Hong Kong was teaching. Research, at least from the government's point of view, was not an important consideration. Government financial support for tertiary institutions was calculated on the basis of the costs involved in producing a graduate. As a result, Hong Kong's research in science and technology has not kept pace with that of its regional rivals in Singapore, Taiwan, and South Korea.

This situation has changed in the past few years. The government has come to realize that support for research would be an important factor in attracting qualified academics and research postgraduate students and in making Hong Kong more competitive in the world market. The change in attitude toward research has led to the establishment of the Research Grants Council in the early 1990s, whose principal responsibility is to support individual research projects in UGC institutions. The RGC has introduced a funding model in which part of an institution's block grant depends upon the quantity and quality of research conducted there. In addition to distributing individual research grants, the RGC has been responsible for the competitive allocation of research student numbers, again in conjunction with base numbers provided by the UGC. The general impression of the RGC, from both local and international perspectives, is that there is a flourishing and growing research culture in Hong Kong.

Strengthening Connections With Mainland China

With the opening up of mainland China since the end of the 1970s, academic exchanges with mainland China had been developing rapidly. Scholars from mainland China see Hong Kong as a most useful and convenient window on the outside world; local academics value exchanges with China to facilitate their research. The Hong Kong government has gradually come to appreciate the significance of such exchanges, and the UGC has been offering funding for them since 1988. The UGC's allocation for academic exchanges with mainland China jumped from HK$2.5 million in 1991-92 to HK$4.4 million in 1995-96 (Postiglione 1997).

Since Hong Kong was handed over to China, its academics are not only playing a bridging role between academics from mainland China and the rest of the world, but also extending their exchanges into many other aspects. Of these exchanges, the trend toward increased movement of students and professionals is of special significance. This role includes increasing the number of both undergraduate and postgraduate students from mainland China, recruiting more academics from mainland China who earned their doctorates at home—as well as those mainlanders who, with doctorates from the United States and other Western countries, have not returned to China—and, in the long term, supplying postgraduate labor to mainland China. However, there might be educational traffic in the reverse direction. The Hong Kong government decided in 1994 to recognize for the first time the right of university graduates from both mainland China and Taiwan to apply as civil servants; one consequence of this decision is that, in the future, increasing numbers of Hong Kong students (particularly those interested in working in government) will be going to mainland China rather than to the United Kingdom or other countries for courses in higher education. It is believed that a two-way educational traffic will be of benefit to both sides, and that the integration of Hong Kong's academics into the global community will be strengthened rather than hindered by their increased engagement with academics in mainland China.

Turning to the American Model

It is clear that the character of the academic profession in Hong Kong is changing in other ways as well. More doctorates are now earned in the United States than in the United Kingdom or other countries. Table 6 shows that, in addition to the large portion of U.S.-educated professors in the major universities of Hong Kong, former U.S. faculty are the deans and heads of almost all science and engineering departments and make up a large majority of the directors of HKUST research institutes.

It is of interest to note that those with higher degrees from the United States rate their training significantly higher than do those who earned higher degrees in the United Kingdom. The same holds true for the perception of faculty about the quality of training they received for research (Mak and Postiglione 1997). Rather than following the changing patterns in British higher education, Hong Kong has begun to draw more on innovations from the United States. Besides strengthening the research role of universities, other changes adopted include the introduction of a credit unit system; moving from the British 3-year model to the American 4-year model; and converting the title system from the British (lecturer, senior lecturer, reader, professor) to the American (assistant professor, associate professor, full professor) model. It is possible that the application of the American model will help Hong Kong universities continue their integration into the global community as well as improve the quality of education and standards of research.

Table 6. Leading scientists and engineers in Hong Kong's major universities by country origin, 1996

University	Total	United States	United Kingdom	Canada	Australia	Hong Kong
Hong Kong University of Science and Technology (HKUST)						
Deans/ department heads	15	14	0	1	0	0
Directors/ research centers	16	12	3	1	0	0
Chinese University of Hong Kong (CUHK)						
Full professors	16	6	4	3	1	2
Directors/ research centers	10	4	3	1	0	2

SOURCE: National Science Board, *Science and Engineering Indicators-1998,* (NSB) 98-1 (Arlington, VA: National Science Foundation).

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ISSUES IN HUMAN RESOURCES IN SCIENCE AND ENGINEERING: INDIA

Atul Wad

INTRODUCTION

India continues to produce a substantial quantity of science and engineering (S&E) personnel through its educational system and through higher education overseas. Over the last 3 decades, there has been a steady increase in student enrollment, adding up to nearly 6.5 million by 1996. However, enrollment in basic sciences has dropped to 19.6 percent (from 30 percent) of the total over this period, and there has not been a significant increase in enrollment in engineering and technology (which account for about 5 percent of the total).

In this paper, the focus is on the trends in the generation of these human resources in India and how certain important economic changes may have an impact on the career paths and opportunities for these personnel.

Current data on S&E personnel in India are limited, with the most recent sources being *Research and Development Statistics* (DST 1996) and the 1998 *Science & Engineering Indicators* report (NSB 1998) of the National Science Foundation (NSF). Nevertheless, broad implications may be drawn based on these data and analyses of current important economic circumstances. This discussion paper is based to a large extent on qualitative assessments of trends in S&E graduate education and is meant to serve primarily as a basis for further discussion and identification of areas for future research and data collection.

S&E graduate education needs to be viewed in the context of the major issues that face Indian S&E personnel and national policymakers: the impact of the dynamic growth of the information technology industry worldwide and its effects on demands for skills, the economic downturn in Asian economies (even though at this point India has not been as adversely affected as other nations in the region), and what NSF refers to as the "circulation" of human resources in S&E. Also important is the growing concern over the need for enhancing technology-based economic development and the consequent demand for enhanced involvement of S&E personnel in the productive sector.

GENERATION OF S&E PERSONNEL IN INDIA

In an overall sense, India continues to produce S&E personnel at a steady rate, and currently has a stock of over 6.3 million (Rao 1998). Of these, however, only about 150,000 are engaged in research and development (R&D), mostly in governmental laboratories. The rest are either overseas or in nontechnical careers; some are in industry. Table 1 shows the growth in doctorate recipients from India (in the United States) over the period 1985-96.

As can be seen, the proportion of total Ph.D.s awarded in S&E areas has remained more or less constant, except in more recent years when it has increased somewhat. The median age for a Ph.D. has stayed somewhat stable as well, at around 29 years.

Within S&E, allocation across fields has changed. The greatest increase has been in the computer and information sciences, which accounted for 3.9 percent of total S&E doctorates in 1985 and 9.1 percent in 1996, reflecting the rapid growth in the information technologies (IT) industry and the attractiveness of this field from a career standpoint. It is noteworthy that many of the Indians in the software and hardware industries in India and overseas hold advanced degrees.

Of these, most had clear plans to stay in the United States after receipt of their Ph.D. According to the DST report, 1,082 of the 1,482 recipients in 1996 had firm plans

Table 1. Number of Ph.D.s from India by year of award, 1985-96

Year	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total.........................	541	579	602	647	679	881	924	1,072	1,139	1,289	1,426	1,481
S&E (percent)......	84	81	83	80	78	80	81	80	81	82	84	84

SOURCE: Government of India, Ministry of Science and Technology, Department of Science and Technology, *Research and Development Statistics,* New Delhi, India, September 1996.

to locate in the United States after receiving their Ph.D.; 456 of these had definite employment plans. Most of the employers (79.2 percent) were in industry/business, and 15.8 were educational institutions. In contrast, in 1985, 47.4 percent of the employers were in industry/business and 44.5 percent were educational institutions.

To bring greater depth to this scenario, data are required on the numbers of advanced degree-holders of Indian origin who have returned to India and the location of their employment there. Typically, even though Indian Ph.D.s have tended to prefer to stay in the United States, the rapid growth in certain sectors of the Indian economy and greater overall mobility should suggest an increase in this recirculation of skills.

There is another side to the coin, however. Even though there are data that indicate that "brain circulation" is occurring for some countries such as Taiwan and South Korea, India and China still experience more "brain drain" than not. This is perhaps understood by the fairly high level of S&E personnel in India actively seeking employment. According to DST, 676,099 science graduates and 100,249 science postgraduates, as well as 152,015 engineering graduates and postgraduates combined, were on the active registers of employment exchanges in 1993. More current data are not available.

Given that economic conditions may have made it favorable for S&E personnel to return to India if they entered specific industry/business areas but that overall employment prospects for them do not seem to have improved, research is needed to determine what specific trends are emerging as a result.

This is particularly important when viewed from a national economic development perspective. Ideally, countries like India need to harness their S&E personnel and capabilities to accelerate the development process and further the development of national science and technology infrastructure, research, and training. A major channel through which this could occur is the national laboratory system (e.g., the Council of Scientific and Industrial Research—CSIR) and national teaching institutes such as the Indian Institutes of Technology (IITs). There has been considerable criticism of the extent to which mechanisms have actually made contributions to the productive sphere; it is only recently, for example, that the CSIR system has been asked to focus its energies on such efforts. This has been accompanied in many cases by budget cutbacks, which have limited the ability of national labs to offer attractive salaries and career prospects to new graduates. The upshot is that the private sector, and in particular the information technology area, is becoming a major career choice for such graduates.

This in turn is having an impact on the supply of future teachers (Rao 1998, p. 29):

> In the field of postgraduate education and research in engineering and technology the following trends are worrisome. (1) The average turnout of Master's Degree holders in engineering technology is only around 5,000 per year and this is against the capacity of more than 15,000. (2) The loss of engineering graduates to software industry is taking place on a large scale with consequences to postgraduate programmes. On account of these negative developments there is an acute shortage of teachers with postgraduate qualifications in engineering and technology. The situation is becoming one of concern as expansion in engineering education will have to go hand in hand with economic growth. (3) The number of doctorates in engineering and technology being produced annually now is only about 400 and 90 percent of them come from only a dozen institutions.

Indeed, as table 2 shows, the number of doctorates in engineering has dropped considerably over the period 1982-94.

Table 2. Doctorate degrees awarded by field

Faculty	1982–83	1990–91	1993-94
Total	6,948	8,383	9,369
Engineering/tech	511	629	348

SOURCE: Government of India, Ministry of Science and Technology, Department of Science and Technology, *Research and Development Statistics,* New Delhi, India, September 1996.

In science, however, the number of doctorates has increased from 2,892 in 1982-83 to 3,505 in 1993-94. The overall total number of doctorates has also increased, rising from 6,948 in 1982-83 to 9,369 in 1993-94.

DST has compiled estimates of the total stock of engineering degree-holders by discipline; these are summarized in table 3.

Table 3. Engineering degree-holders by field				
Discipline/Year	1986	1990	1995	2000
Total	390,830	492,180	660,660	848,660
Civil	94,540	11,940	153,160	186,830
Mechanical	108,400	131,200	164,220	197,980
Electrical	76,390	87,030	106,220	125,870
Chemical	23,660	27,510	32,300	37,700
Telecom	25,520	41,830	67,290	96,260
Metallurgy	11,960	13,120	14,880	16,780
Automobile	730	1,140	2,720	5,140
Aeronautical	1,360	1,530	1,760	1,950
Other	20,410	32,440	66,930	110,350

SOURCE: Government of India, Ministry of Science and Technology, Department of Science and Technology, *Research and Development Statistics,* New Delhi, India, September 1996.

The specific field of computer software and hardware is not detailed separately but is probably included within telecommunications, electrical engineering, and other.

It is perhaps worth comparing these figures with the numbers of first university degrees in S&E in India over the period 1985-95 (table 4).

Table 4. First university degrees in S&E in India, 1985-95			
Field	1985	1990	1995
All univ. degrees	646,748	750,000	750,000
Engineering	21,088	29,000	29,000
Math. & comp. sci	NA	NA	NA

SOURCE: National Science Board, *Science & Engineering Indicators - 1998,* NSB-98-1 Arlington, VA, 1998.

Clearly, these is a general lack of available data on graduates in computer sciences (and mathematics); this is an important area in which further and more refined data collection is needed in order to better understand the changing composition of S&E degrees.

S&E and Productivity

One of the major purposes of enhancing the quality, quantity, and proper deployment of S&E is economic development and the strengthening of the economy. Indian national science and technology (S&T) policy has always been based on this need as a central focus (along with an emphasis on self-reliance). Since independence, the generation of highly qualified scientists and engineers (and the establishment of premier educational institutions such as the IITs) have been driven by this objective. However, accomplishments in terms of concrete and positive contributions to productivity by S&T have been questionable, and one of the “negative” effects of an imbalance between the supply of personnel and the economy’s absorptive capacity has been brain drain.

Today, the discussion has turned from brain drain to brain circulation, which may apply to some Asian countries more than others. Brain circulation appears to be occurring in some countries (but may change with the recent Asian economic crises). This takes place in the form of graduates returning to jobs back home, networking with colleagues in their countries of origin, and thereby creating more of a dynamic two-way flow of talents and skills between the United States and the home country.

Of paramount importance, however, is to investigate to what extent this type of circulation actually contributes to home countries’ scientific and technological infrastructure (broadly defined to include research, training, policy, transfer of knowledge, etc.) and hence, in turn enhance the economic development process.

For example, considering that India is primarily an agricultural country and is the number one producer of certain commodities such as jute, sugar, fruits, and vegetables, it is—in terms of productivity—on the low end of the spectrum (Rao 1998, p. 19) (table 5).

Table 5. Indian agricultural productivity				
Type of Plant	Production		Yield	
	Annual (1000 T)	World Rank	Yield kg/ha	World Rank
Jute	1,260	1	1,465	10
Fruits/veg	100	1	Variable	Below 10
Raw sugar	13-14,000	1	10%	Below 5

SOURCE: P. Rama Rao. "Science and Technology in India: Retrospect and Prospect." Address to the 85th Annual Session, Osmania University, Hyderabad, India, January 3, 1998.

The potential contribution of technological know-how and skills is critical in improving productivity in agriculture, a mainstay of the economy. Yet the trend in doctoral degrees awarded in agriculture from Indian universities has declined in recent years. The trend in doctoral recipients in agricultural sciences from the United States shows a similar decline, but precise data are not available (table 6).

Table 6. Doctoral degrees awarded in agriculture in India

1988	1989	1990	1991	1992	1993	1994	1995
712	688	703	715	715	611	572	572

SOURCE: Government of India, Ministry of Science and Technology, Department of Science and Technology, *Research and Development Statistics,* New Delhi, India, September 1996.

This is the type of trend that raises concerns for the long term. Regardless of the tremendous growth and advances in areas such as IT, and the admittedly positive implications of these for productivity improvements in all sectors of the economy, the need for basic technological capabilities that can continue to improve agricultural efficiencies is critical to the long-term economic development of the nation.

Moreover, technological capacities are required for the further processing of agricultural commodities into value-added products, the economic benefits of which are growing rapidly worldwide. Adding value to agricultural resources is a mainstay of economic development: moving up the "value chain" is central to the wealth creation process that underlies economic development. For this to occur, the country needs personnel with skills in appropriate areas—food processing, fermentation, packaging, chemical engineering, tissue culture, biotechnology, etc. With these skill sets properly harnessed, the Indian economy could build a value-added industrial base that generates wealth from its agricultural and natural resource base.

For example, there is a growing demand for high-quality flavors and extracts (essences) by the global food and beverage, aromatics, and perfume industries. Indian spices, botanicals, fruits, and vegetables are acknowledged to be very high in taste and flavor content even though yields may be low. Market demographics have been changing in recent years: there is a growing consumer demand for exotic tastes and more variety in flavors and aromatics. The growth of new markets, for example aromatherapy and organic foods, is another driver of demand.

To meet these new demands and enter these markets competitively, capabilities in new technologies that provide higher extract yields and higher efficiencies are required. These technological developments are occurring in various countries around the world (substantially in the United States), and it is essential that India develop S&E personnel with skills in these areas. Such skills must be built upon a solid foundation of training and research in the appropriate area of agricultural engineering.

An important consideration here is that technical skills by themselves may not be adequate. There has to be an appreciation of market trends (and opportunities) and incentives for S&E personnel to pursue them. The knowledge of market opportunities needs to be dealt with by appropriate modifications to the teaching/research program. Incentives for S&E personnel can only come from private industry and through national policies.

Broader Economic Context of S&E Education

Rao (1998) makes a strong and crucial argument that the broader economic context within which scientific and engineering activities take place—including education—must be taken into consideration in all aspects of S&T policy. Of particular importance are the commercial aspects of technology. To fully capitalize on the competitive resources of the country, there is a need to focus S&T activities in such a way as to optimize the commercialization, in a competitive sense, of scientific and technological know-how.

In this regard, education in S&E must be based on a broader concept of knowledge than simply functional specialization. Of specific importance are the areas of finance, organization and management, and marketing. These are areas with which S&E personnel need to have a working familiarity. The base of such expertise, interestingly enough, may already be developing, with various government agencies involved in S&T in India becoming more involved with venture capital, technology commercialization, and market-driven approaches to S&T. The recently created Technology Development Board is one such example; its mission is to promote the commercial development of technology and mobilize the resources and inputs needed for this end.

This need is present in most sectors of the Indian economy—health, pharmaceuticals, chemicals, agriculture, telecommunications, transportation, energy, etc. The challenge for the future is to be able to identify, with some accuracy, which are the opportunity areas of the future and to develop educational programs to generate the skill sets that will be required. This is admittedly a major undertaking. Fortunately, in the United States and Europe, educational and research programs in the relevant areas already exist and can be taken advantage of by Indian students.

Another dimension of the global context is the very process of globalization itself. Corporations are becoming increasingly global in their character, and the economies of the world—as evidenced by recent economic events in Asia and Latin America—are becoming increasingly intertwined. As a result, one finds U.S. corporations with a global reach paying more attention to the recruitment of talent from the countries in which they operate and depending increasingly on skills available in these countries. This applies not only to the mainstream areas of S&E but also to the newly emerging ones, such as IT, as well. For example, nearly every major U.S. software company has established a development operation in India, with the intention of utilizing the vast and still relatively inexpensive technical resources available there. This has two effects: first, there is tremendous mobility in the IT field between the United States and India, and the number of Indians in this industry—for example, in Silicon Valley—has skyrocketed in the past decade. Second, the growth of the industry is drawing people away from other career paths in S&E, with the consequent implications for long-term economic development discussed earlier.

There is another trend that is gradually emerging that is of significance in educational terms. Indian engineering graduates, mainly from the IITs, are now being found in high-level positions in the financial sector. For example, an IIT graduate is now head of Citibank worldwide. Many of the senior staff in multilateral financial institutions, such as the International Finance Corporation and the World Bank, are Indian engineering graduates from the 1970s and 1980s. They in turn are becoming role models for future generations of engineering graduates.

In the past, for the most part, Indian students came to the United States to study S&T with a clear intention of staying in that field throughout their careers. A subtle but important change may be occurring in more recent times, in that students see an initial S&T education as a channel to a career in an altogether different area—finance, consulting, business, etc. This is not altogether a bad thing; in fact, for some time now, it has been known that few IIT graduates have stayed in engineering as a career, and have succeeded in other fields, particularly in the private sector.

In a sense, this was the original vision of the IITs: to generate Indian "technocrats" who would take on leadership roles in technology and industry, and hence contribute to the economic development of the country. As it happened, a large proportion of these graduates accomplished this, but overseas. Whether this trend is changing and more engineering graduates are returning to India after their education (and perhaps a brief career) overseas is an issue that needs to be explored.

From the perspective of organizations concerned with S&T, such as NSF and national S&T agencies, these trends raise an important question. To what extent is advanced S&T education to be seen as precisely that, preparing students for careers in their respective fields of S&T, and to what extent is it an intellectual training ground that prepares these students for a broader panorama of career options? And which of these two is the more important from a long-term economic development perspective?

This issue has several implications in terms of financing of graduate education, establishment of new institutions, and the types of support that can or should be provided to students.

Furthermore, if indeed one result of this trend is a downward pressure on the supply of trained S&T graduates further aggravated by the poor employment prospects in S&T areas, measures need to be taken to address this issue. Rao (1998) points to the "assured placement scheme" of the Department of Atomic Energy in India, which first brings graduates into their own training school where they are coached for a year in an advanced field of importance to the department. They are then assured of a job at the end of the year. A similar approach could be adopted by private industry in India as well.

Recent Economic Crises

Some mention has been made of the impact of the recent economic crises in Asia on the ability of students from these countries to pursue advanced education in the United States and on the circulation process.

The most immediate effect of the Asian economic crises would be on the ability of foreign students to afford education in the United States without financial support of some kind. There is anecdotal evidence that this is taking place (Honan 1998), partly due to rising costs of education in the United States and partly because other countries are recruiting students more vigorously. Nine of the 10 countries that send the greatest number of students to the United States are Asian (Canada is the only non-Asian country). Additionally, the financial crisis has forced many Asian students to seek cheaper housing, get part-time jobs, and transfer to colleges in other countries. To what extent this overall trend is reflected in trends in S&E graduates requires research.

The Asian crisis would have had a greater impact on the plans of students from the worst affected countries (South Korea, Thailand); its effects on Indian students may have been less. However, the India rupee has also been losing value steadily, which is likely to have an impact over time. NSF analysis of foreign doctoral recipients and their stay rates in the United States shows that India and China have the highest rates; this is likely to continue for the reasons outlined earlier.

The Asian economic crisis does highlight one issue that bears deeper consideration—the relationship between productivity-driven economic considerations and the demand for and behavior of S&E graduates. The argument has been made that a major reason for the downturn in these economies was a lack of long-term and targeted investment in productive wealth-generating efforts that would add value to local resources and generate sustainable competitive industries. Instead, much of the investment was going toward speculative ventures, real estate, and debt financing of noncompetitive industries, where the need for highly trained S&E personnel is low. One would then expect that most of the jobs and opportunities for S&E personnel would be in academia and the government. In India, this has certainly been the case, given the low demand for S&E personnel in the private sector. Yet it is in the private sector, where their knowledge can be applied to the development of competitive technology-based enterprises, that their full value should be realized—at least in terms of contributions to productivity.

Furthermore, in an economic downturn, not only does private industry cut back on R&D expenditures, but the government typically also cuts budgets in S&T-related areas. All of this has the net effect of reducing even further the demand for S&E personnel in S&E careers. The only major source of demand under these conditions would be overseas employers (such as in the United States), and that would be subject to the sector priorities in those economies. Thus, the growth in the information industry in the United States (and its counterpart in India) is drawing an increasing number of Indian engineers because of both its economic attractiveness and the decline of opportunities in other fields.

Thus we have a downward spiral effect where past economic policies, based on a lack of focus on the role of S&T to economic growth (and the consequent low demand for such skills), produce conditions that further deteriorate this demand. This subject—the relationship between economic policies and demand conditions for S&E personnel—requires further investigation.

In the past, the implications of broad economic trends and conditions have not been stressed in the analysis of educational needs in S&E and patterns of S&E education. In today's more integrated and dynamic global economy, it would be prudent to bring these factors into an analysis of this critical issue. This in turn means broadening the disciplinary base for the study of S&E education to include expertise in technology and economic development, economic policy, technology commercialization, and competitive strategy, among others.

Issues for Further Research

Clearly, there are a number of issues that need to be addressed to develop a more current and accurate understanding of the situation today and in the future with respect to S&E graduate education. In the case of India, the lack of data is in itself a problem, but the types of data that need to be gathered and the relationships that need to be studied also need to be reassessed. Some of these are summarized below.

Comparative Data on Distributions Across S&E Fields in the United States and India

Of particular interest here would be the changes in distribution between new fields (e.g., IT) and traditional areas, as well as distribution changes within fields (e.g., food processing). In addition, data on distribution between the United States and India in terms of degree recipients, and the employment locations of both groups by field, would provide better insight into current trends.

Data on Economic Conditions and Employment Choices of S&E Graduates

The correlation of broad economic indicators, such as those used by the World Bank and the United Nations Development Programme, as well as assessments of the competitiveness of different countries (e.g., the *World Competitiveness Report*), with employment paths and patterns of demand for skills in S&E would provide very useful data for future education planning and reform. Of importance here is the need for a conceptual framework that builds upon analytical principles in economic development and allows propositions to be developed about the relationships between economic development dynamics and career patterns and choices of S&E personnel in India.

Time-Series Data on Career Paths of Indian Scientists and Engineers

As discussed earlier, many Indian engineering graduates are now in senior positions in other fields—business, consulting, finance, etc. This is an important trend both in terms of how we evaluate graduate S&E education and how we develop new educational programs and policies. Just as the IITs were established based on a "technocratic" vision, there may be an emerging need for educational institutions to integrate S&E with such areas as entrepreneurship, innovation, economic development, and finance to create a new generation of what the United Nations (UN) refers to as "techno-entrepreneurs" for the modern global economy.

Trends in Sources of Funding

Patterns of funding and the composition of sources of funding for R&D, graduate education, and training is another area for more thorough data collection. This is particularly important because there is an ongoing shift away from public sector funding for R&D and a growing emphasis on technology commercialization. Of interest would be changes in the distribution between Indian and U.S/foreign sources of funding and the types of support being made available from these sources.

Impact of S&T Policies on Graduate Education

During the 1970s, considerable emphasis was given to the role of S&T policies and policy mechanisms in strengthening S&E capabilities in developing countries. The UN's Vienna Program outlines eight areas where policies needed to be developed in S&T; one is human resources. During the 1980s and 1990s, there was a reduced emphasis on S&T policies, but it may now be useful to assess the impact of the S&T policies developed and implemented by countries such as India on the current situation with respect to S&T human resources.

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Graduate Education Reform and International Mobility of Scientists in Japan and Related Information for Korea

Shinichi Yamamoto

Introduction

Since the establishment of a system of higher education in Japan at the end of the 19th century, it has been one of the driving forces in leading Japan into industrialization and modernization. However, Japan has experienced great economic and social changes that now demand subsequent changes in the university system.

"University reform" is the key concept in understanding the current situation of higher education in Japan. The Basic Plan for Promotion of Science and Technology, which has just been initiated by the government, will be a great boost for the movement to reform university research. Korea, one of Japan's neighbors, is also experiencing a similar kind of reform movement affecting its university and research systems.

Universities and colleges have played several roles in Japan: training researchers, teachers, and other types of professionals; carrying out research and development; and identifying prospective young people who might later play an important role in Japanese society. The character of these roles, however, is now changing greatly due to the massification of higher education and the increased sophistication of research in science and technology. The research and research training functions of universities need to be reevaluated and improved, while also responding to various educational demands by students of a mass higher education system in which more than 47 percent of the 18-year-old population now participates. It has become difficult for each individual institution to respond to these needs at the same time.

Within this changing environment, some reforms that can now be observed are competitive allocation of research funds, expansion of graduate training accompanied by new financial aid programs, encouragement of research cooperation with industry, and restructuring of research units at major universities. After discussing the reforms taking place in graduate education in Japan, a brief description is here given of recent trends in graduate education in Korea.

Nature of Graduate Education Reform in Japan

Necessary reforms in graduate education have been discussed since the early 1970s, based on the idea that the system in Japan is very weak and inclined to train future academics rather than other types of professionals. The Ministry of Education, Science, Sports, and Culture (hereafter referred to as Monbusho) began introducing more flexibility through systemic reforms; it has devoted much effort to expanding the capacity of graduate schools and creating new programs at many national universities. A feature of graduate education policy recently introduced by Monbusho is a more competitive mode for obtaining research grants and other kinds of resources. For example, special competitive funds are made available both for graduate programs and graduate students. New types of fellowships fund individual prospective students, while other special funds provide institutional support for graduate programs. The effects of these policies will be seen in the near future.

Today, all national universities in Japan, as well as two-thirds of the private universities, have graduate programs. Graduate enrollment currently exceeds 170,000, including about 80,000 in science and engineering programs. This is more than 10 times the 1960 enrollment. For science and engineering, the number of students is 23 times larger.

Massification of Higher Education and the Decline in the Population of 18-Year-Olds

The research environment at universities has changed radically over the past years. The most important change has been the "massification" of higher education, which has made the traditional notion of the unity of research and teaching difficult to maintain. The reform and expansion of graduate education in Japan cannot be understood without mentioning the trend toward massification of higher education at the undergraduate level. Graduate education has been recognized (by university faculties as well as by the government and industry) as a crucial device for avoiding problems, such as the lack of balance between research and teaching, caused by the massification of undergraduate education.

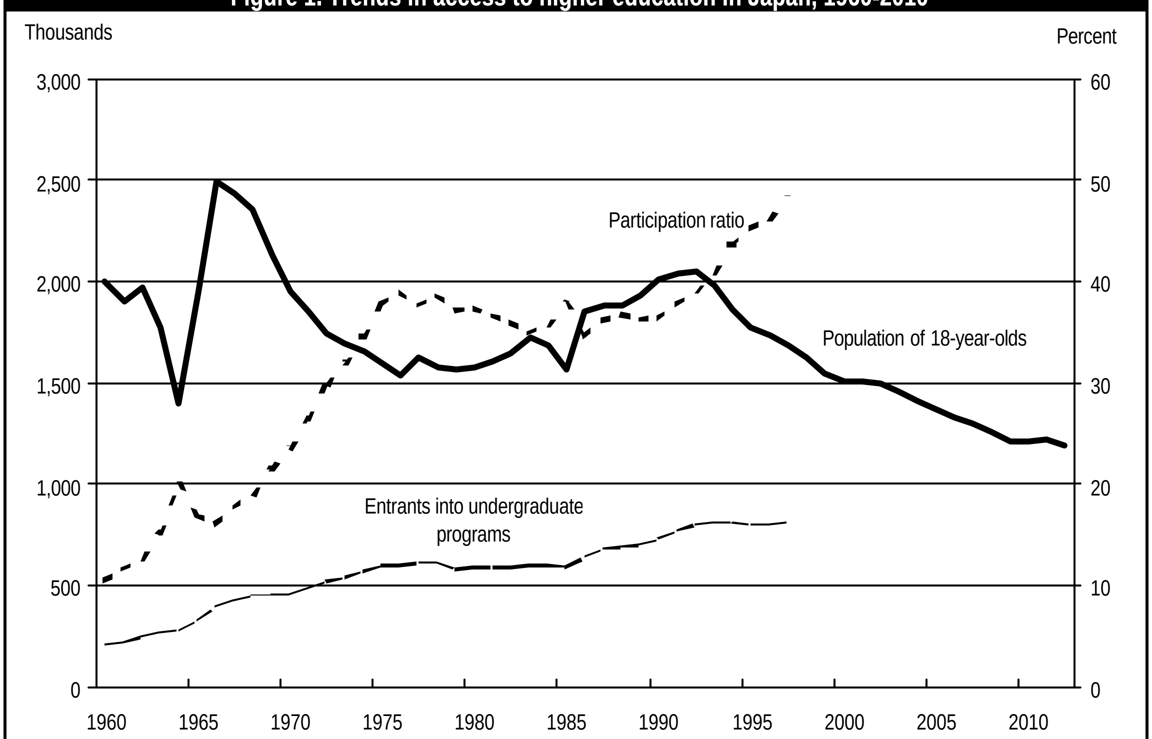
Japan experienced its first period of rapid growth in higher education after World War II in the 1960s and early 1970s. The participation ratio of the 18-year-old population in higher education grew rapidly from only 10.3 percent in 1960 to 38.6 percent in 1976 (figure 1). This growth was caused by various factors (Yamamoto 1997); among them, people's desire for higher education based on the belief that it would bring great personal benefit and the government's intention to expand the scale of higher education in science and engineering in response to the need for economic growth. Due to these factors, the proportion of science and engineering students in total enrollment in undergraduate programs grew from 18 percent in 1960 to 23 percent in 1976.

By that time, it was realized that massification brought not only growth of higher education in terms of number of students but also a radical change in the character of the system. Higher education was no longer for the "elite" but was available for the masses. The demand for education created a diversified system of institutions, ranging from the highly academic to the extremely practical.

In response to this rapid massification and qualitative change in higher education, Monbusho initiated a new policy that was intended to control the quantity and improve the quality of university education in the mid-1970s. Growth in the participation ratio flattened out, and enrollment also stopped growing. This policy, however, actually protected the existing higher education system; real university reform did not begin until the 1990s.

The second stage of massification started at the beginning of 1990s. The participation ratio of 18-year-olds grew again, from 36.3 percent in 1990 to 47.3 percent in 1997. This time, the share of students in science and engineering did not change but remained at around 23 percent. This rapid regrowth was triggered by an increase in the population of 18-year-olds in the late 1980s. This regrowth mechanism can be explained as follows: each university and college tries to expand enrollment when the population of 18-year-olds grows; the government also encourages each institution to accept more students because it is afraid of an increase in the number of people who cannot enroll in universities and colleges. This growth in capacity at each institution encourages 18-year-olds to

Figure 1. Trends in access to higher education in Japan, 1960-2010



SOURCE: The Monbusho Survey of Education.

attend universities and colleges at rates greater than the government anticipated, just as the "multiplier" used in explanations of economic growth. With a mass higher education system, people tend to go to college because their neighbors do.

This second stage of massification, however, was followed by a serious problem. As shown in figure 1, a steady decline in the 18-year-old population—from 2.05 million in 1992 to 1.20 million in 2009—will considerably lower the potential higher education enrollment. Except for a few prestigious institutions, most universities will have to consider how to deal with this future shortage of applicants and how to attract students.

Along with the massification of higher education, a growing number of people have complained about the content of education. Teaching tends to be concentrated on academic material, while many students prefer to take practical courses they think will be useful in future jobs outside academia. Another difficulty is a perceived decline in student interest in learning. Many students who might not have enrolled in higher education 2 decades earlier are not accustomed to studying abstract material in academic language. Universities must respond to this more diversified student population and improve teaching techniques and curriculum. So-called "faculty development" (FD) has become a fashionable phrase in Japan when discussing the improvement of teaching. Along with FD, universities are being forced to reform in response to this new situation, and to attract and retain students.

The System of Graduate Education in Japan

The current graduate education system in Japan has been developing since its introduction after World War II. Enrollment in graduate education, though much smaller than in the United States and major European countries, has grown more rapidly than undergraduate enrollment during this period. Now, approximately 10 percent of students (26 percent in science and engineering) who finish undergraduate programs advance to graduate programs.

Graduate schools offer two kinds of programs—a 2-year master's degree program and a 3-year doctoral program. The doctoral programs generally admit students who finish a master's degree program. Enrollment in graduate school generally requires the successful completion of a bachelor's degree. However, a recent reform enables each graduate school to admit prospective students who have not yet finished their undergraduate program and to grant degrees to those who have completed a shorter coursework program.

Japanese doctoral degrees are classified into two categories. One is the "coursework doctorate" (university-based doctorate), granted to those who finish 3 years of coursework and write a doctoral thesis. The other is the "thesis doctorate" (*Ronbun* doctorate), granted to those employed in industry or others who submit a thesis (based on their industrial research) to graduate schools and pass an examination. The level of both doctorates is the same according to the definition in Monbusho's Degree Order. However, a thesis doctorate has tended to be recognized as a "grand doctorate" rather than as an alternative to a coursework doctorate. Granting doctorates has sometimes been regarded in academic circles as praise for esteemed scholars for their exceptional work. This notion has tended to prevent academics from viewing doctorates as a "license" for future researchers and has made doctorates difficult to obtain for young people who are in doctoral programs, especially in the humanities and social sciences.

In the sciences, the number of coursework doctorates has traditionally exceeded the number of thesis doctorates; in engineering and medicine, on the other hand, thesis doctorates have exceeded coursework doctorates. With the expansion of university doctoral programs, however, the proportion of university-based engineering degrees has been increasing. By 1992, more doctoral engineering degrees were earned for research within university laboratories than in industrial research laboratories. This increase was partly due to the fact that each graduate school in engineering had encouraged people who had once enrolled in a master's program to enroll in shorter graduate programs (mostly 1 year) to obtain a doctorate.[1]

Under the Japanese doctorate system, there is no clear distinction between a Ph.D. and a professional doctoral degree. Recipients of either type of degree are called "doctor," although credentials require indication of a specialty and the name of the university that granted the degree.

[1]Under the current Japanese system, the minimum coursework requirement for a doctorate is 3 years, including master's degree coursework. If a person has previously enrolled in a 2-year master's program or has equivalent ability, the minimum coursework requirement is 1 year.

Graduate schools are quite separate from undergraduate programs. This structural distinction is one of the unique features of the Japanese university system, in contrast to European systems where undergraduate and graduate structures are not so clearly distinguished. The U.S. graduate education system is funded by individual grants; this is unlike Japan's system, where Monbusho provides general university funds to the graduate programs at national universities. Some European countries indicate that they are now looking at the U.S. system of graduate education. One of the biggest problems is that graduate schools are much smaller than undergraduate departments. Most faculty members want to teach at graduate schools while, in reality, they usually have their affiliation with undergraduate departments and are heavily involved in undergraduate teaching. Faculties have long claimed that graduate schools should be further expanded.

Japanese graduate schools are now aiming to train professionals with advanced specialized skills, as well as train researchers to work in academia and other institutions. Most efforts, however—especially in the humanities and social sciences—have been devoted to training academic researchers. People who want to work for business and government have tended to end their studies at the undergraduate level. This relates to the fact that leading Japanese companies each year have recruited new bachelor's degree recipients of potential ability and given

Table 1. Master's and doctoral degrees by field in Japan

Field	1991	1992	1993	1994	1995
	Master's degree				
Total	29,550	33,293	37,213	42,015	47,525
Humanities	2,348	2,473	2,749	2,947	3,413
Social sciences	2,672	3,095	3,613	4,169	5,135
Science	3,204	3,504	3,862	4,457	4,946
Engineering	14,346	16,309	18,198	20,352	22,610
Agriculture	2,028	2,372	2,622	2,971	3,136
Health	1,316	1,403	1,659	1,749	1,871
Home economics	168	195	221	201	290
Education	2,436	2,666	2,850	3,204	3,699
Arts	674	730	743	884	985
Others	358	546	696	1,081	1,440
	Doctoral degree				
Total	10,885	11,576	12,486	13,044	13,632
Coursework doctor total	4,779	5,134	5,718	6,203	6,979
Humanities	42	56	90	133	147
Social sciences	67	90	88	123	174
Science	586	638	761	811	908
Engineering	983	1,184	1,432	1,613	1,925
Agriculture	385	376	446	508	587
Health	2,503	2,624	2,670	2,736	2,886
Education	25	21	25	24	32
Others	188	145	206	255	320
Ronbun doctor total	6,106	6,442	6,768	6,841	6,653
Humanities	117	149	171	175	198
Social sciences	133	153	195	178	184
Science	306	371	407	324	335
Engineering	1,111	1,178	1,351	1,396	1,372
Agriculture	485	448	476	500	521
Health	3,853	4,032	4,042	4,125	3,896
Education	24	39	47	52	53
Others	77	72	79	91	94

SOURCE: The Monbusho Survey of Education.

them long-term in-service training as future managers. Companies do not seek people with specific or advanced skills.

Thus, advancing to graduate programs instead of getting a job after obtaining a bachelor's degree has not been attractive except for those who intended to be university researchers. A few exceptional cases are those holding master's degrees in engineering or doctoral degrees in medicine. The reason for the success of master's programs in engineering was the growing demand for specialized skills in this field when Japan's economy was increasing rapidly. This economic growth triggered policymakers and industry to demand expanded master's programs in engineering. Once prospective students regularly advanced to graduate programs, having a master's degree in engineering gradually became essential for employment in mainstream industry. Today, universities that offer master's degree programs train students intensively for 3 years from their final years in undergraduate programs until the end of the master's course.

Graduate enrollment differs by institution type (national, local, public, and private). The majority of students take their undergraduate courses at private institutions, while national universities exceed others in the scale of graduate education. Similar differences exist among the disciplines (table 2). In the humanities and social sciences, most students leave their institutions with bachelor's degrees; graduate education is very minor compared with the huge scale of undergraduate programs. Advanced research activities in this group are highly concentrated in a few institutions. More students enter graduate programs in science and engineering. Master's programs in engineering are regarded as the most successful case of graduate education in Japan. Doctoral enrollment in this field is also much greater than in the humanities and social sciences.

Expansion of Graduate Education

As mentioned above, until the late 1970s, the function of the Japanese graduate education system had been mainly the research training of future academics. In some areas, such as engineering, growing enrollment had gradually changed the character of graduate education—i.e., shifting it from an emphasis on academic research training to professional training. Thus, in the 1970s and 1980s, Monbusho discussed and introduced systemic reforms.

Although graduate education aims at both academic research and professional training, it has been regarded as an important locus of research activity. Due to the massification of university education, concerns about university research have shifted from undergraduate departments to graduate schools. Graduate schools seem to be a sanctuary not only for faculty members who seek the unity of research and teaching, but also for policymakers who regard university research as an engine for economic growth and technological innovation.

Table 2. Number of students finishing each program, 1997

By type of institution	Level			
	Undergraduate	Master's programs	Doctoral programs	
Total	524,512	50,430	9,860	
National	104,100	31,025	7,024	
Local	15,808	2,000	446	
Private	404,604	17,405	2,390	
By field	**Level**			
	Undergraduate	Master's programs	Doctoral programs[a]	Doctorates granted[b]
Total	524,512	50,430	9,860	12,031
Humanities and social sciences	299,324	4,234	1,570	522
Science and engineering	136,773	26,393	4,359	4,663
Health	23,571	2,033	3,370	6,480
Others	64,844	17,770	561	366

[a] Number of students who finished coursework in that year.

[b] Number of doctorates granted in that academic year including both coursework doctorates and ronbun doctorate. It can be seen that there are many students who leave their coursework without receiving a doctorate in the humanities and social sciences.

SOURCE: Monbusho, Basic School

The growing number of graduate students, especially in engineering, has reflected the new expectations of the industrial sector. Master's degree programs have grown far more rapidly than those at the undergraduate level. The proportion of students who advanced from undergraduate to master's degree courses was low even in engineering during the 1960s and early 1970s. By 1996, however, it reached nearly 25 percent; at the University of Tokyo, for example, 69 percent of undergraduate students at the School of Engineering advanced to graduate courses in that year. On the other hand, in the humanities and social sciences, this ratio has remained low.

Although enrollment differs by discipline, graduate education has been closely connected to research intensity at Japanese national universities and is influenced by university finances. The level of general university funds allocated for each national university from Monbusho differs greatly for universities with master's and doctoral programs. The amount of general university funds allocated for each research unit (*Koza*) that deals with doctoral programs is more than two times greater than that of any type of research unit that has no relation to graduate education (*Gakkamoku*). For private universities and local public universities, doctoral programs bestow a prestigious status upon neighboring institutions, even if they do not attract enough students into their graduate schools.

Thus, graduate education has been expanding not only by responding to growing demand, but also due to the desire of faculties to increase their funding and status. Today, all national universities have at least master's

INCREASING FLEXIBILITY IN JAPANESE GRADUATE EDUCATION

A number of changes have been made with the aim of bringing greater flexibility to the graduate school system since the late 1970s:

1. The aims of doctorate courses have been expanded to include not only the traditional goal of training researchers to work in universities and other institutions, but also the training of professionals with advanced specialized skills that enable them to contribute to various sectors of society.

2. It has become possible to establish evening graduate courses to meet the needs of workers.

3. Graduate schools are now able to reduce the required duration of study for students of exceptional ability.

4. Students in master's degree courses are now able to receive research guidance in other universities and institutions for up to 1 year when this is deemed to be of educational or research benefit.

5. To provide a way for students who show exceptional aptitude for research to begin graduate studies earlier than usual, the system has been altered to allow such students to proceed directly to master's degree course studies after completing the third undergraduate year.

6. Students who have completed their undergraduate programs and have been involved in research at universities or research institutions for at least 2 years are now deemed qualified to enter the upper division of doctorate courses even if they have not completed master's degree courses.

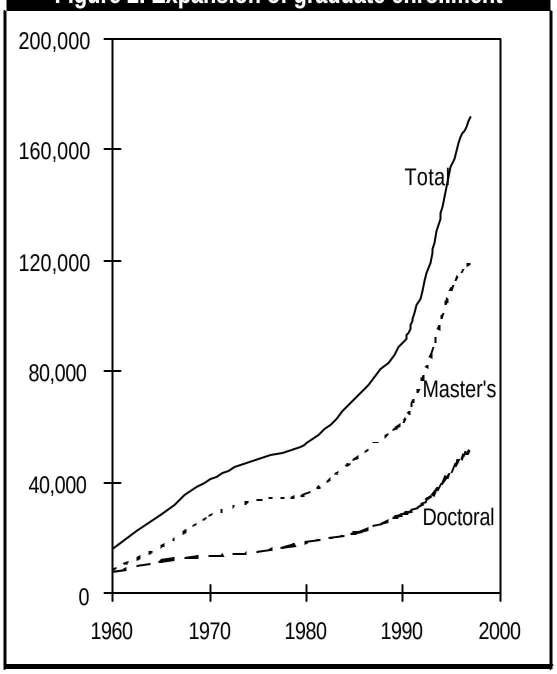
7. In master's degree courses designed primarily to train professionals with advanced specialized skills, the requirements concerning degree theses have been changed to enable the thesis requirement to be waived at the discretion of the graduate school when this is deemed appropriate from an educational viewpoint.

8. People with outstanding knowledge and experience in specialized fields and with advanced abilities in education and research can now be considered qualified to be graduate school teachers. The aim of this change is to attract human resources from nonacademic sectors of society so that people with exceptional knowledge and experience in specialized fields can contribute to graduate education and research.

SOURCE: Monbusho (1996).

programs and 80 percent have doctoral programs. As for private universities, 19 percent have master's programs and 47 percent have doctoral programs; just 34 percent have only undergraduate programs. The annual growth of graduate enrollment in Japan was the highest among industrialized countries in the world. While the United States experienced about 1.8 percent annual growth during the 1980s, Japan's graduate enrollment increased by 5.6 percent.

Figure 2. Expansion of graduate enrollment



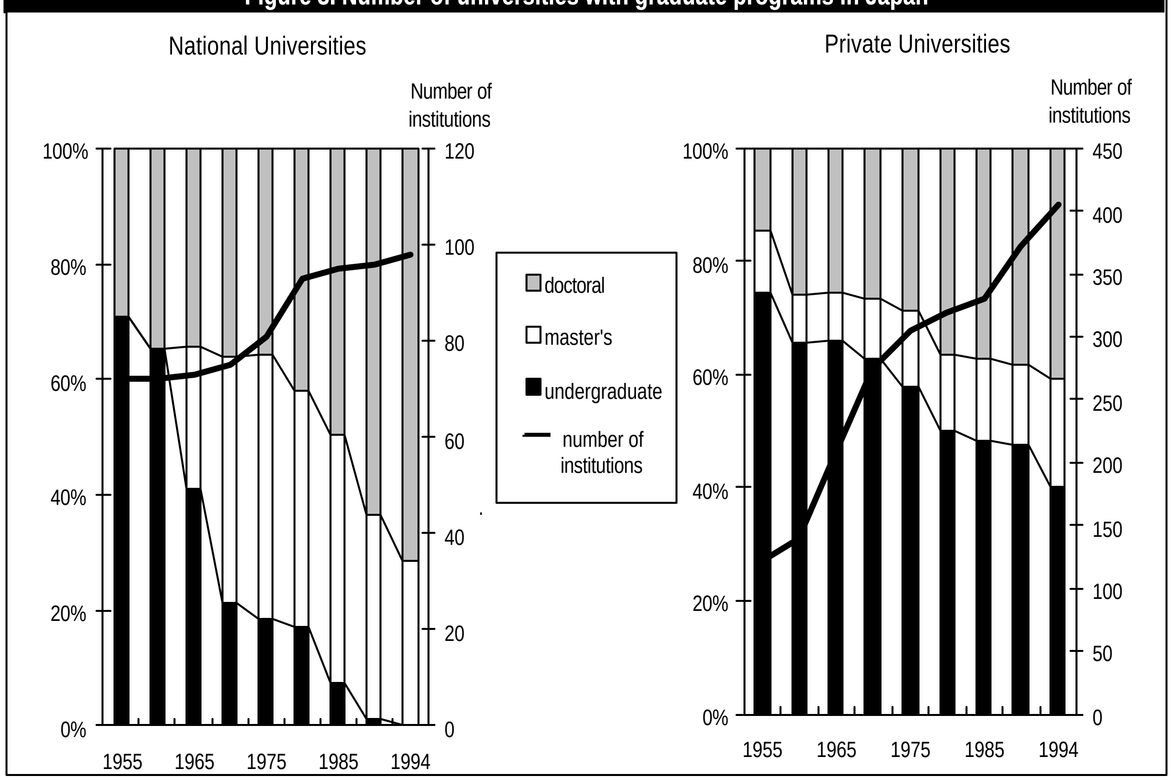
SOURCE: Monbusho, Basic School Survey.

Table 3. Enrollment in graduate programs in Japan: master's and doctorate, by field, 1960-97

Field	1960	1970	1980	1990	1997
	Master's programs				
Total	8,305	27,714	35,781	61,884	119,406
Humanities	2,870	5,157	5,469	6,009	10,729
Social sciences	2,370	4,607	4,050	6,366	15,380
Science	987	2,983	3,741	6,484	12,109
Engineering	1,223	10,251	14,864	28,399	51,277
Agriculture	372	2,063	2,546	4,046	6,943
Health	140	909	1,497	2,710	4,909
Other	343	1,744	3,614	7,870	18,059
	Doctoral programs				
Total	7,429	13,243	18,211	28,354	52,141
Humanities	1,016	1,876	2,860	3,594	5,592
Social sciences	894	1,727	2,430	2,654	4,830
Science	900	2,263	2,589	3,067	5,831
Engineering	391	2,356	2,358	4,315	10,847
Agriculture	339	839	1,095	1,742	3,632
Health	3,709	3,769	6,191	11,794	17,187
Other	180	413	688	1,188	4,222

SOURCE: Monbusho, Basic School Survey.

Figure 3. Number of universities with graduate programs in Japan



SOURCE: The Monbusho Survey of Education.

The System for Supporting, Training, and Employing S&E Graduates in Japan

Research Funding for Graduate Education

The growth of general university funds was almost frozen in Japan during the 1980s, due to the governmental budget deficit problem. This situation caused serious problems in graduate education because it had long been maintained by general university funds. However, revitalization of university research was considered critical in promoting advanced research and economic competitiveness. Monbusho also increased other types of research funding other than general university funds. These funds are not formula-based but are provided on a competitive basis. Thus, the structure of university research funding has changed greatly over the last several years. Special funds have been set up for graduate schools (on an institutional basis) as well as for new fellowships for doctoral students and postdoctoral researchers (on an individual basis).

Special budgetary mechanisms are available for graduate schools that are expected to produce outstanding educational or research achievements or that are actively involved in new ventures. In fiscal year 1987, Monbusho established a system for subsidizing advanced equipment for graduate schools with the aim of achieving rapid improvement in the conditions of graduate education and research. Under this system, funds are made available to graduate programs that generate excellent educational and research results. The funds are used to install advanced educational facilities needed by scientific fields and educational activities. In fiscal year 1995, the government allocated 6,343 million yen for this purpose.

A special expenditure system, the *Kodo-ka* fund, was established in fiscal year 1992 to give priority to the advancement of education and research, especially at graduate schools, through support of educational and research activities, including joint research, research exchanges, the use of teaching assistants, and international exchanges. In fiscal year 1995, 9,981 million yen were allocated for this purpose.

The aim of these new policies, along with a growing amount of competitive grant-in-aid programs (*Kaken-hi*), is to give additional resources to selected schools and scholars whose research quality and performance are outstanding. A new funding program, Research for the Future, which began in 1996 and is managed by the Japan Society for the Promotion of Science (JSPS), is funded through capital investments made by the Japanese government to promote and expand the frontiers of scientific research.[2] Funding is decided by the JSPS committee after designation of the specific research fields to be pursued.

In addition, some universities, such as the University of Tokyo, have recently shifted their research units (*Koza*) from undergraduate departments to graduate schools (*Juten-ka*). By doing so, they have succeeded in increasing their research funding by 25 percent from Monbusho. The Center of Excellence program is another example of selective allocation of resources. This program aims to establish a superior research base within a university, and Monbusho provides active support to those institutions recognized as centers of excellence. As a result, the university funding structure has greatly changed from relying on general university funds toward a reliance on specific and competitive funds.

Table 4. Major funds allocated to national universities

Type of Funding	Million yen		
	1987	1992	1997
General university fund	97,824	117,873	154,052
Grant-in-aid	45,080	64,600	112,200
Contract research from industry[a]	22,361	48,184	52,783
Contract research from government	5,451	9,449	41,853

[a] Donations in 1997 included large capital investment funds.
SOURCE: The Monbusho Survey of Education.

Financial Support for Graduate Students and Postdoctoral Researchers

Financial support for graduate students and postdoctoral researchers is important for research training. For graduate students, scholarship loans provided by the Japan Scholarship Foundation (JSF) have played the

[2]Many efforts have been undertaken to improve the difficult economic situation in Japan. Research as investment has emerged under these circumstances.

biggest role.[3] These loans enable students who lack financial resources to attend graduate schools. More than 40 percent of master's degree program students, and more than 60 percent of doctoral program students, used these loans in the 1970s. Although the growth of JSF scholarship loans did not follow the expansion of the student population (those figures have now declined to 30 percent of master's students and 50 percent of doctoral students), the loans provide basic financial support for graduate students. Students who, upon graduation, are employed in universities or related institutions as researchers for some years do not need to return their scholarship loans.

In 1985, Monbusho established a new and more competitive fellowship program for young researchers, Fellowships for Japanese Young Scientists. With the aim of cultivating young researchers who will conduct innovative and trail-blazing research, this fellowship program provides a limited number of promising young researchers with fellowships and research grants so as to allow them to concentrate on their research, which they conduct in laboratories or under supervising researchers of their choice for a specified period (2 to 3 years). This new fellowship, which is administered by the JSPS, is provided for graduate students and postdoctoral researchers on a highly competitive basis. In fiscal year 1997, 2,420 doctoral students and 1,070 postdoctoral researchers were granted this type of fellowship. Thus, competitive funding for individuals has been promoted.

Under the JSPS fellowship program for young Japanese researchers, postdoctoral fellows receive 354,000 yen (approximately US$3,000) a month, and doctoral students receive 202,000 yen (US$1,700) a month. Research funding of up to 1.5 million yen is also provided. The JSF provides scholarship loans of 83,000 yen a month for master's degree course students and 115,000 yen a month for doctorate course students. In addition to the fellowship, other types of support are provided through a teaching assistant program and a research assistant (RA) program. Unlike the U.S. system, the RA is directly funded by institutions without a direct link to particular research grants.

As part of the promotion of the Program to Support 10,000 Postdoctorals, which is included in the Science and Technology Basic Plan of 1996, these new kinds of competitive support devices will be expanded not only by Monbusho, but also by other governmental agencies, including the Science and Technology Agency. The target amounts of annual support differ greatly (table 5).

Table 5. Main financial support for graduate students and post-doctoral researchers in 1998

Sources/mechanisms of support	Graduate students		Post-doctoral	Annual amount of support (1,000 yen)
	Master's	Doctoral		
Total enrollment[a]	105,079	38,343		
	Monbusho related			
JSF scholarship loans[b]	27,210	19,750	NA	MC:996, DC:1,380
JSPS fellowships	NA	2,440	1,330	DC:2,424, PD:4,248
Teaching assistantships	3,538	6,853	NA	MC,DC: 528
Research assistantships	NA	2,562	NA	DC:1,056
Other	NA	NA	2,360	NA
	STA and other ministries			
Fellowship from STA[c]	NA	NA	1,087	from 3,240 to 7,488
Fellowship from MITI[d]	NA	NA	133	8,640
Other	NA	NA	1,422	NA

[a] Japanese students only.
[b] JSF: The Japan Scholarship Foundation is a JSPS-like special public organization under the umbrella of Monbusho.
[c] STA: Science and Technology Agency.
[d] MITI: Ministry of International Trade and Industry.

KEY: NA = not applicable
MC=Master's course, DC=Doctoral course, and PD=Postdoctorate.

SOURCE: The Monbusho Survey of Education.

[3]Although scholarships are not considered loans in U.S. terminology, Monbusho considers them so because JSF scholarships (*Shogaku-kin*) should be returned (with some exceptions) under the Japanese system.

Employment

The labor market for master's students has been generally satisfactory, especially for engineering students. These are hired by various kinds of industries and are playing a key role in the growth of industry and the economy. In contrast, the labor market outlook for doctoral students is not optimistic. One of the biggest markets for doctoral students continues to be the academic sector. This market is going to shrink because of the decline in the population of 18-year-olds. In addition, current economic difficulties make this matter worse because industries are hesitating to hire doctoral degree-holders. The labor market in industry has tended to be in specific fields. Getting a job in industry has continued to be difficult for doctoral students in the humanities and social sciences. Furthermore, the salary for Ph.D.s is almost the same as for people who finish undergraduate programs and enter employment 5 years earlier—that is, a bachelor's degree recipient's salary increases to that of a Ph.D. if he or she continues to work for 5 years at the same company instead of studying at graduate schools for 5 years to get a doctorate.

A March 1997 survey (table 6) of the careers of students who had completed graduate courses showed that of the 50,430 who had completed master's degree courses, 7,992 entered doctorate programs, while 34,223 entered employment. The main industrial sector in which graduates were employed was manufacturing (17,117). A total of 9,860 people had completed doctorate courses. Of these, 6,231 (63.2 percent) entered employment. Although industry was a major employment sector, getting a job at a university was the leader in many fields.

Demand for graduates of master's degree courses in science and engineering is especially high, but there has been a steady rise in demand for graduates in the humanities and for graduates of doctorate courses. There is evidence, however, that society still does not always place a high enough value on graduate school education. Moreover, not all graduate schools have developed educational programs that offer attractive content and provide an appropriate response to current demand.

Table 6. Employment of graduate students, 1997

Field	Total	University teaching	Industry total	Manufacturing[a]	School teacher	Health related	Further study	Other[b]
				Master's				
Total	50,430	536	31,073	17,117	2,080	534	7,992	8,215
Humanities	3,723	50	616	72	227	25	1,149	1,656
Social science	5,611	58	2,289	320	66	29	1,271	1,898
Science	5,267	9	2,985	1,615	184	18	1,529	542
Engineering	23,337	56	20,214	12,850	64	23	2,011	969
Agriculture	3,056	7	1,835	882	38	17	717	442
Health	2,033	91	1,008	802	2	329	398	205
Education	4,167	120	747	83	1,430	62	333	1,475
Other	3,236	145	1,379	493	69	31	584	1,028
				Doctoral				
Total	9,860	1,828	2,507	922	49	1,817	35	3,624
Humanities	920	210	108	5	19	2	10	571
Social science	650	255	66	6	2	1	6	320
Science	1,145	116	392	108	14	4	5	614
Engineering	2,434	447	1,245	619	6	1	5	730
Agriculture	780	123	282	71	4	12	3	356
Health	3,370	530	284	88	0	1,796	5	755
Education	180	70	21	1	0	0	1	88
Other	381	77	109	24	4	1	0	190

[a] Manufacturing is a subset of the "total" in industry.

[b] Other includes nonresponses.

SOURCE: Monbusho, Basic School Survey.

Under these circumstances, Monbusho's University Council now predicts that enrollment in graduate programs—master's and doctoral degrees combined—will increase from 170,000 in 1997 to 250,000 by 2010. In other words, as shown in table 7, the number of graduates in each year will increase from 60,000 to 93,000 or 94,000. As for supply and demand, demand is predicted to exceed supply for master's degrees, while current policies will lead to a supply exceeding demand for doctorates even in science and engineering. The situation in the humanities and social sciences is projected to be much worse. Thus, an emerging policy issue is how to improve the educational and research quality relevant to actual demand and also improve the environment around graduate education that is now poorly organized. In other words, a crucial point for graduate schools will be whether they can produce master's and doctorate degrees attractive to industry, government, and the business world.

Table 7. University Council estimates for Japan on supply and demand of master's and doctoral students, 1997-2010

Field	1997	2010 supply		2010 demand	
	Actual	High	Low	High	Low
	Master's				
Total	50,430	76,561	74,900	79,947	72,635
Humanities	3,723	5,612	5,139	4,792	4,537
Social science	5,611	10,386	9,281	8,423	7,748
Science	5,267	7,612	7,512	8,670	7,780
Engineering	23,337	33,428	33,751	40,397	36,211
Agriculture	3,056	3,556	4,362	4,918	4,451
Health	2,033	3,218	3,158	2,826	2,640
Education	4,167	6,643	6,344	5,022	4,779
Other	3,236	6,106	5,353	4,899	4,489
	Doctoral				
Total	9,860	17,974	17,878	12,931	11,957
Humanities	920	1,728	1,662	1,110	1,059
Social science	650	1,570	1,406	773	742
Science	1,145	2,038	2,026	1,667	1,495
Engineering	2,434	4,824	4,640	3,774	3,322
Agriculture	780	1,555	1,438	1,098	998
Health	3,370	4,523	5,135	3,777	3,660
Education	180	467	428	212	204
Other	381	1,269	1,143	520	477

NOTE: "High" is an estimate from recent 10-year trends; "low" is from recent 15-year trends.

SOURCE: University Council of Japan.

Japanese Educational Reform Programs as of August 1997

Revitalization of Higher Education Institutes

- **Implementation of university reform.** Responding to the revision of the National Standards for the Establishment of Universities in 1991 and the initiation of a self-monitoring and self-evaluation system, each university now reviews its education and research system, improves its curriculum as well as its method of education, and actively implements the self-monitoring and self-evaluation system. To further promote university reform, each university will improve its evaluation system by listening to the opinions of outside knowledgeable persons and experts, such as academicians, heads of related municipalities, and representatives of local industry. Each university will continuously review and evaluate reforms and try to publicize as much information as possible, including the results of self-evaluations.

- **Promotion of enrichment in graduate schools and reorganization of undergraduate departments.** Monbusho will examine models of higher education that play a leading role in advanced scientific research and that respond to the global demand for capable individuals while meeting the challenges of decreasing college-age population and changing industrial structure. At the same time, Monbusho will promote enrichment of graduate schools and reorganization of undergraduate departments.

  Several reports to the University Council called for reforms in graduate education. These reports included suggestions for "allowing more flexibility in the existing systems of graduate schools" (December 1988), "the improvement and enhancement of graduate schools" (May 1991), and "the quantitative development of graduate schools" (November 1991). Monbusho is using these recommendations to reform the graduate education system. It will also enhance and strengthen graduate schools by establishing postgraduate and nondegree courses for graduates mainly in the field of pioneering and interdisciplinary research.

- **Improvement and enhancement of scholarship loan program.** The scholarship loan program for graduate students will be improved and enhanced to respond to the growing needs for training researchers and specialized professionals.

Training Promising Talent for the Future Advancement of Science and Technology, and Promotion of Science and Research in Response to Social Needs

- **Promotion of science and technology education to heighten the interest of young students in science and technology.** Monbusho aims to heighten elementary and lower secondary school students' interest in science and deepen their understanding of technology. It will support educational activities in science and technology for young people by utilizing science museums as well as university museums and by holding exhibitions related to science and technology. Moreover, the ministry will seek to increase the attraction of young people to science and technology through the "science volunteer" system, including the teaching staff of universities and colleges of technology as well as industrial researchers. Science museums' educational facilities can use these volunteers to give lectures and/or to carry out experiments for students.

- **Cooperative training among universities, institutes, and industry.** Monbusho is promoting internship programs with industry in which students work professionally in their major area for future career purposes. Monbusho will hold discussions between interested parties, including universities, colleges of technology, and industry, as well as knowledgeable persons and experts in technology.

Enrichment of education and research on venture business at institutions of higher education is aimed at training more capable venture business specialists. Monbusho is looking to attract highly qualified people in business into teaching. It is requesting industry's active cooperation with institutes in the areas of personnel interchange, provision of funds, and provision of information on markets and technology.

- **Enhancement of human resources in the science and engineering field.** Monbusho has promised to carry out the reorganization of departments and courses in science and engineering fields, and to promote modernization of educational facilities for laboratory work to enhance innovation in Japanese science and technology in the future. Furthermore, it seeks to support creative education programs that consist of various activities to cultivate students' creativity at universities and colleges of technology, and will disseminate best practices in developing creative human resources.

- **Personnel training and improvement of research environment in response to social needs.** Monbusho has promoted and initiated a 10,000 Postdoctoral Fellowships Program to support innovative young researchers. This will provide for the funding of research assistants within universities and national laboratories. At the same time, it is attempting to create better research environments by improving facilities and equipment. Further, it will allow cooperative relationships with other related ministries and agencies for the joint funding of research projects.

- **Enhancement of competitive funds.** Competitive funds will be enriched to promote inventive and innovative research in institutes. To make the funds distribution process more selective and efficient, Monbusho will promote implementation of prior, midterm, and posterior evaluations by outside organizations; disclosure of evaluation results- and reflection of evaluations on the distribution of funds.

SOURCE: Monbusho.

The Impact of Financing and Sources of Support for Graduate Education on Time to Degree

There are no official statistical data concerning the relation of financing for graduate students to their time to degree in Japan. However, a 1993 survey showed that the biggest reason why students did not continue their doctoral studies was because they had financial problems (Yamamoto 1996).

Regarding time to degree in Japan, there is great diversity by field. There are very few degrees granted compared to enrollment in the humanities and social sciences, while the success rate of degree completions is much higher in the fields of science, engineering, and medicine. In science and engineering, the ratio of doctoral degree granting is reasonably high; the ratio is far lower in the humanities and social sciences (table 9).

This fact reflects the differences in degree granting standards by field—i.e., whether the doctoral degree is a license for researchers or a prize for accomplished researchers in a particular field. Different modes of training may also affect the rate of degree granting. In science and engineering, the laboratory-intensive apprentice mode allows for easier communication between students and mentors, while the latter case is more difficult under the library-intensive individualistic research mode (Gumport 1993).

Distribution of Doctoral Degrees Within Countries and Abroad, and Foreign Doctoral Recipients

Monbusho conducts no official survey regarding the number of doctoral degrees granted to Japanese students who study abroad. However, the National Science Foundation's (NSF's) survey on U.S. universities' doctoral grants to foreign students sheds some light on this matter. According to an NSF analysis, "Compared to major Asian countries of origin, the number of students from Japan earning doctoral degrees in the United States is relatively small. Japanese industries often finance advanced training of their employees in U.S. universities for

Table 8. Sources of financial support for graduate students in Japan, according to a 1993 survey (percentages)							
Field	Parent/ spouse	Self-support	JSF's loan	Other scholarship	JSPS fellowship[a]	TA/Ra[a]	Other
	Master's						
Total	56	11.6	23.8	7.5		0.4	0.6
Humanities	46.1	19.4	26.1	6		1.2	1.2
Social science	46	20	27	6		0.5	0.5
Science	55.8	5.4	30.6	7.5		0.7	0
Engineering	58.7	10.4	21.7	8.1		0.2	0.8
Agriculture	59.5	9.9	22.9	6.8		0.8	0
Health	57	5.6	28	9.4		0	0
Education	68.8	12.5	12.5	6.3		0	0
Other	56	13.6	27.3	2.3		0	0
	Doctoral						
Total	25.2	19.4	44.3	4.3	4.9	0.4	1.5
Humanities	26.3	33.8	33.8	2.5	2.5	0	1.3
Social science	22.5	28.2	40.8	1.4	4.2	1.4	1.4
Science	16.9	10.2	54.2	6.8	11.9	0	0
Engineering	25	14.2	44.6	8.2	4.7	0.7	2.7
Agriculture	29.7	13.5	56.8	0	0	0	0
Health	36	12	48	0	4	0	0
Education	10	40	50	0	0	0	0
Other	34.3	11.4	40	2.9	8.6	0	2.9

[a] Since JSPS fellowships and teaching assistantships/research assistantships were not fully implemented in 1993, answers for these columns are incomplete.

NOTE: Data were compiled from responses to the question, "What is your primary source of support?"

SOURCE: Yamamoto, S. Graduate Schools in Japan From the Perspective of Academic Research. *University Studies* 15:1-287, (1996).

Table 9. Doctorate granting ratio in Japan			
	1990	1995	1995-90
Field	Percent		(Ratio)
Total	63.4	67.4	1.1
Humanities	3.2	14.0	4.4
Social science	13.1	21.4	1.6
Science	65.1	68.9	1.1
Engineering	70.9	79.9	1.1
Agriculture	68.1	69.5	1.0
Health	85.2	85.0	1.0
Education	12.4	15.0	1.2

NOTE: The doctorate granting figures are obtained by dividing the number of doctorates granted by the number of entrants into doctoral programs 5 years before (for health, 4 years before).

SOURCE: The Monbusho Survey of Education.

1 to 2 years, but relatively few remain long enough to complete a doctoral program" (NSB 1998). This means that there are relatively few Japanese who obtain doctoral degrees in science and engineering at U.S. universities.

In addition, the author's sample survey of the faculty of Tsukuba University (table 10) shows that there are a substantial number who received degrees from foreign universities in the humanities and social sciences. In science and engineering, according to the NSF analysis, there are very few faculty members who earned their Ph.D.s at foreign universities. This contrast between the humanities and social sciences on the one hand, and science and engineering on the other, is a reflection of the fact that Japanese universities have tended to decline in the number of doctoral degrees in the humanities and social sciences granted to those who studied in doctoral programs in Japan. As mentioned earlier, it is not easy to change the national attitude toward doctorates in the humanities and social sciences, where a doctorate is perceived more as an award for an established scholar than a license for further research.

Patterns of International Mobility

The numbers of Japanese students who study abroad and foreign students who study at Japanese universities are shown in tables 11 and 12. Note that the Japanese students' figures do not exactly reflect the situation of study abroad because they were obtained from emigration data asking about the purpose of travel.

Table 10. Doctoral degrees of the University of Tsukuba's faculty granted by Japanese and foreign universities (sample survey)						
Field	No doctorate		Granted by Japanese universities		Granted by foreign universities	
	Professor	Associate professor or below	Professor	Associate professor or below	Professor	Associate professor or below
Humanities total	40	84	28	14	10	17
Philosophy	5	5	4	2	1	2
History	6	18	16	6	2	5
Literature	15	29	5	4	4	4
Language	14	32	3	2	3	6
Social science total	22	26	33	35	21	20
Social sciences	19	19	10	12	3	4
Political sciences	3	7	23	23	18	16
Natural sciences total	0	5	73	176	3	5
Biology	0	0	17	37	1	0
Mathematics	0	3	15	28	0	0
Physics	0	0	19	53	0	2
Chemistry	0	1	9	26	1	1
Geosciences	0	1	13	32	1	2
Engineering total	0	4	70	127	7	9
Applied physics	0	0	16	33	4	3
Material science	0	0	16	31	0	0
Engineering mechanics	0	2	16	26	1	1
Electrical engineering	0	2	22	37	2	5

SURVEY: Survey of University of Tsukuba's faculty by Yamamoto.

Since the mid-1980s, Monbusho has been implementing the 100,000 Foreign Students Plan, which aims to increase the number of students from abroad to 100,000 by the year 2001. This goal assumes the acceptance of 30,000 students at the graduate school level. As of May 1997, about 20,000 foreign students were studying at graduate schools in Japan, while 32,000 were studying in undergraduate programs. The attainment of 100,000 students by the beginning of the 21st century now seems unrealistic due to the economic recession in Japan and other Asian countries. However, Monbusho thinks it is important to improve admission systems for foreign students, especially at the graduate level, from the viewpoint of promoting international exchanges in education as part of Japan's efforts to make an international contribution appropriate to its rising international status.

Table 11. Number of Japanese students studying abroad, 1990 and 1995		
Country	1990	1995
Total	29,216	59,468
Australia	218	675
Austria	196	251
Canada	312	774
China	806	8,526
France	863	1,157
Germany	1,200	1,236
South Korea	562	392
U.K.	657	2,042
United States	24,000	43,770
Other	402	645

SOURCE: The Monbusho Survey of Education (from data of the Ministry of Justice).

Education and research guidance for foreign students must reflect those students' needs. Some universities are actively facilitating the admission of foreign students through measures that include the expansion of Japanese language education programs, the introduction of

Table 12. Number of foreign students studying at Japanese universities and colleges, 1960-97				
Year	Total	Under-graduate	Graduate	Junior colleges
1960..........	4,703	3,874	557	272
1970..........	10,471	7,730	1,857	884
1980..........	15,008	10,913	2,644	1,451
1990..........	38,444	23,571	12,306	2,567
1997..........	55,114	32,432	20,051	2,631

SOURCE: The Monbusho Survey of Education.

instruction in foreign languages, and provision for theses written in foreign languages. Efforts are also being made to improve education and research guidance systems in graduate departments to which large numbers of foreign students have been admitted. Measures in this area include the appointment of more teaching staff to research programs.

Current Situation of Korean Graduate Education and Its Reform

Higher Education and the Granting of Degrees

There are numerous similarities in the school systems of Japan and the Republic of Korea. In both countries, a linear school system of the 6-3-3-4 type has been adopted. This means Korea has a school system with 6 years of elementary school, 3 years of middle school, 3 years of high school, and 4 years of university or college. Every citizen who finishes upper secondary school (high school) is eligible to apply for admission to institutes of higher education. Institutes of higher education in the Republic of Korea are classified into four categories: (1) colleges and universities offering 4-year undergraduate programs (medical and dental colleges, 6 years); (2) 2- to 3-year junior colleges; (3) universities of education; and (4) miscellaneous schools.

Among those higher education institutions, 4-year colleges and universities may have graduate schools. Enrollment in graduate schools is shown in Table 13. These are classified into three types in accordance with their functions and goals: professional graduate schools, general graduate schools, and open graduate schools. This situation differs from Japanese graduate education, which has no formal classifications and in which academic research and professional training are not separated within a single system.

Professional graduate schools prepare students for professional careers in education, business administration, public administration, and other fields. The academic degree that the professional graduate schools confer is a professional master's degree. General graduate schools aim to foster creativity, initiative, and leadership in specialized academic disciplines. General graduate schools award a master of arts or master of science to those who complete the graduation requirements. Students in doctoral programs at general graduate schools must have a master's degree or equivalent, a scholarly background in their field of specialization with some demonstrated research experience, and recommendations from individuals in their field of specialization. Doctoral degrees are shown in Table 14.

Development and Reform of Higher Education

The current higher education system was introduced after the establishment of the Republic of Korea in 1948

Table 13. Enrollment in Korean graduate schools, as of 1997					
Field	Grand total	Master's degree course			Doctoral course
		Total	General	Professional	
Total..	151,358	128,097	60,634	67,463	23,261
Humanities............................	15,323	12,669	6,454	6,215	2,654
Social sciences......................	36,251	32,639	9,674	22,965	3,612
Natural sciences.....................	50,802	39,778	29,377	10,401	11,024
Medical and pharmacy...........	13,010	8,512	7,022	1,490	4,498
Arts and physical education....	8,502	8,021	4,907	3,114	481
Teaching profession...............	27,470	26,478	3,200	23,278	992

SOURCE: Korean Ministry of Education, *Statistical Yearbook of Education* (Seoul, 1998).

Table 14. Granting of doctoral degrees at Korean universities, March 1996 to February 1997

Total	2,713
Humanities	700
Social sciences	649
Natural sciences	2,444[a]
Medical and pharmacy	1,120
Arts and physical education	100
Teaching profession	144

[a] Doctorates in engineering total 1,420 and are included with natural sciences.

SOURCE: Korean Ministry of Education, *Statistical Yearbook of Education,* Seoul, 1998.

under the strong influence of the American system. After going through hard times, the Korean higher education system experienced a large quantitative expansion in the 1960s and 1970s owing to remarkable economic progress. Following a rapid expansion as in Japan, Korean education endeavored to emphasize and enhance the quality of education, and the Fifth Republic clearly established in the constitution the institutionalization of life-long education. In addition, the republic set as one of the nation's top priorities the formation of a sound personality through education and reform of civil education, emphasizing science and life-long education.

In March 1985, the Presidential Commission on Educational Reform was established under the direct supervision of the president.[4] To achieve the goal, set forth in a 1992-96 plan, of Educating Koreans as the Prospective Leaders for the 21st Century, the commission carried out extensive studies through December 1987 and recommended various kinds of reform measures, including reform of the school system, development of high-level manpower in science and technology, and a drastic increase in educational investment. The recommendations were adopted and enacted consecutively; later, in May 1988, the Advisory Council for Educational Policy was inaugurated as an advisory council to the minister of Education.

The 1990s have witnessed advances in education through the realization of quality education and educational welfare. A particular concern is the pursuit of qualitative, rather than quantitative, growth. The above-referenced plan of Educating Koreans as the Prospective Leaders for the 21st Century exemplifies the goals of Korean education.

[4]Incidentally, Japan also established a National Council on Educational Reform during the same period (1984-87) under the strong initiative of Prime Minister Nakasone; the recommendations of the council still have a strong influence on current educational reform in Japan.

In response to the growing importance of science and technology, the Ministry of Education recently initiated a discussion on the further reform of the graduate education system in Korea, which aims at further supporting leading graduate schools by a reallocation of resources.

Foreign Students in Korea and Korean Students in Foreign Countries

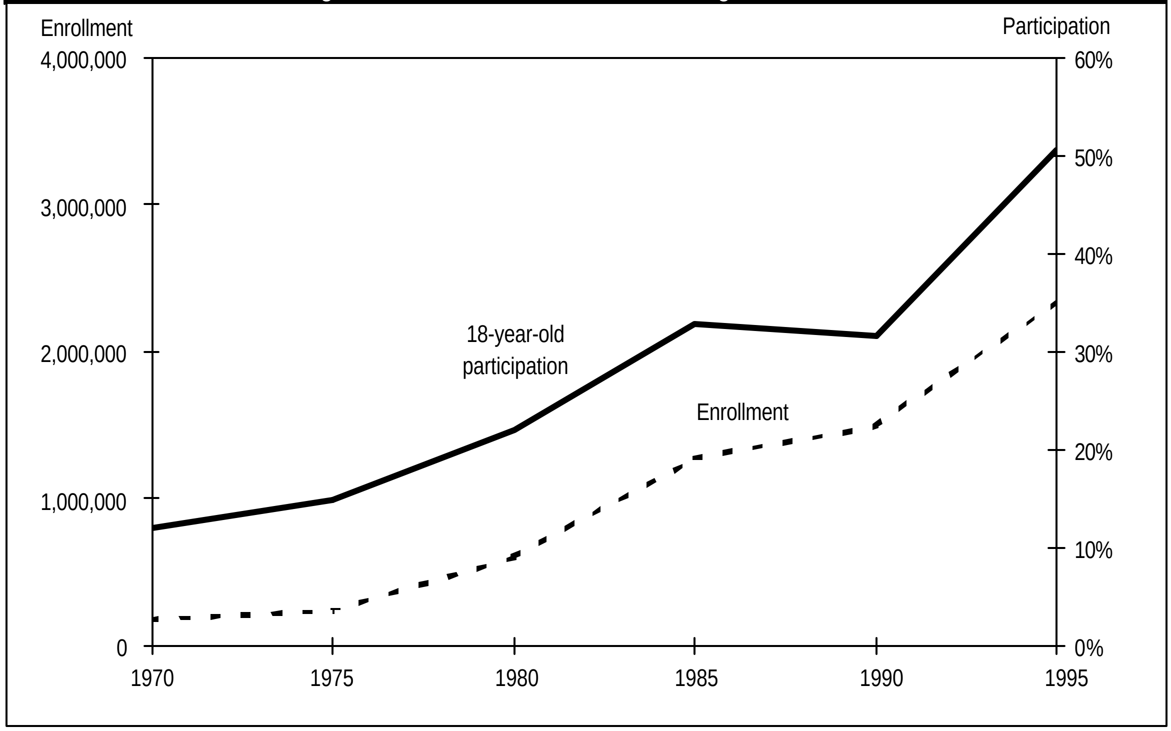
The number of international students attending higher educational institutes in Korea has increased steadily in recent years. As of June 30, 1996, the total stood at 2,143. (see Table 15.) By type of educational institution, about 40 percent of these foreign students attended graduate schools at universities; the rest attended undergraduate and other courses.

One of the features of doctorate granting for Koreans is that a relatively high percentage is granted Ph.D.s by foreign universities. For example, there were 1,004 Koreans who obtained doctorates in science and engineering at U.S. universities in 1995, compared to 2,444 science and engineering doctorates awarded by Korean universities in the following year (see table 14 and NSB 1998). This is a great contrast to Japan's situation, where 4,540 doctorates were awarded at Japanese universities in 1995, while only 154 Japanese obtained doctorates in science and engineering at U.S. universities that same year (see table 1 and NSB 1998). Table 16 indicates similar degree-earning tendencies regarding Korean university faculties, although the data are not very recent.

Conclusion

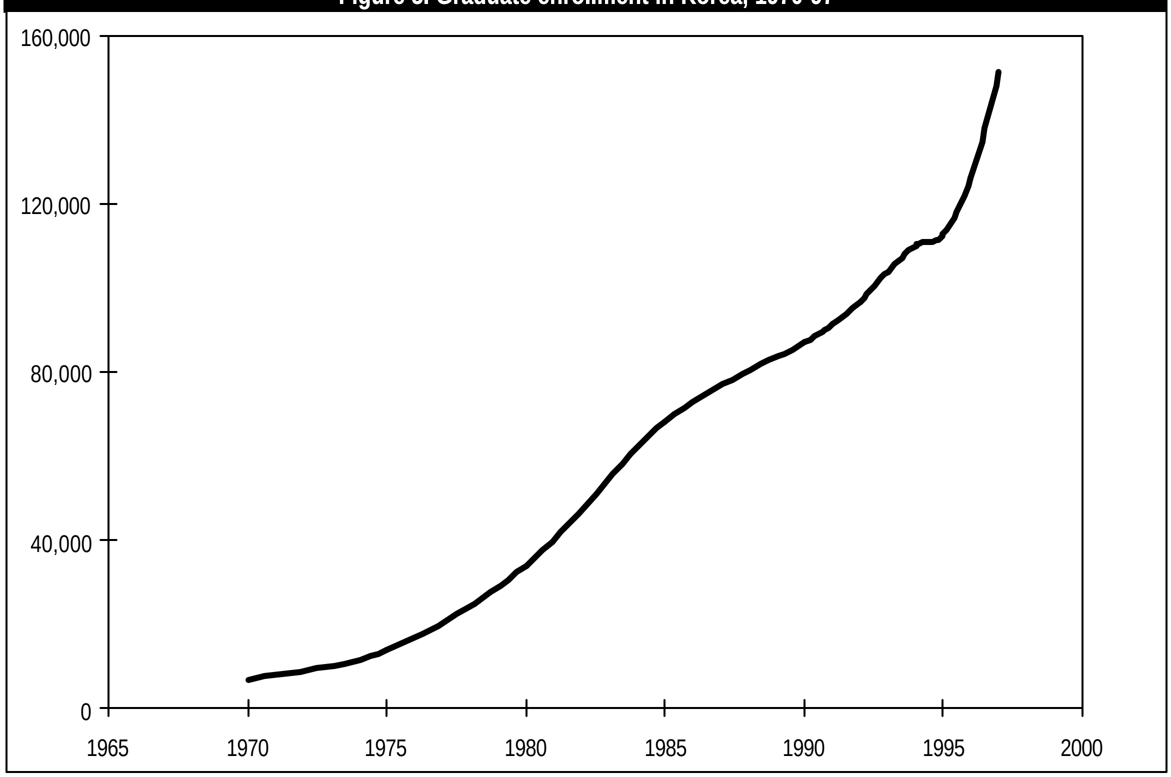
Japan and Korea are now making efforts to adjust their graduate education systems to global levels and quality standards, under the pressures of the ongoing massification of higher education and of international competition in scientific research. Both countries have confronted the growing impact of Western culture and civilization since the latter part of the 19th century and have tried to establish their own higher education and scientific research systems. The establishment of the Imperial University at Tokyo in 1886 was one of Japan's strong responses.

Figure 4. The massification of Korean higher education



SOURCE: Korean Ministry of Education, *Statistical Yearbook of Education.* Annual Series.

Figure 5. Graduate enrollment in Korea, 1970-97



SOURCE: Korean Ministry of Education, *Statistical Yearbook of Education.* Annual Series.

Table 15. Foreign students at Korean universities

Nationality	Total	Undergraduate	Graduate	Others
Total	2,143	1,279	803	61
Argentina	49	44	4	1
Canada	58	27	31	0
China	486	181	291	14
Germany	14	9	5	0
Japan	395	242	149	4
Malaysia	130	99	1	30
Paraguay	28	27	1	0
Taiwan	444	398	37	9
United States	299	130	169	0
Others	240	122	115	3

SOURCE: Korean Ministry of Education, *Statistical Yearbook of Education* (Seoul, 1998).

Table 16. Origins of university faculty doctorates by country and field, 1983 (percentages)

Field	Korea	North America	Europe	Asia	Others
Total	61.1	21.9	8.7	8.0	0.3
Humanities	39.2	38.3	15.7	6.5	0.3
Social sciences	47.2	36.4	11.6	4.7	0.2
Science	53.5	29.7	6.0	9.4	0.4
Engineering	56.8	19.1	10.3	13.6	0.2
Linguistics	60.1	14.1	18.9	6.6	0.1
Business administration	65.5	26.1	5.4	3.0	0.0
Arts and physical education	24.6	60.7	11.5	3.3	0.0
Fishery	53.0	6.1	19.7	21.2	0.0
Medicine	90.2	3.7	1.6	4.4	0.1
Agriculture	63.4	14.7	3.9	17.1	0.9

SOURCE: Lee, S.H., "The Emergence of Modern Univeristies in Korea," in P.G. Altbach, ed., From Dependence to Autonomy: The Development of Asian Universities, pp. 312-47 (1993).

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Graduate Education Reforms and International Mobility of Scientists and Engineers in Taiwan

Yugui Guo

Historical Review

Taiwan, an island off the southeast of mainland China, is one of the most densely populated areas in the world: 35,873 square kilometers in size with more than 21 million inhabitants. Taiwan was part of China before it was ceded to Japan in 1895. During the 50 years of Japanese occupation, a Western-style system of education was first introduced into Taiwan via the Japanese (Chen 1997). One university, one high school, and three junior colleges were established during that time. The enrollment was very small, and the function of these institutions was to provide a research capability and high-level manpower in support of Japan's policies of colonization and expansion.

At the end of World War II in 1945, Taiwan was restored to China. The island's educational system was soon replaced by the one adopted on the mainland since 1922, which mainly follows the American prototype (Chen 1997). After the Chinese National Party moved its seat to Taiwan in 1949, Chinese educational policy was imposed on the island more thoroughly than before and Japanese influence diminished further.

Since then, Taiwan has developed rapidly. To meet the needs of immediate economic development and the growing demand for skilled human resources, higher education expanded rapidly between the 1950s and 1980s. Tables 1 and 2 show that, during this interval, the number of tertiary institutions increased by a factor of 15 (from 7 in 1950-51 to 107 in 1987-88), while enrollment swelled 54 times (from 6,665 in 1950-51 to 362,001 in 1987-88). Graduate enrollment increased from almost nothing in 1950-51 to 15,121—including 12,426 master's degree students and 2,695 doctoral students—in the 1987-88 academic year. This rapid expansion in higher and graduate education was driven by many forces, including the development of secondary education; the needs of a growing college-age population for higher and advanced education; and, most important, the takeoff of the economy since the 1970s. This last gave a great impetus to higher and graduate education in Taiwan.

Table 1. Number of tertiary institutions in Taiwan (1950-88)

Academic year	Type of Institution		Total
	Universities and colleges	Junior colleges	
1950-51	4	3	7
1960-61	15	12	27
1970-71	22	70	92
1980-81	26	77	103
1987-88	39	68	107

SOURCES: Ministry of Education, *Educational Statistics of the Republic of China,* 1997, pp. 2-5. Shun-fen Chen, "Taiwan," in Philip G. Altbach, Editor, *International Higher Education: An Encyclopedia* (Garland Publishing, Inc., 1991), pp. 550-51.

Table 2. Enrollment at tertiary institutions in Taiwan (1950-88)

Academic year	Master's	Doctorate	Undergraduate	Junior college[a]	Total
1950-51	5		5,374	1,286	6,665
1960-61	426	11	26,737	7,888	35,060
1970-71	2,129	166	92,850	55,301	150,446
1980-81	5,633	673	153,088	105,246	264,640
1987-88	12,426	2,695	192,933	153,947	362,001

[a] First-, second-, and third-year students at 5-year junior colleges are excluded.

SOURCES: Ministry of Education, *Educational Statistics of the ROC*, 1997, pp. 2-5. Shun-fen Chen, "Taiwan," in Philip G. Altbach, Editor, *International Higher Education: An Encyclopedia* (Garland Publishing, Inc., 1991), pp. 550-51.

Current System

Higher and graduate education in Taiwan have witnessed a remarkable development since the mid-1980s. This development has been coupled with a series of political, economic, and social reforms that emerged with and were affected by changes in domestic and international contexts.

Higher education in Taiwan is offered by three types of institutions: (1) junior colleges, (2) independent colleges, and (3) universities. By 1997, there were a total of 67 junior colleges, 44 independent colleges, and 26 universities. Junior colleges provide 2- to 3-year programs leading to a diploma (similar to the American associate degree in terms of academic standards). Those with only one or two schools are called independent colleges. Universities consist of at least three colleges (or schools). Both independent colleges and universities offer 4-year programs leading to a bachelor's degree. Many of them also offer master's-level programs, and some offer doctoral-level programs, depending on the academic performance of the department concerned. In the 1996-97 academic year, 67 independent colleges and universities offered bachelor's-level training. There were 536 master's programs and 116 doctoral programs in these universities and independent colleges. Four-year undergraduate enrollment has increased by 75 percent over the past 9 years (from 192,933 to 337,837), while enrollment in master's and doctoral degree programs has risen to 35,508 and 9,365—2.6 times and 3.5 times the figures for the 1987-88 academic year, respectively.

One of the characteristics of the Taiwan higher education system is that there are more private institutions than public ones. In 1997, out of 137 colleges and universities, 51 are public and 86 are private (Li 1997). However, of 24 universities, 16 are public and 8 are private; out of 43 independent colleges, 21 are public and 22 are private (Ministry of Education 1997). The universities are all comprehensive in nature, while the independent colleges generally focus on specific disciplines such as fine arts, medicine, technology, and teacher training. Among the 4-year institutions, public institutions are preferred over private by most students because the faculty qualifications of the former are usually better. In addition, tuition rates in the public sector are one-third those in the private sector. For example, in the 1996-97 academic year, the public institutions enrolled 25,423 master's degree students and 8,288 doctoral degree students, while the private sector institutions enrolled 10,084 master's degree students and 1,077 doctoral degree students. Recently, the Ministry of Education proposed that private universities with limited resources concentrate their efforts on the teaching of undergraduate students. This can be interpreted as a governmental intention to develop a policy of stratification, with public institutions emphasizing both graduate programs and research activities, and private institutions emphasizing undergraduate teaching.

Governance and Finance

According to the constitution of Taiwan, the state has the power to supervise educational institutions at all levels. Thus, higher education in Taiwan has for a long time been marked by strong centralization. The institutions of higher learning are regulated with little flexibility. Almost every policy regarding higher education is made by the central government.

The Ministry of Education not only approves the establishment of new institutions, departments, and programs, but also controls the size of enrollment, tuition rates, required courses, minimum graduation credits, and other factors at all institutions, both public and private. Presidents of public institutions are chosen and appointed by the Ministry of Education. Those of private ones are appointed by their board of trustees with the approval of the Ministry of Education. As most of Taiwan's university presidents are closely connected with the ruling party, and many of them were former government officials, the government's control of the presidency often results in a degree of politicization on campus.

All public colleges and universities receive government funding. Public institutions receive their annual budgets from the government with specific amounts for each budget category, and tuition collected from students must be returned to the government. For private institutions, the major source of income is tuition. Government subsidies to them are limited, usually up to 15 to 20 percent depending on the efficiency of education and overall accreditation each year. In 1997, the total expenditure of government on education reached US$15.3 billion, more than 5 percent of the gross national product (GNP).

The reason that all public schools are entitled to full support derives from the constitution. Article 164 of Taiwan's constitution states: "Expenditures of educational programs, scientific researches and cultural services shall not be, in respect of the Central Government, less than 15 percent of the total national budget; in respect of each province, less than 25 percent of the total provincial budgets, and 35 percent in the level of municipality or county" (Li 1997). This provision financially and legally guarantees the development of higher education.

The centralized character of the higher education system has been widely criticized; beginning with the political reforms of 1986—especially since the lifting of martial law in 1987—Taiwan's higher education system has gradually been transformed. The promulgation of the newly revised University Act in early 1994 further laid a legal foundation for decentralization and depoliticization. According to this new act, the relationship between the government and universities has been changed, with more autonomy granted to universities. The three major reforms are as follows (Li 1997):

- **University autonomy.** Under the newly implemented educational reform policy, the main function of the Ministry of Education is to "oversee" and "guide" universities instead of "governing" them, and all public universities have been granted the right of self-governance. Specifically, university presidents will no longer be appointed by the Ministry of Education, but selected either by a search committee or by votes from all faculty members in the university. However, the University Act still specifies that the Ministry of Education holds final power over the appointment of presidents of national universities (Law 1995). Deans, chairpersons, and new faculty members to be employed are also determined by the faculty. Original core courses are no longer mandatory, depending on the decision of the curriculum committee of the faculty senate of the university.

- **Diversifying budgets.** The Ministry of Education will no longer allocate the complete budget to each public university. Instead, support will be limited to an allocation of a ceiling of up to 80 percent of the total overall budget requested for a given fiscal year. Each institution must undertake efforts to raise funds and find resources from the society at large, rather than being solely dependent on the government.

- **Transfer of credits.** A new policy on the transfer of credits has also been approved under the current reform campaign. Students do not have to restrict themselves to a single university, but are now allowed to take courses at other universities, if time permits. They are even allowed to transfer credits earned overseas during summer programs on the condition that the corresponding university is an accredited institution of higher learning.

These reforms have reflected the trends of decentralization, democratization, and internationalization of higher education in Taiwan in the past several years. As a result, the higher education system is becoming decentralized to a large extent, although all institutions still receive budgets from the Ministry of Education. As the budget of a public institution is to come from diversified sources, there will be a greater chance for institutional autonomy. Allowing students to travel overseas to take a few courses as part of their university studies will broaden their international perspective and better enable them to fulfill their educational goals.

Degree Structure and Graduate Training

The degree structure and model of graduate training in Taiwan were introduced from the United States. The levels of academic degrees are connected with the different phases of Taiwan's higher education. The academic degrees are divided into three categories: bachelor's degree, master's degree, and doctorate degree (Ministry of Education 1995 and 1997).

Bachelor's Degree

After taking the highly competitive Joint Entrance Examination set each year by a board composed of university presidents, successful high school graduates are assigned to a university based on their preference and examination results. Once they are admitted to universities, they have to take 128 credits over 4 years, which is the minimum requirement for completion of a bachelor's degree. Though course content generally tends to be closely focused on a student's major subject, there is a current trend toward a wider choice of electives. The bachelor of medicine degree requires 7 years, the bachelor of dentistry 6. Some law and architecture departments require 5 years.

Master's Degree

Master's degree programs admit university/college graduates, including 3-year junior graduates with 2 years of job experience and 2-year and 5-year junior graduates with 3 years of job experience, to receive education for 2 to 4 years. For the master's degree, 24 credits and a thesis are generally the minimum requirements, followed by a written examination and an oral defense. A minimum residence of 2 years is required.

Doctorate Degree

The doctoral degree programs admit those having a master's degree and university/college graduates majoring in medicine who have received professional medical training for a minimum of 2 years. At least 18 credits and a dissertation are the minimum requirements, together with a written examination and an oral defense. The doctoral degree usually takes 4 to 6 years to complete. To achieve the goal of life-long education, many universities and graduate institutes create advanced education opportunities by offering various in-service training programs.

The current degree structure and graduate training are undergoing two important changes. The Ministry of Education is planning to establish an associate degree for graduates of junior colleges and to create master's degree programs for in-service employees in 1999 (Cultural Division of Taipei 1998, pp. 24 and 28). These reforms will encourage more people to pursue college studies and increase enrollments in both junior colleges and master's degree programs.

In Taiwan, students wishing to enter a doctoral degree program must pass an entrance examination conducted by the university. Since 1990, a special program has also been available through which students in master's degree programs may apply for direct admission to the doctoral program in their respective institute. They must have earned a grade point average of 85 or higher for their first year of study,[1] be ranked in the top one-third of their class, and have shown a strong capacity for independent research. In addition to the regular full-time students, some qualified students from government and industry are enrolled in doctoral programs through on-the-job training programs sponsored by their respective employers. Most of them are part-time students. Like the regular full-time students, they must pass the entrance examination to become eligible for enrollment in the graduate programs and must successfully complete the graduate program requirements to earn the degree.

To become formal candidates for the doctoral degree, graduate students must pass a qualifying examination. In most universities, students who do not pass the qualifying examination within 2 or 3 years after entering a doctoral program are dismissed from the university. In addition to their coursework, graduate students are also involved in research projects sponsored by the National Science Council, other government entities, or industry. These research projects are carried out under the supervision of advisors, and usually serve as an exploratory or feasibility study that sometimes is a potential framework for the students' doctoral dissertations.

For each doctoral enrollment, the Ministry of Education subsidizes about US$150 for operating expenditures and US$1,200 for expenditures on books, equipment, and facilities; these go directly to the institution. Thus, graduate students only pay part of their overall educational cost by meeting the tuition and miscellaneous fees, which amount to about US$550 per semester. Furthermore, all full-time doctoral students receive a monthly stipend of about US$300, and the top 10 percent are awarded a scholarship of US$550 for the first 3 years, which is provided by the Ministry of Education (Chang and Hsieh 1997). The doctoral degree awarded by universities in Taiwan is a research degree certifying that the recipient has the capability and training needed to engage in independent scholarly work.

Expansion of Graduate Education

Graduate education in Taiwan has witnessed a rapid expansion in the past 20 years. Table 3 and figure 1 indicate that, from 1975-96, total enrollment increased 10 times while enrollments of master's students and doctoral students increased 9 times and 30 times, respectively. This striking development has been attributed to various factors, including rapid economic and scientific growth, universal secondary education, growing demand of college-age cohort for higher education, and other factors. However, the most important driving force is the political reform that occurred in 1987, which resulted in a quite remarkable growth in graduate enrollment over the next 9 years. In 1996, 35,508 master's students—2.5 times as many as in 1988 (14,119)—were enrolled; doctoral en-

[1]The grading scale is from 0 to 100 at all levels. Many universities and colleges use the following scale on their English transcripts: 85-100 = A, 70-84 = B, and 60-69 = C. The minimum passing score is 60 for undergraduate students and 70 for graduate students.

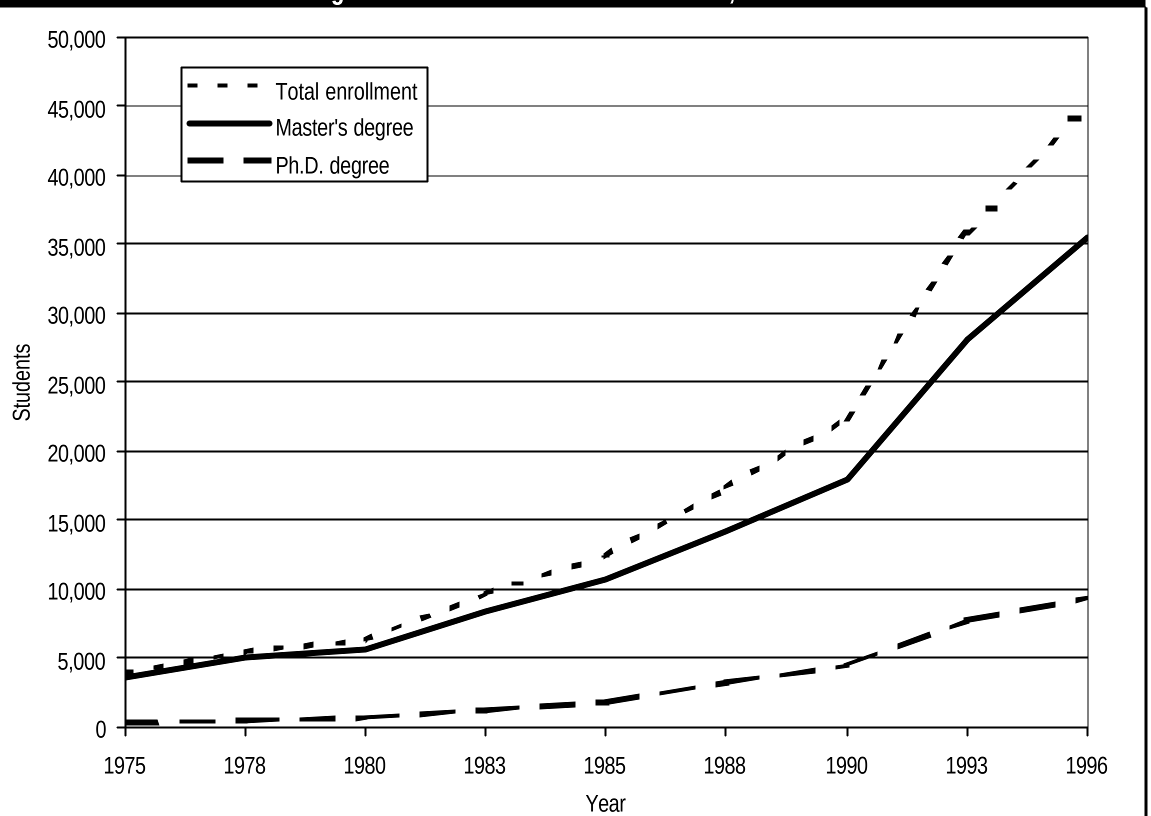
rollment had almost tripled during the same period, rising from 3,222 to 9,365. Since doctoral enrollment showed even faster development, its proportion increased in the degree structure. Before 1988, the enrollment ratio of master's to doctoral students was always more than 10 to 1. After 1988, the situation changed: in 1996, the ratio was only 3.5:1.

Table 3. Graduate enrollment in Taiwan, 1975-96

Year	1975	1978	1980	1983	1985	1988	1990	1993	1996
Total enrollment........................	3,912	5,442	6,306	9,647	12,418	17,341	22,372	35,830	44,873
Master's students..................	3,614	4,974	5,633	8,427	10,638	14,119	17,935	28,117	35,508
Ph.D. students......................	298	469	673	1,220	1,780	3,222	4,437	7,713	9,365

SOURCE: Ministry of Education, *Educational Statistics of the Republic of China,* 1997, pp. 20-21.

Figure 1. Graduate enrollment in Taiwan, 1975-96



SOURCE: Ministry of Education, *Educational Statistics of the Republic of China,* 1997, pp 20-21.

HOME- AND U.S.-AWARDED DOCTORAL DEGREES

As in most other developing and newly industrializing economies (NIEs), graduate education in Taiwan, especially doctoral training, has been lagging behind the economy in terms of its rate and level of development. Graduate education needs a heavier investment than education at any other level. In addition to financial support, a higher development level of science and technology (S&T) is necessary to ensure the quality and standards of graduate education. Graduate education is closely linked with and conditioned by the development of the national economy. For example, before 1967, Taiwan had a per capita GNP of as low as about US$260. There were no doctoral programs at Taiwan universities, only 170 master's programs. However, when Taiwan had a per capita GNP of US$964 in 1975, 90 doctoral programs had already been created at Taiwanese universities, and 32 doctoral degrees were awarded in that year. Though doctoral education developed steadily in the following 20-year period—for example, in 1995, there were 578 doctoral programs nationwide, and 1,053 doctoral degrees were awarded—compared with some other developed countries, the establishment of doctoral training in Taiwan is still small and weak. Despite its growth, the number of students seeking graduate education abroad, and efforts to entice them to return, is evidence that doctoral education in Taiwan far from satisfies the needs of economic development and the demands of young people for advanced studies.

A majority of Taiwanese students go to the United States; table 4 and figure 2 show that the total number of doctoral degrees (9,847) awarded by American universities to students from Taiwan is as much as twice the number (4,481) awarded by Taiwanese universities in the past 20 years. The United States provides approximately 77 percent of Taiwan's doctoral degrees in natural science and engineering (S&E) (NSF 1993, p. 25). However, Taiwan built up its advanced degree capability and expanded its doctoral-level training in the mid-1980s. The recent trend shows that the number of home-awarded doctoral degrees has been approaching that awarded in the United States. In 1995, the number of U.S.-awarded doctoral degrees decreased for the first time, dropping from 1,576 in 1994 to 1,485 in 1995.

S&E FIELD-OF-STUDY STRUCTURE OF HOME-AWARDED GRADUATE DEGREES

As noted previously, centralization is one of the major features of Taiwan's higher education system. The government controls enrollments in each field and directs the development of higher education to meet the needs of society. As early as the 1950s and 1960s, the Taiwanese higher education structure was biased toward the humanities and social sciences rather than science and technology, as the economy in Taiwan was still labor intensive. The Ministry of Education was influenced by a 1962 Stanford report which suggested that in the 1960s there would be a surplus of graduates from the humanities and social sciences, but a shortage from S&T (Law 1996). Since then, the government has been channeling students into such marketable fields as engineering, natural sciences, and—more recently—business.

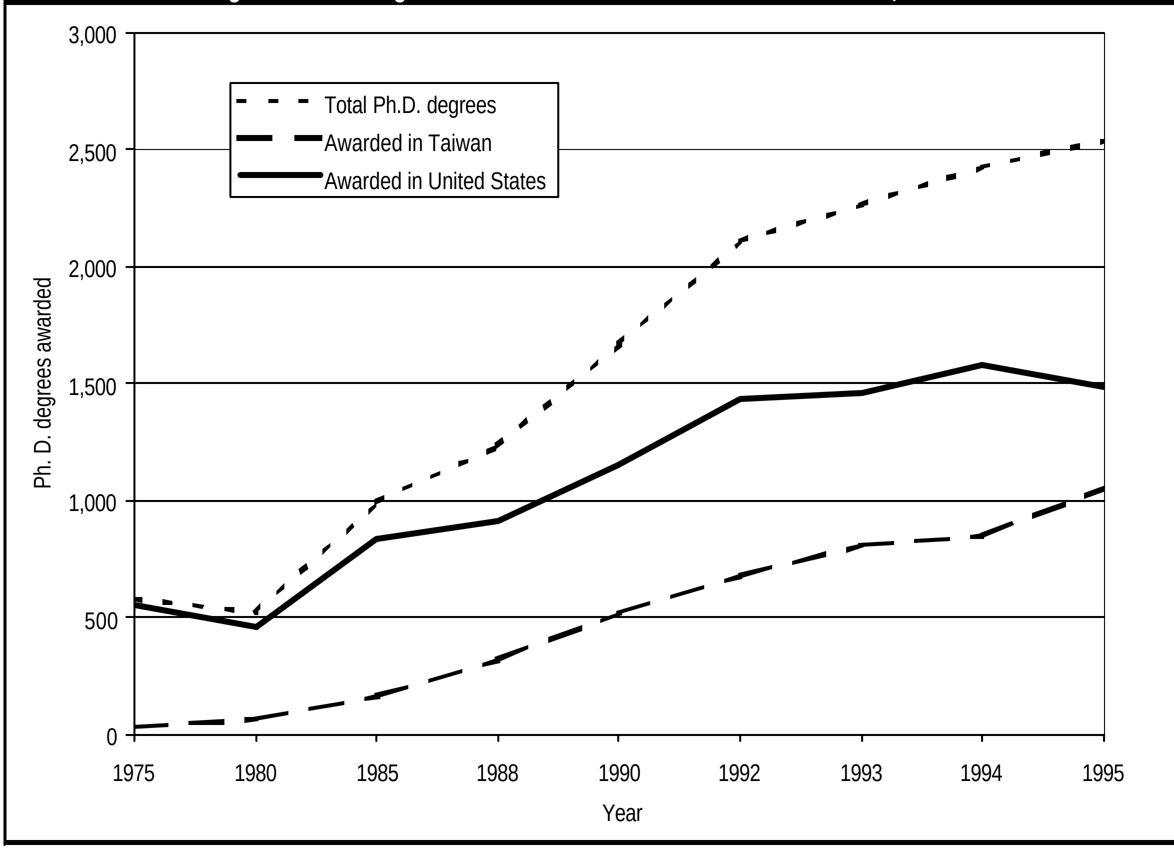
The statistics in table 5 and figure 3 show that the percentage of master's degrees awarded in the social sciences (out of all S&E fields) slowly decreased from 13 percent in 1975-80 to 10.1 percent in 1991-95, while that of doctorates dropped from 11.1 percent to 7.4 percent. On the other hand, the share of master's degrees awarded in the natural sciences and engineering (out of all S&E fields) slowly increased from 67.9 percent in 1975-80 to 71 percent in 1991-95, while that of doctorates rose from 70 percent to 74.4 percent. Within the five broad S&E fields, engineering has consistently had the largest degree population in the past 2 decades. During the period 1991-95, the proportions of master's and doctoral degrees in engineering reached 55 percent and 56.1 percent, respectively. Natural sciences ranked second after engineering, with proportions of master's and doctoral degrees of 16 percent and 18.3 percent, respectively. The

Table 4. Ph.D. degrees awarded at home and in the United States, 1975-95

Year	1975	1980	1985	1988	1990	1992	1993	1994	1995	Total
Total Ph.D. degrees	580	519	994	1,231	1,667	2,109	2,264	2,424	2,538	14,326
Awarded in Taiwan	32	64	161	319	518	678	808	848	1,053	4,481
Awarded in United States	550	455	833	912	1,149	1,431	1,456	1,576	1,485	9,847

SOURCE: Ministry of Education, *Educational Statistics of the Republic of China,* 1997, pp. 24-5; and National Science Foundation, Division of Science Resources Studies, Survey of Earned Doctorates.

Figure 2. Ph.D. degrees awarded at home and in the United States, 1975-95



SOURCE: Ministry of Education, *Educational Statistics of the Republic of China,* 1997, pp. 24-5; and National Science Foundation, Division of Science Resources Studies, Survey of Earned Doctorates.

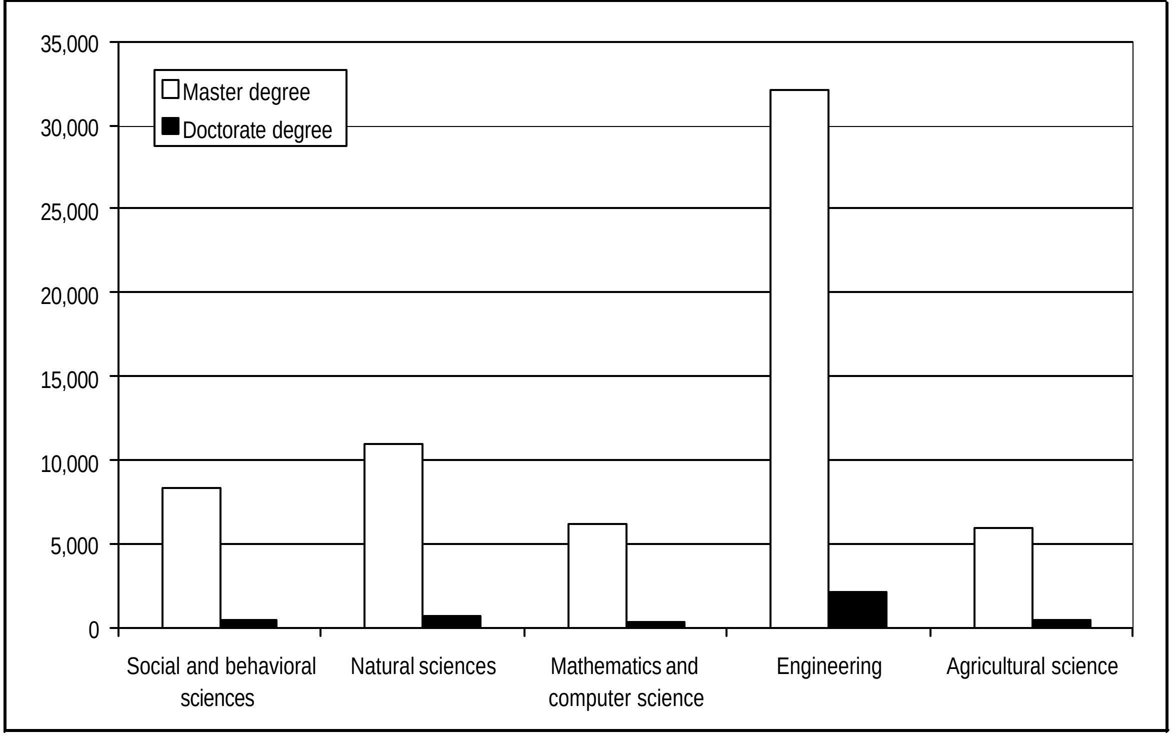
proportions for agricultural science used to be higher before the mid-1960s. After Taiwan began industrializing in the late 1960s, the percentage of agriculture degrees gradually dropped. In the period 1991-95, the shares of master's and doctoral degrees in agriculture were 8.4 percent and 9.6 percent, respectively.

Table 5. S&E field-of-study structure of master's and doctorate degrees awarded in Taiwan, 1975-95

Year	Total S&E degrees		Social and behavioral sciences		Natural sciences		Math. and computer science		Engineering		Agricultural science	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
	Master's degree											
Total................	63,399	100.0	8,276	13.0	10,930	17.2	6,141	9.7	32,148	50.7	5,904	9.3
1975-80.......	6,333	100.0	1,304	20.6	1,478	23.3	548	8.6	2,127	33.6	876	13.8
1981-85.......	9,404	100.0	2,083	22.1	1,780	18.9	646	6.7	3,988	42.4	907	9.6
1986-90.......	17,175	100.0	1,817	10.6	2,796	16.3	1,740	10.1	9,259	53.9	1,563	9.1
1991-95.......	30,487	100.0	3,072	10.1	4,876	16.0	3,207	10.5	16,774	55.0	2,558	8.4
	Doctorate degree											
Total................	4,164	100.0	464	11.1	732	17.6	322	7.7	2,183	52.4	463	11.1
1975-80.......	139	100.0	43	30.9	25	18.0	2	1.4	40	28.8	29	20.8
1981-85.......	345	100.0	77	22.3	55	15.9	14	4.0	134	38.8	65	18.8
1986-90.......	1,105	100.0	154	13.9	181	16.4	83	7.5	564	51.0	123	11.1
1991-95.......	2,575	100.0	190	7.4	471	18.3	223	8.7	1,445	56.1	246	9.6

SOURCE: National Science Foundation, Division of Science Resources Studies, Survey of Earned Doctorates.

Figure 3. S&E field-of-study structure of master's and doctorate degrees awarded in Taiwan, 1975-95



SOURCE: Ministry of Education, *Educational Statistics of the Republic of China,* Annual Series.

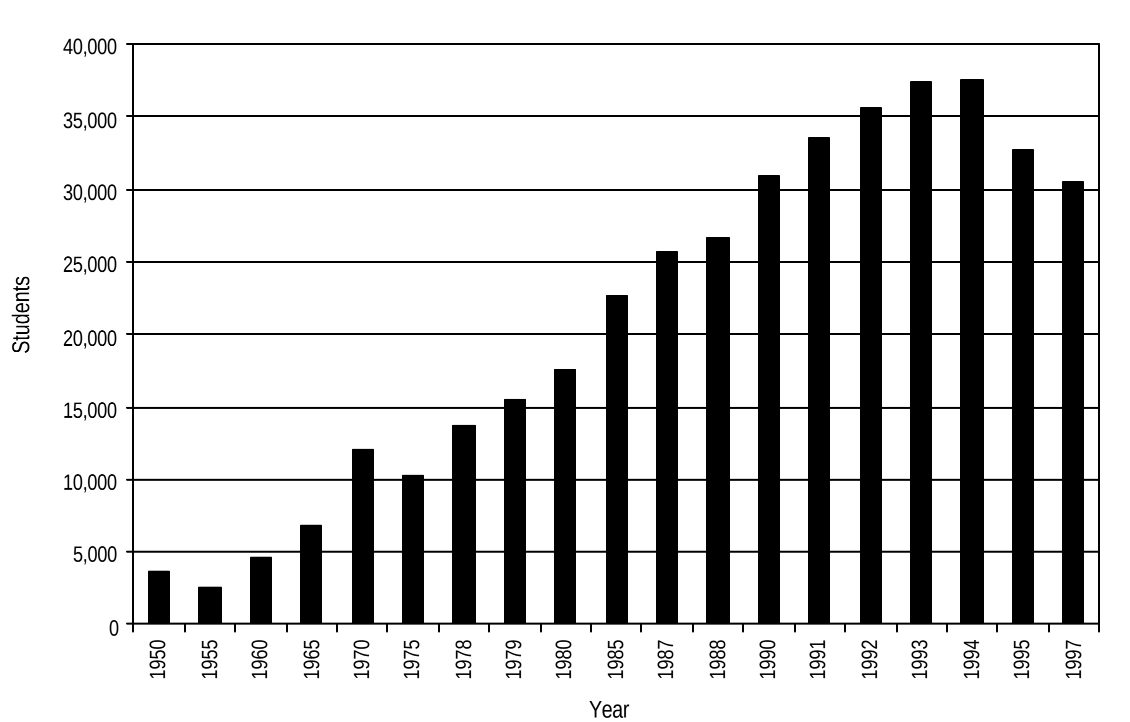
The issue of governmental intervention in the development of higher education has been controversial. Since economic development has been at the top of the government's agenda, it has been an important factor in determining graduate enrollment in different fields. Although many people in Taiwan believe that higher education should be geared to the nation's economic development, the government has been criticized for being too involved in the projected technical manpower needs of society, and thus overlooking the importance of the social sciences and humanities. Critics argue that policies regarding changes in higher and graduate enrollments need to be made on a broad basis, taking the social and cultural development of the nation into consideration (Chen 1991).

Overseas Study and International Mobility of Scientists and Engineers

The phenomena of study abroad and international mobility of scientists and engineers in Taiwan are correlated and have been affected by many societal factors. For example, it is a Chinese tradition that parents are respected and honored if they avail their children of advanced education or overseas study. Thus, the demand for higher education in Taiwan has been growing in the past 4 decades. However, due to the small and limited higher education establishment, as well as political restrictions, there are limited opportunities for higher and graduate study in Taiwan. Students mainly study abroad to fulfill their own and their parents' ambitions. American universities enroll a huge majority of them (over 90 percent) and account for approximately 77 percent of Taiwan's doctoral degrees in natural sciences and engineering (NSF 1993).

The steady annual increase of students from Taiwan between 1950 and 1997 is shown in figure 4. In the peak year of 1994, 37,581 Taiwanese students were enrolled in 921 accredited colleges and universities in the United States. In 1995 and 1996, enrollment dropped to 32,702 and 30,487, proportionally reflecting the decrease of advanced students coming to the United States. These students instead chose to study in Taiwan. A large number of Taiwanese students have chosen to stay and work in America upon successful completion of their studies. Some of them have become naturalized American citizens, taking challenging, well-paying positions in various sectors ranging from higher education and research organizations to well-recognized business corporations (Li 1995).

Figure 4. Taiwanese students studying in the United States, 1950-97



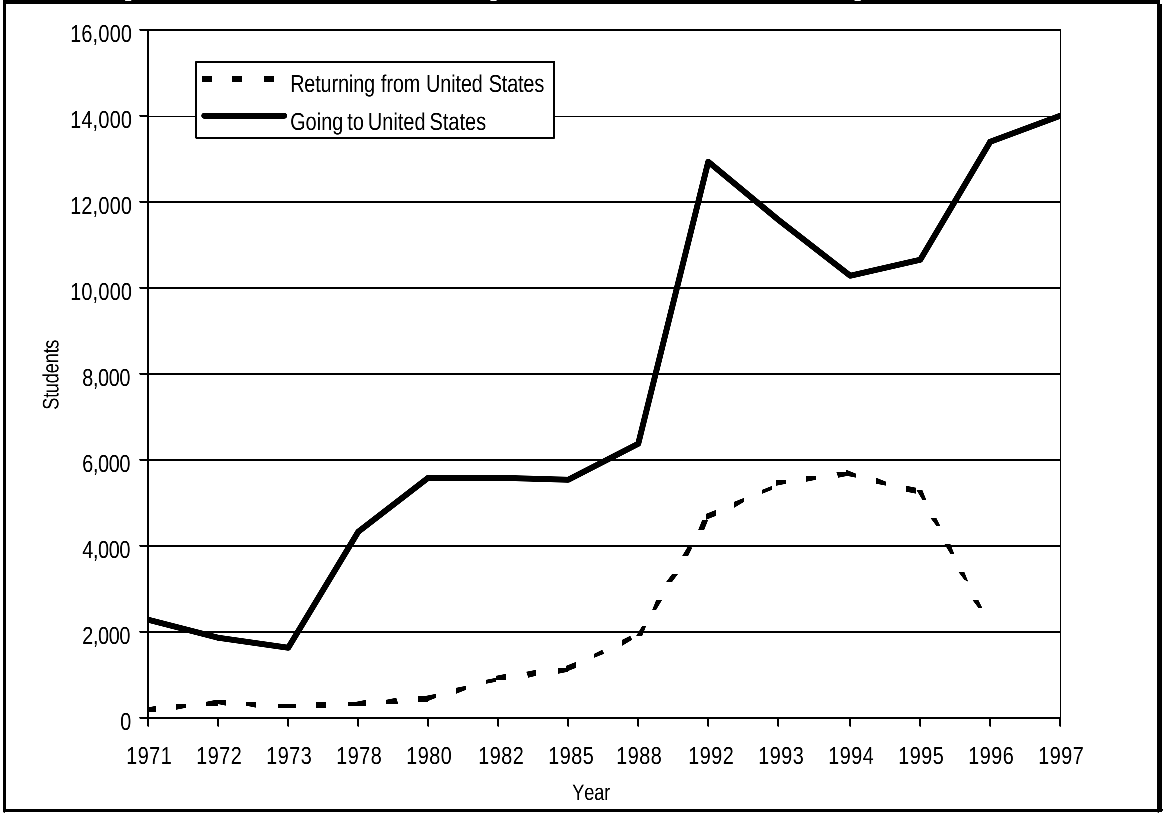
SOURCES: Cultural Division of Taipei Economic and Cultural Representative Office in the United States, *Cultural & Educational Digest,* January 1998, p. 28; Chen-ching Li, "Returning Home After Studying in the USA: Reverse Brain Drain in Taiwan," *Cultural & Educational Digest,* pp. 20-24. Cultural Division of Taipei Economic and Cultural Representative Office in the United States, *Cultural & Educational Digest,* 1995; and Chen-ching Li, "Toward a Rejuvenated National Goal: Reform and Internationalization of Higher Education in Taiwan, Republic of China," *Cultural & Educational Digest,* pp. 34 - 42, Cultural Division of Taipei Economic and Cultural Representative Office in the United States, 1997.

Figure 5 shows the historical trends of Taiwanese students entering and leaving the United States in the period between 1971 and 1997. Until the 1990s, Taiwan had suffered a serious "brain drain" for almost 40 years. It was reported that, between 1950 and 1980, the Ministry of Education issued approvals to 63,061 college graduates to study abroad; only 7,240 of them returned. During this period, the brain drain from students not returning from study abroad reached a high of 90 percent. The brain drain slowed gradually in the 1980s: it decreased to 80 percent between 1981 and 1987 (Chen 1991).

However, it was only at the end of 1980s that Taiwan started to benefit from its international students and their connection. A return flow of American-trained scientists and engineers has occurred in recent years. There are a number of societal variables that appear to account for this change. The most important variable is the economy. The statistics in figures 5 and 6 show a close correlation between economic development and return flow. The strong increase of per capita GNP since the late 1980s put Taiwan in the group of NIEs. Rapid economic development has offered a great number of job opportunities for returning students with advanced degrees and professional expertise. The nationwide Ten Construction Project infrastructure development, together with the establishment of the Hsinchu Science-Based Industrial Park in 1980, has opened many new avenues for young returned students to start new challenging careers. According to the 1994 annual report of the Science-Based Industrial Park, 1.05 percent of the employees hold Ph.D. degrees, 10.08 percent have master's degrees, and 17.92 percent have bachelor's degrees. Of the total 34,564 employees hired to work in the Science-Based Industrial Park, a large number of junior professionals were from the United States (Li 1995).

The political situation is the second important factor that has affected study abroad and the international mobility of scientists and engineers in Taiwan. As Taiwan's international status is unusual, its development has always been affected by the triangular relations among the People's Republic of China (PRC), the United States, and Taiwan itself. For example, in 1972 there were 367 stu-

Figure 5. Taiwanese students entering the United States versus returning to Taiwan, 1971-97



SOURCE: Ministry of Education, Educational Statistics of the Republic of China, 1997, pp. 54, 56-57, 60; Chen-ching Li, "Returning Home After Studying in the USA: Reverse Brain Drain in Taiwan," *Cultural & Educational Digest,* pp. 20-24 Cultural Division of Taipei Economic and Cultural Representative Office in the United States, *Cultural & Educational Digest,* 1995a; and Cultural Division of Taipei Economic and Cultural Representative Office in the United States, June 1998, p.11.

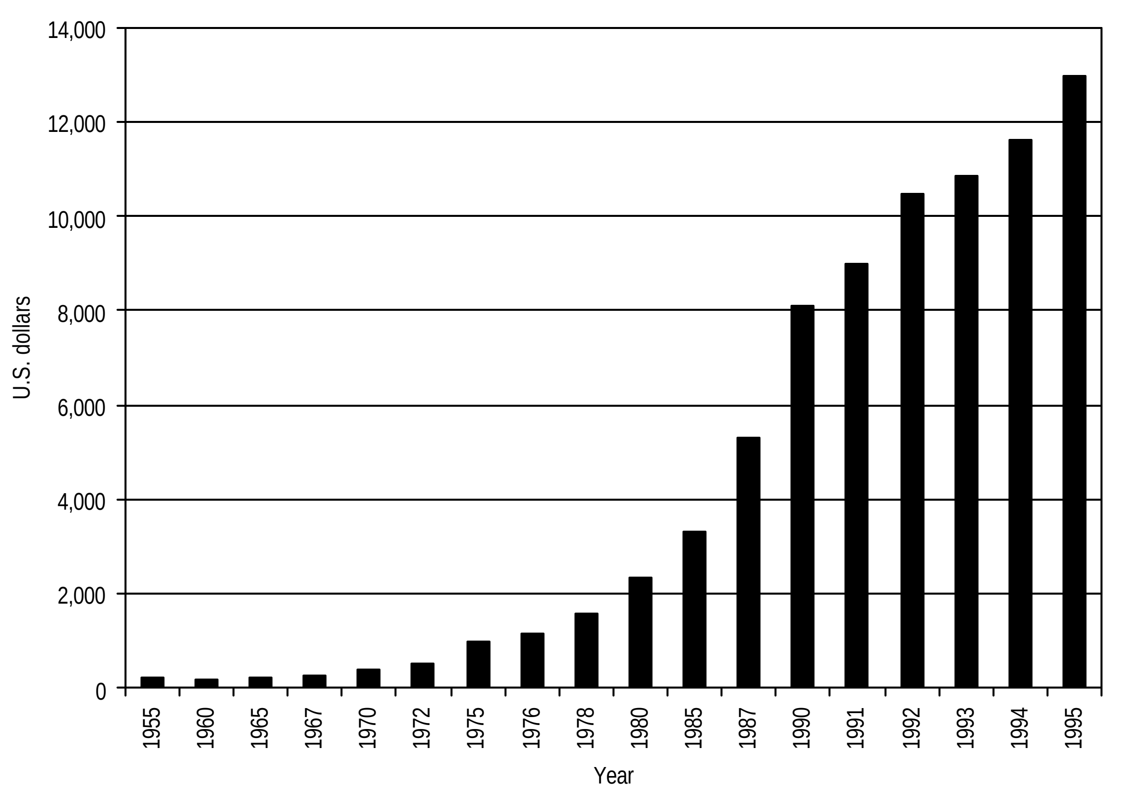
dents with advanced degrees going back home. However, the so-called "Nixon Shock"[2] of 1972 caused the number to drop from 367 to 276 the following year (Li 1995). The political impact lingered for almost a decade, continuing even when former president Carter announced normalization of relations between the United States and the PRC in 1978: this was followed by an immediate decline in the number of returning students from 431 to 331 in that year. Only when the U.S. Congress enacted the Taiwan Relations Act in 1979 did the number of returning students gradually begin to rise. In 1987, coupled with an economic boom, Taiwan lifted martial law and some other restrictions, and the number of returning students soared from 1,977 in 1988 to 4,674 in 1992. It later reached 5,700 in the peak year of 1994.

After 1995, however, the number of returning students dropped sharply to 2,185 in 1996. The reasons for this decline in returning students seem complex. There are three possible explanations. First, the job market in Taiwan for returning students is not as exciting as it was before 1992. The returnees had to compete for fewer jobs. Second, the economy in America has steadily improved in recent years, providing more job opportunities. Third, but not necessarily least, is the fact that the decline could be attributed to the military crisis on the Taiwan Strait in 1996.

At the same time that the return flow increased, the Taiwanese government lifted restrictions governing students going overseas and allowed high school graduates to go abroad to pursue undergraduate studies. As a result, the number rose from 6,382 in 1988 to 12,936 in 1992. After that, as Taiwan increased its internal capacity for graduate education in science and engineering, more and more students decided to stay home for graduate studies instead of traveling abroad. A recent rise is probably attributable to two factors. One is the growing number of graduates from junior colleges and high schools applying

[2] Under the secret and careful arrangement of Dr. Henry Kissinger, former president Richard M. Nixon paid a visit to China in 1972 and signed the historic Shanghai Communiqué, stating that the United States acknowledged that there is only one China, and that Taiwan is part of China. The abrupt U.S. recognition of the PRC shocked the whole world - especially Taiwan - with an unpredictable political impact.

Figure 6. Per capita GNP in Taiwan, 1955-95



SOURCE: Chen-ching Li, "Returning Home After Studying in the USA: Reverse Brain Drain in Taiwan," *Cultural & Educational Digest,* pp. 20-24 Cultural Division of Taipei Economic and Cultural Representative Office in the United States, 1995a.

for undergraduate programs, or only for summer sessions, in American universities. The other may be the affect of unstable relations with mainland China, especially during and after the military crisis on the Taiwan Strait in 1996.

Special mention should be made of the role of the Taiwanese government in attracting the return of students. The government has made a concerted effort to attract back S&T personnel educated in the United States. Its Manpower Planning Department assesses required manpower with advanced degrees for strategic industries, plans for recruitment from abroad, and expands S&T university education in Taiwan accordingly (NSF 1993). The government has also set up the National Youth Commission, affiliated with the Executive Yuan (which is like the cabinet) to recruit university graduates with Ph.D. and master's degrees to join in national development. The commission offers a subsidy in airfare for both the graduating student and his/her spouse, plus up to two children, if they decide to go back to Taiwan for career development. The commission has established channels of communication with overseas scholars so they can be recruited more easily when their services are needed. By the end of January 1998, a total of 15,914 students and professionals abroad had joined the commission's database network (Cultural Division of Taipei 1998, p. 13).

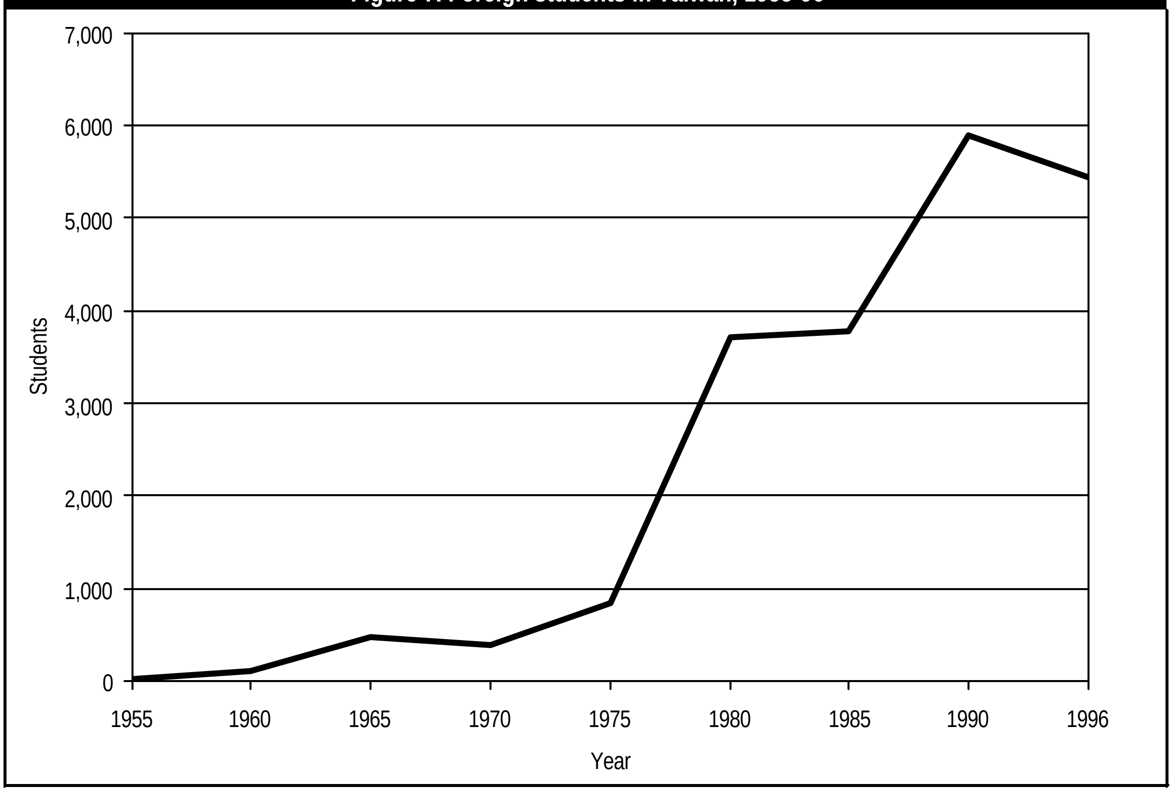
Besides attracting foreign-educated students to return home, Taiwan also imports S&T through the recruitment of foreign scientists and engineers, particularly from developed countries, to work in Taiwan. Since the promulgation of the "Guidelines for Long-Range Development of Science" in 1959, overseas scientists and engineers have been brought into Taiwan's higher education system as special-chair lecturers, national research professors—to guide research work and hold research seminars on a yearly contractual basis—or as visiting professors to give lectures on a short-term basis. The demand for overseas scientists and engineers increased sharply when Taiwan began industrializing: 413 expatriate scientists were employed between 1963 and 1970, and 2,783 between 1971 and 1980. In 1987, 399 foreign experts were invited to teach or supervise research work in Taiwan's higher education institutions. Meanwhile, "several top mainland scientists and engineers were employed to do research in Taiwan after it resumed non-diplomatic (informal) relations with mainland China in the late 1980s" (Law 1996). According to the latest report, beginning July 1, 1998, Taiwan will lift more restrictions in order to import more scientists and engineers from abroad and from mainland China (Cultural Division of Taipei 1998, p. 15).

To increase its international involvement, Taiwan has also provided scholarships for international scholars, researchers, and students to study in Taiwan. The historical trend is shown in figure 7. Currently, over 5,000 foreign students are studying at Taiwan's colleges and universities. Most of them are enrolled in the fields of the humanities, social sciences, and languages. Recently, the Ministry of Education has decided that, starting with the 1998-99 academic year, it will provide a scholarship (with each person receiving about US$5,000 each month) to 20 foreign professors and researchers and 100 foreign students each year to encourage them to conduct research or study in Taiwan (Cultural Division of Taipei 1998, p.11).

Conclusion

In the past 40-plus years, higher and graduate education in Taiwan have experienced rapid development. Since the political reform that took place in the late 1980s, Taiwan's higher education system has gradually turned to decentralization, democratization, and internationalization. However, the higher education system in Taiwan is relatively small, and it remains dependent on other countries for much of its advanced training. For economic and political reasons, many students remained abroad after they completed their studies for many years, and Taiwan used to suffer from a significant brain drain; things have changed, however, in recent years. The rapid economic development in Taiwan offers a great number of job opportunities for returning students with advanced degrees and professional expertise. More and more students return home, and Taiwan has benefited from the reverse flow of its overseas students and researchers in recent years. Countering this trend, however, have been international politics affecting overseas study and the international movement of scientists and engineers in Taiwan. This influence will continue as long as the issue of Taiwan's relationship to the PRC remains unresolved. Finally, whether the Asian economic crisis of 1998 will affect patterns of overseas study and the movement of scientists and engineers in Taiwan should be monitored.

Figure 7. Foreign students in Taiwan, 1955-96



SOURCE: Ministry of Education, *Educational Statistics of the Republic of China,* 1997, pp. 44-46.

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European Region

Higher Education in France and the International Migration of Scientists

Dominique Martin-Rovet, Damien Terouanne, Jean-Baptiste Thibaud, and Elizabeth Neher

The French System of Higher Education

The Current Situation: A French Original

One of the major reasons for the complexity of the French system lies in the dichotomy, unique in Europe, between its universities and the elite *Grandes Ecoles*. This coexistence of two different types of institutions arises from historical circumstances. In the 18th century, the political establishment, which was wary of the Church's power over the university, founded the *Grandes Ecoles* to train the ranks of military and technical personnel needed by the state. In the past, preference was given to one or another of these institutions, depending on the political climate of the country. During the 20th century, however, the increasing importance of technology has slowly but surely turned the *Grandes Ecoles* into the sole route to the highest positions in French government. Institutions designated as *Grandes Ecoles* or simply *Ecoles* have proliferated, especially in the fields of economy and business.

Between 1960 and 1997, the number of students enrolled in higher education rose from 310,000 to 2.1 million. The students are distributed between the *Ecoles* (238 engineering schools, 230 business schools), which select 9.5 percent of the students in higher education; the general university system, which educates 62 percent of the total; technical and technological higher education institutions (*Instituts Universitaires de Technologie, écoles universitaires d'ingénieurs*), which account for 16 percent; and paramedical and social training, which make up the remainder. Both the universities and the *Grandes Ecoles* (with the exception of business schools) are a part of the national public system and free for students.

The Universities. University education is divided into three cycles.

1. The first cycle (equivalent to freshman and sophomore years of college) leads to the *Diplôme d'Enseignement Universitaire Général* (General University Diploma) in 2 years.

2. The second cycle leads to the *licence*, equivalent to a bachelor or arts degree and 1 year of study toward a master's degree.

3. The third cycle leads to a higher level professional degree (*Diplôme d'Etudes Supérieures Spécialisées* in 1 year) or a doctoral degree.

The *Grandes Ecoles*. One of the great advantages of the *Grandes Ecoles* in engineering and business is the quality of their student population. Most of these schools pick their students through competitions, primarily among candidates from *Grandes Ecoles* preparatory classes. This educational track, over 2 or 3 years, attracts the best students from the best high schools. The *Ecoles* offer better conditions, with smaller class sizes and better equipment and facilities (computers, classrooms, laboratories) than most universities. The cost to the government is significantly higher: $12,500 per student per year, as opposed to $5,900 in the standard first cycle.

Finally, the graduates of the *Ecoles* are able to find professional employment much more easily than their contemporaries from the university system, due to an education aimed at a particular goal, the contacts they made with the business world during their educational career, and their alumni networks.

A System in Crisis

At the University. A large number of students fail during the first, general, cycle: 34 percent drop out in the first year, and only 28 percent successfully complete the 2 years. In addition, the degree awarded does not lead to any particular professional position.

The quality of instruction in the universities suffers in part due to the system used to evaluate the professors, which looks at research and scholarly publications. A diploma does not necessarily make employment easier to find, since public service is no longer the major outlet for graduates, and the private sector does not value the degrees. The business world and the needs of the high-technology sector of the economy are, in their turn, not well understood by the universities.

University research suffers also from a lack of means, coordination, and links to the private sector. The university administration is inefficient and does not have enough autonomy. It cannot recruit the technical personnel it needs. The different faculties and the engineering schools within the universities guard their independence jealously.

Unlike the *Grandes Ecoles,* which can be selective, the universities are required to accept all candidates. In practice, legal (e.g., limited space in the medical schools) or illegal means of selection control recruitment. University diplomas, which are theoretically all supposed to have the same value and which are awarded by the state without reference to a particular university site, are, in fact, ranked on the job market according to campus.

In the *Grandes Ecoles*. The percentage of students in the engineering *Grandes Ecoles* went from 14 percent of total engineering enrollment in 1900 to 3.7 percent in 1997. Selection has become more and more rigorous, and the student population more and more unbalanced. Most of the students are from the families of government officials and corporate executives. The majority of those participating in the competitions for the most elite schools (*Ecole Normale Supérieure*, *Ecole Polytechnique*) come from only about 10 high schools.

The mostly theoretical instruction provided does not always leave enough time for less theoretical work, for innovation, or for work on specific projects. Ideas necessary to the vitality of business, like intellectual property rights and human rights, are not always addressed in sufficient detail. Students are not always trained in scientific research and its methods. Finally, there is insufficient external evaluation of the education and the degrees.

Counseling at the universities is scarce, so the students depend primarily on other information sources when making choices. In the *Grandes Ecoles,* those choices are most often guided by the reputation, rather than by the content, of the studies. The nature of the two styles of instruction is converging as the universities become more industry-oriented. With the disappearance of its *raison d'être*, the difference between the two is gradually becoming less apparent.

Proposed Reforms: Reorganizing the French Educational System for the 21st Century

In this period of increased economic competition, market forces sweeping the professional world cannot ignore higher education. But the logic of the marketplace, already at work in some countries, brings with it monetary discrimination and a growing gap between a few elite institutions where quality comes with a very high price tag, and a large, more or less mediocre, system for the vast majority of students. In France, this trend in higher education would eliminate equal access to education, one of the foundations of the republic.

The French system of higher education has been in existence for almost 1,000 years. As in almost every other country in the world, it is faced with three major challenges: the growth of its bureaucracy, the diversification of knowledge and skills needed, and the increasing costs of education.

With most European countries confronting these questions, this is a particularly propitious time to inaugurate reforms. A commission appointed by Prime Minister Lionel Jospin has just released a report on the subject.[1] This paper summarizes the report's principal conclusions.

Redefining the Missions of Higher Education. Higher education should allow each student to identify his or her individual strengths and to pursue studies in different disciplines by increasing contacts and connections between the different university departments.

Currently, researchers in public institutes such as the National Institute of Health and Medical Research (INSERM) and the National Committee for Scientific Research (CNRS) are not required to teach; university professors conducting research have been able to spend much of their time in their laboratories, since it has always been the quality of their research that is used to

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[1] "Toward a European Model of Higher Education," report of the commission presided over by Jacques Attali, STOCK, May 1998.

evaluate them. All publicly funded researchers, in both the institutes and the universities, must be required to spend more time in the classroom.

Education should combine formal training for business and technology with the transmission of cultural appreciation (literature, philosophy, humanities) and general knowledge. It should encourage the faculty to strive for innovation.

Continuing education must take its place in the system of higher education. It must award diplomas with the same value as those of regular university degrees by allowing students to alternate between periods of work and study. It must allow the unemployed to receive training that is useful in the job market.

The system should also provide means for students from more modest backgrounds, who tend to pursue studies that are technically oriented, to switch to educational tracks that are more academically and intellectually inclined by creating more bridges between the two tracks.

Another goal would be to emphasize a global perspective and encourage integration with the European Community's educational system. This might be achieved by offering all students in higher education a term of study abroad and by accepting the best foreign students and instructors into the French school system. It would require improving recruitment, using English for some subjects, easing the bureaucratic procedures for recognizing diplomas from other countries, harmonizing the curricula with those of the other countries of the European Union, and—finally—adopting the European Union's evaluation criteria and procedures.

New Principles of Organization—National Level. France's system of higher education needs to become more coherent in setting curricula, levels of degrees, and geographic distribution of its campuses. Campuses must be located near the emerging centers of excellence, the *Pôles Universitaires Provinciaux* consisting of the best university and *Grandes Ecoles* departments in a region (including the campuses of neighboring countries) linked in networks. These "university centers" will have a common teaching and research orientation.

Each university center will need to establish more regular contractual relationships with the state, allowing the center more autonomy. These relationships will be based on a campus plan and quadrennial contracts, which will allow the universities more initiative in defining their academic offerings.

As a reasonable balance to this increased autonomy, a regular evaluation of the strengths and performance of each campus or university department will influence its financing. To this end, the creation of a new *Agence Supérieure d'Evaluation* has been proposed, which would be outside the authority of the Ministry of National Education. Academic evaluation would be conducted by peers.

Evaluation of professors would take teaching abilities into account. It would initiate a system of student evaluations and incorporate them into reviews of the instructors. The professors would have to be able to relocate, and there would be greater possibilities for mobility in posts. A pay scale that would be more responsive to merit while providing better salaries would accompany these new requirements.

New Principles of Organization—Local Level. As in an urban community, these campuses of higher education must organize themselves under a single administration, sharing materiel and human resources, creating a comprehensive curriculum, and encouraging exchanges between establishments. Entrepreneurial enterprises must be encouraged on these campuses through the availability of capital risk funding, especially in the fields of software engineering, biotechnology, and materials. Career advancement and continued education via alumni associations must be expanded to include the entire campus.

Reforming the Curricula. The curricula must be reworked to facilitate transfers between the universities and the *Ecoles*, and the degrees must be more equivalent to those awarded in other countries. The primary objective would be to make all new diplomas have a recognized value in the job market and lead to real careers.

In the universities, university education would be divided into:

- A *licence* in 3 years, consisting of individually accumulated credits, allowing each student to mix studies and work. The first semester would be aimed at choosing a major; the last year, including a term of work-study, would have a general professional orientation. Class sizes would be reduced by using secondary school instructors. Technological education would follow the same schedule.

- A new *maîtrise* in 2 years after the *licence* would serve to further a particular major course of study. The second year would be dedicated to an individual research program or to subjects that would complement the major field.

- A doctoral program 5 years after the *licence*, called *Ecoles Doctorales*, would offer the option of taking the *maîtrise* exams after 2 years. It would include multidisciplinary studies, career counseling, and more interaction with industry. Research would start earlier in the curriculum than is currently the case.

The first 3 years of medical studies would be grouped with biological sciences, resulting in a new biomedical *licence*. Limitation in the number of enrollments would not commence until after the *licence*. A doctorate in medicine would take the same amount of time as in other disciplines and would be open to students from other scientific fields.

This plan, called "3-5-8," is more or less parallel to the American system of higher education given the fact that, in France, high school lasts 1 year longer than in the United States.

In the *Grandes Ecoles*:

- Preparatory classes would be phased out once the changes had been made in the first university cycle. The entrance exams would change so as to open enrollment in the *Ecoles* to students following technology tracks.

- While remaining an elite track for technical training, the *Grandes Ecoles* would grant the *licence* at the end of the first year, and the new *maîtrise* at graduation.

- The monopoly held by the *Grandes Ecoles* in filling government posts will be ended.

Conclusion

Financing all these reforms, especially the lengthening of the first university cycle, will require a significant national effort. But demographics indicate that the population entering the universities will be falling, and the proposed regrouping will realize savings as well. Fiscal and regulatory measures should encourage business and regional governments to join in this effort.

Without requiring uniformity of systems, the countries of Europe should standardize their curricula and diplomas within a new framework that is neither bureaucratic nor strictly independent. The European Union still needs to define a policy for higher education; this could be one of its major tasks in the next decade.

Doctorate and Postdoctorate

Focus on the French Doctorate

France, with its long tradition of higher education, produces a considerable number of Ph.D.s. In fact, it produces a higher percentage of doctors per million inhabitants than any other industrialized country.

Table 1. Ph.D. theses per million inhabitants

Country	Number of theses		Population (millions)	Theses per million inhabitants
Australia	(1993)	1,803	17.7	102
Canada	(1993)	3,356	29.0	116
Denmark	(1992)	512	5.2	98
France	(1995)	9,800	58.5	168
Germany	(1993)	12,400	81.0	153
Great Britain	(1994)	8,300	58.0	143
India	(1987)	4,177	*(est.)* 700.0	6
Italy	(1998)	2,400	57.0	42
Japan	(1993)	12,000	124.5	96
Mexico	(1990)	269	86.2	3
United States	(1994)	41,011	260.0	158

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

Given that France ranks fourth in research and development (R&D) budget, after the United States, Japan, and Germany, and fifth in the publications world share after the United States, the United Kingdom, Japan, and Germany, its influence in science education is remarkable. Its success is also due to a conscious national effort over the past 10 years to improve and expand its higher education establishment.

Between 1989 and 1997, the number of Ph.D.s awarded doubled from 6,000 to 12,000. The following table shows this growth through the year 1996. All disciplines demonstrated this strong growth. The social sciences and humanities represent almost one-fourth of the Ph.D.s awarded. Physics and chemistry and the life sciences were also popular.

The proportion of women receiving Ph.D.s reached 36.8 percent (42.3 percent of French and 25.4 percent of foreign recipients) in 1996. These numbers increase steadily but vary greatly from one scientific discipline to another. In the life sciences, more than half of the Ph.D. recipients are women. The percentage is also high in the social sciences, law, and physics and chemistry. The lowest percentages are observed in mathematics, computer sciences, and engineering.

Funding for graduate studies has traditionally come from the Ministry for Education, Research and Technology. It allocates grants for 3 years, allowing the student to complete the research for a thesis. This program was begun in order to shorten the number of years spent on preparing a thesis, which could take as many as 7 to 10 years. This 3-year period does not include the 2 years of the third cycle after the French *maîtrise*, which is devoted to classes.

The doubling of the number of degrees has had a great deal to do with the difficulty facing students who graduate with a *maîtrise* when they start looking for employment. The unemployment situation has had an impact too on the type of funding available. Since 1996, ministry scholarships have been granted to no more than 28 percent of all students. Foundations and corporations fund more than one-third of the total. Nearly 1 in 10 Ph.D. students have to support themselves by working. A full 28 percent of the graduate students have no scholarships or reported income whatsoever. This is a source of great concern.

It is important, nonetheless, to emphasize that this situation varies greatly from discipline to discipline. More than half of the students in the social sciences and hu-

Table 2. Ph.D.s awarded from 1989-96

Disciplines	1989	1990	1991	1992	1993	1994	1995	1996
Total	5,963	6,782	7,198	8,585	9,295	10,602	9,801	10,963
Mathematics	198	233	247	296	356	418	364	426
Physics and chemistry	1,378	1,466	1,537	1,897	1,940	2,168	1,943	2,148
Geosciences	328	335	313	418	410	439	453	499
Computer and information sciences	810	868	903	1,029	1,085	1,176	1,237	1,342
Life sciences	1,223	1,436	1,409	1,664	1,843	1,972	1,882	1,999
Social sciences and humanities	1,017	1,256	1,425	1,746	2,006	2,540	2,197	2,414
Law	545	621	706	832	908	1,071	906	1,139
Engineering	464	567	658	703	747	818	819	996

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

Table 3. Percentage of women who received Ph.D.s, 1992-96

Disciplines	1992	1993	1994	1995	1996
Total	31.9	33.1	35.1	34.9	36.8
Mathematics	17.5	18.7	16.5	20.5	20.9
Physics and chemistry	31.0	32.8	34.2	34.5	39.5
Geosciences	24.6	28.0	37.8	34.5	32.1
Computer and information sciences	17.6	16.1	20.3	20.1	19.9
Life sciences	45.9	47.2	51.8	51.0	50.7
Social sciences and humanities	41.2	43.6	42.7	41.2	44.7
Law	31.2	32.0	33.1	30.4	36.0
Engineering	14.8	14.6	13.7	16.6	18.3

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

manities have no funding or insufficient resources. By contrast, around 90 percent of the students in physics and chemistry, computer sciences, life sciences, and engineering are fully funded.

Of positions overseas, 46.3 percent are in North America. It is the most favored destination for those in the life sciences and engineering. The European Union (other than France) is now in second place, after North America, with 41.3 percent of positions abroad, compared to 40.2 percent in 1995. More than one young Ph.D. in two in physics and chemistry opts for a position in a European Union country. Japan attracts only 3.2 percent of the postdoctorates going abroad. All other countries combined attract 7.8 percent.

Table 4. Origin of funding for Ph.D.s awarded in 1996

Disciplines	Scholarships from the MENRT	Scholarships from other sources	Salaries	No funding	Total
Total	2,936	3,521	964	2,919	10,340
Mathematics	141	137	27	116	421
Physics and chemistry	755	999	80	216	2,050
Geosciences	227	183	15	39	464
Computer and information sciences	478	617	77	117	1,289
Life sciences	684	711	213	340	1,948
Social sciences and humanities	181	197	377	1,363	2,118
Law	197	164	126	595	1,082
Engineering	273	513	49	133	968

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

The Postdoctorate

The postdoctoral position was not common in France before the 1970s. Most scientists found employment in the university or in the public research institutes. Ph.D.s led, almost automatically, to permanent government positions. Today, tight budgets and increased numbers of graduates have moved the threshold at which scientists can find such employment to a more advanced stage of their careers. In addition, the internationalization of science has made a postdoctorate in another country highly desirable. There is also almost no financing available in France for French postdoctorates. Therefore, more and more French Ph.D.s are having to seek postdoctoral positions abroad.

Until now, it has been impossible to deal with this situation in France with any kind of concerted national effort, since the status of postdoctorate implies a lack of permanence. French law and French unions are opposed to the permanent creation of temporary positions for French citizens. Foreigners, however, are not covered by these limitations.

An estimated 1,900 or more Ph.D.s actually took postdoctoral positions after defending their theses in 1996. As in the 3 preceding years, two-thirds of the postdoctoral positions are located abroad. The exact proportion is 66.7 percent. Only 350 French Ph.D.s pursued postdoctoral terms in France, compared to 400 the previous year.

North America (the United States and Canada) is still the preferred destination for postdoctorates this year.

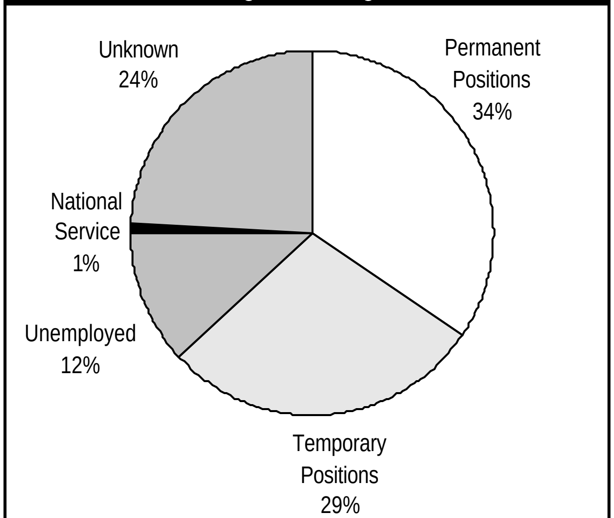
A postdoctorate in France lasts at least 2 years. More than one in eight postdoctorates will eventually stay in the country offering the postdoctoral position: 103 postdoctorates (73 French and 30 other nationalities).

Employment for Scientists

Two years after getting their degrees in 1996, 34 percent of Ph.D. recipients have found permanent employment. Another 29 percent have found temporary positions, and 12 percent are still unemployed. The remaining 24 percent did not respond to a request for information. This, of course, renders extensive interpretation dubious. The general tendencies shown by the responses, however, confirm the experienced judgment of researchers in the field.

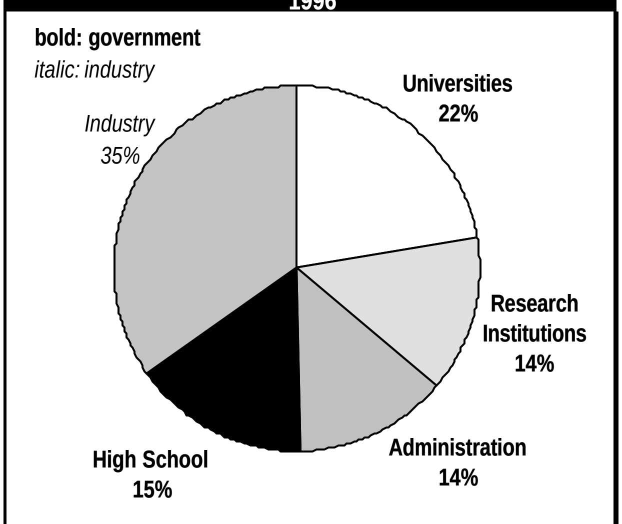
Of the permanent positions offered to the 3,559 Ph.D.s, 65 percent are with the French government: 22 percent work as assistant professors, 14 percent serve as research scientists in public institutions, 15 percent teach in high schools, and 14 percent work in the administration. Only 1,246 found jobs in industry.

Figure 1. Professional positions held by the 10,340 Ph.D.s who got their degrees in 1996



SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

Figure 2. Permanent positions held by 3,559 Ph.D.s in 1996



SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

This means that out of more than 10,000 Ph.D.s per year, only 12 percent find jobs in industry, and less than one-fourth were able to follow the traditional path of French doctoral recipients by finding permanent government positions. The number of positions in industry is an estimate based on survey responses and confirms the perception in France that industry does not recruit a significant percentage of Ph.D. recipients. In France, the largest employment sector is small business. However, high-tech small businesses are scarce, and the large industrial firms are still recruiting the majority of their professional workforce directly after graduation from the *Grandes Ecoles*. This situation is one of the reasons young French scientists come to the United States (see last section of this paper).

Foreign Students in France

General

France has always been one of the favorite destinations of immigrants from the rest of Europe, from Africa, and more recently from Asia. Immigrants come to France when migrating to the West, and also when migrating from the former French colonies. The French educational system is one of the major attractions. In 1996-97, there were 1,449,129 students in French universities, of which 125,205 (8.6 percent) were foreigners. For the past 10 years, this percentage has declined slightly. In 1985-86, 13.6 percent of the entire student population came from other countries.

Half of the foreign student population comes from Africa; they are evenly distributed among all the sciences and humanities. Twenty-nine percent come from other European countries, and show a marked preference for the humanities and social sciences. Just 2,774 students (2 percent) come from the United States to study in France. Nearly all of them take liberal arts and social sciences. Only 100 pursue courses in science and engineering (S&E).

Doctoral Students

The distribution of students by region of origin at the doctoral level shows approximately the same proportion as that of all foreign students in French universities.

That same year (1996-97), there were 2,807 doctoral degrees awarded to foreign students, representing 27.1 percent of all doctorates awarded that year. The proportion of foreign degree recipients was 1.2 percent

Table 5. Foreign students in French universities 1985-96

Foreign Students	1985	1989	1991	1992	1993	1994	1995	1996
Number of foreign students in thousands...	132	132	137	138	140	134	130	125
% of foreign students..................................	13.6	11.8	11.2	10.7	10	9.4	8.9	8.6

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

Table 6. Foreign students in French universities 1996-97 (by region and discipline)

Region	Law	Economics	Liberal arts and social science	Science and engineering	Medicine, pharmacy, and dentistry	Total
Total	15,418	16,368	47,033	27,811	18,575	125,205
% foreigners	8.2	10.7	9.1	5.5	12.6	8.6
Europe	5,557	3,905	17,563	6,055	2,736	35,816
European Union	4,394	2,823	13,627	4,443	1,657	26,944
Asia	1,358	1,512	6,451	3,761	3,249	16,331
Africa	7,485	10,392	16,560	16,616	11,937	62,990
Americas	989	527	5,333	1,290	609	8,748
United States	353	59	2,225	104	33	2,774
Brazil	93	71	687	274	94	1,219
Canada	126	67	600	152	56	1,001
Oceania	7	10	95	23	5	140
Stateless	22	22	1,031	66	39	1,180

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

Table 7. Foreign candidates receiving the French doctorate in 1996

Country of origin	Number	Percent
Asia	276	9.8
Eastern Europe	136	4.8
Europe	365	13.0
Latin America	261	9.3
Near & Middle East	240	8.6
North Africa	1,015	36.2
North America	53	1.9
Sub-Saharan Africa	399	14.2
Other	62	2.2

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

lower than in 1995, although the proportion of Europeans remained the same at 18.4 percent. All scientific disciplines were affected by this slight reduction. At this level too, more than half of the degree recipients in 1996 came from Africa. Even now, Europeans tend to pursue doctorates in their own countries. Nearly 10 percent come from Latin America. This relatively high number reflects the fact that France is a traditional refuge for immigrants seeking political asylum from these countries. Latin Americans prefer France as an alternative to the United States and Spain.

Mathematics attracts the highest percentage of foreign students pursuing doctorates, although the highest number of students is found in the humanities and social sciences. Physics and chemistry attract the next highest number.

The rate at which foreign students return to their countries of origin has dropped slightly; half of them do go home in the 18-month period following their thesis defense.

Table 8. Distribution and rate of return of French Ph.D.s of foreign origin (1997)

Disciplines	Number of foreign doctors	Percentage of all doctors	Number of returns to country of origin	Percentage of returns to country of origin
Total	2,807	27.1	992	35.3
Mathematics	161	38.2	42	26.1
Physics and chemistry	500	24.4	196	39.2
Geosciences	149	32.1	52	34.9
Computer and information sciences	366	28.4	91	24.9
Life sciences	345	17.7	125	36.2
Social sciences and humanities	633	29.9	244	38.5
Law	343	31.7	121	35.3
Engineering	310	32.0	121	39.0

SOURCE: French Ministry for National Education, Research and Technology (MENRT), 1997.

Postdoctorates

Postdoctoral positions have not been the norm in France; scientists have always been employed by the government in the past, and the temporary nature of postdoctoral positions has been alien to employment policy. The Anglo-Saxon experience with the benefits of postdoctoral work in a different scientific environment has, however, won over the French scientific community. Funding programs and positions have not yet been established enabling French labs to hire French nationals in large numbers as postdoctorates. Funding does exist for them to hire foreign nationals. Every year, about 500 new foreign postdoctorates find employment in French labs.

The proportion of foreigners at the postdoctoral level has greatly decreased. In 1995, this group still accounted for 38 percent; in 1996, it was down to only 22 percent foreigners. The percentage of postdoctorates returning to their own countries is between 35 and 50 percent by the end of 2 years.

Young French Scientists in the United States[2]

Each year, American universities receive 450,000 foreign students. This number, which might seem high, actually represents no more than 3 percent of the total population of students in the United States in all years of study. For comparison, about 9 percent of the students in the French university system come from other countries.

Despite this disparity in percentages, the United States, which is the world leader in R&D, has a reputation for being very attractive for students and scientists worldwide. It is only through more detailed analysis that it is apparent that the number of foreign students in the United States is especially high in science and engineering. That percentage increases with grade level. Almost half of the foreign students in the United States are in S&E. While only 3.7 percent of the bachelor's degrees (the American equivalent of the *licence*) awarded in S&E go to foreign students, that percentage climbs to 24 percent at the master's degree level (*troisième cycle*), and reaches 39 percent among doctorate-holders.

France only ranks 16th in terms of the number of its citizens enrolled as students in American universities. Among the 8,000 doctorates in S&E awarded each year to foreign students in the United States, only about 100 go to French citizens. This means that there are no more than 500 French citizens currently pursuing their doctorates in American universities.

The attraction of American R&D, however, is not limited to university studies. Many doctors come here for postdoctoral positions (postdoctorates) in American laboratories. Among scientists from countries like France, which has an excellent system of public education, it is much more common to seek experience in the United States at the postdoctoral stage than during the university career. The problems encountered in the past few years by young doctorate-holders when they seek to enter the French workforce have only served to exaggerate this tendency. The data presented in this report confirm that today there are *at least twice as many postdoctorates as doctoral candidates in the population of French citizens who are identified as being involved in science and engineering and are currently in the United States*.

These young scientists, who demonstrated their intellectual excellence during their university careers, and who often sought a postdoctorate appointment in the United States as something that would enhance their chances of one day finding employment as staff in a French university or public institution, represent the population commonly defined when speaking of a "brain drain." A closer look at the situations of these French postdoctorates in the United States and at their aspirations shows that they tend more toward being temporarily overseas, with plans to return eventually to France, than permanent expatriates.

This section looks at the physical presence of French scientists and engineers in the United States using data obtained from the National Science Foundation (NSF) and other American institutions. It is supplemented with the results of a survey of French doctoral candidates and postdoctorates in North America conducted by the CNRS Washington office.

[2]This section is based on American data and is excerpted from Damien Terouanne, *French Presence in the United States in Science and Technology* (Arlington, VA: National Science Foundation, forthcoming).

The data available from American government agencies and other institutions made it possible to study separately four populations that constitute the French presence in the United States:

- people born in France, having a college or graduate degree in science or engineering obtained either in the United States, France, or elsewhere, who are counted as permanent residents of the United States;
- scientists and engineers moving to the United States each year for professional or other reasons;
- French students enrolled in American universities; and
- French students pursuing a Ph.D. in an American university.

That last population is a subgroup of the third category, but since the data about the two groups were of both different origin and nature, a separate presentation was deemed preferable.

French Citizens With Bachelor's or Graduate Degrees Living in the United States

The data presented in this section came from NSF's SESTAT Integrated File database, which contains the results of three surveys conducted among people with college or graduate degrees *living as permanent residents* in the United States. The data used for this current study concern persons born in France, less than 76 years old, with a bachelor's or graduate degree obtained either in this country or elsewhere, living in the United States at the time of the 1990 census.

Throughout this part of the study, therefore, we are looking not at the movement of a group of people, but at a permanent population of French citizens living in the United States having a college or graduate degree. The first findings look at all degrees—S&E as well as all other majors. The figures on those with S&E degrees are then studied in greater detail.

Four levels of degrees are considered: the bachelor's (baccalaureate +3 in France); the master's (baccalaureate +5 or 6); the Ph.D. (doctorate); and professional degrees (law degree, medical degree, etc.). Only the first three degrees apply when analyzing the S&E population.

The fields comprising S&E are:

- the physical sciences;
- the life sciences, including the Ph.D. in medicine;
- the social sciences, including psychology;
- mathematics and computer science; and
- engineering.

General Findings. In 1990, the United States census counted 31,400 permanent residents born in France with college or graduate degrees. Of those surveyed, 71.3 percent had obtained their highest degree in the United States, 23.7 percent had obtained it in France, and 5 percent received their highest degree in other countries.

Among those surveyed, 57.9 percent studied or graduated from high school in the United States, with 35.5 percent having completed secondary school in France, and 7 percent in other countries. Of that population, there were 8,960 with degrees in S&E, 28.6 percent of the total.

There were 2,810 French citizens with a doctorate from an American, French, or other institution who were counted as being permanent residents of the United States in 1990. The origin of their doctoral degrees is as follows:

- 920 French doctorates—33 percent,
- 1,830 American doctorates—65 percent, and
- 60 from a third country—2 percent.

Persons With Degrees in S&E: Country in Which They Received Their Secondary and Higher Education. Of those 8,960 French citizens surveyed in the United States in 1990 having a degree in S&E, most received their entire secondary education in the United States or finished their secondary education there (59 percent); an even higher percentage (74 percent) obtained their highest degree in the United States (see tables 9 and 10).

Table 9. Country in which French citizens living as permanent residents in the United States, with degrees in science and engineering, received their secondary education

Disciplines	Secondary schooling						
	France		United States		Other		Total
Total	2,662	30%	5,267	59%	1,026	11%	8,955
Engineering	573	26	1,292	58	344	16	2,209
Life sciences	528	27	971	49	483	24	1,982
Math and computer science	324	33	655	66	16	2	995
Physical sciences	203	38	168	31	167	31	538
Social sciences	1,034	32	2181	68	16	0	3,231

SOURCE: National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Data System (SESTAT) Integrated File, 1993.

Table 10. Country in which French citizens living as permanent residents in the United States, with degrees in science and engineering, received their graduate degrees

Disciplines	Highest degree obtained in:						
	France		United States		Other		Total
Total	2,045	23%	6,649	74%	260	3%	8,954
Engineering	303	14	1,784	81	122	6	2,209
Life sciences	569	29	1,412	71	0	0	1,981
Math and computer science	255	26	740	74	0	0	995
Physical sciences	65	12	335	62	138	26	538
Social sciences	853	26	2,378	74	0	0	3,231

SOURCE: National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Data System (SESTAT) Integrated File, 1993.

Some variation by discipline is evident among the general trends. For example, of the French citizens having their highest degree in engineering, 81 percent were either entirely educated in the United States or finished their degrees in the United States. On the other hand, only 62 percent of those with degrees in the physical sciences pursued or finished their studies in the United States.

At all levels of education, French citizens with degrees in S&E and living in the United States as permanent residents were more often educated in the United States than in France.

Influence of Secondary Studies in the United States on Choice of Discipline. The data in table 9 allows a concentrated look at the population of French citizens in the United States with degrees in S&E who completed their secondary education in the United States. The degrees obtained by these 5,270 individuals are distributed as follows:

- 25 percent in engineering (1,290 diplomas),
- 18.5 percent in the life sciences (970 diplomas),
- 12.5 percent in mathematics and computer science (655 diplomas),
- 3 percent in the physical sciences (168 diplomas), and
- 41 percent in the social sciences (2,181 diplomas).

For the purposes of comparison, degrees awarded in the United States in S&E (bachelor's, master's, and doctorates together) over the last 20 years are distributed in about the same way:

- 21.2 percent in engineering,
- 16.6 percent in the life sciences,
- 12.0 percent in mathematics and computer science,
- 7.2 percent in the physical sciences, and
- 43 percent in the social sciences.

One conclusion naturally arises from the similarity of these distributions: French citizens who obtain their secondary education in the United States tend to follow the same paths in college and graduate studies as their American counterparts.

Country in Which the S&E Degree Was Obtained, by Level of Degree. If we look at the country in which the highest diploma was obtained by level of degree (bachelor's, master's, Ph.D.), one trait is immediately apparent: the proportion of French diplomas in S&E increases with level of degree. Most of those surveyed who have a bachelor's degree (or equivalent) as their highest level diploma obtained that degree in the United States (figure 3). This means that few French citizens who come to the United States with a college education do not pursue a higher degree. At the master's stage, 30 percent of those surveyed have a French diploma. The proportion is as high as 48 percent among those with doctorates.

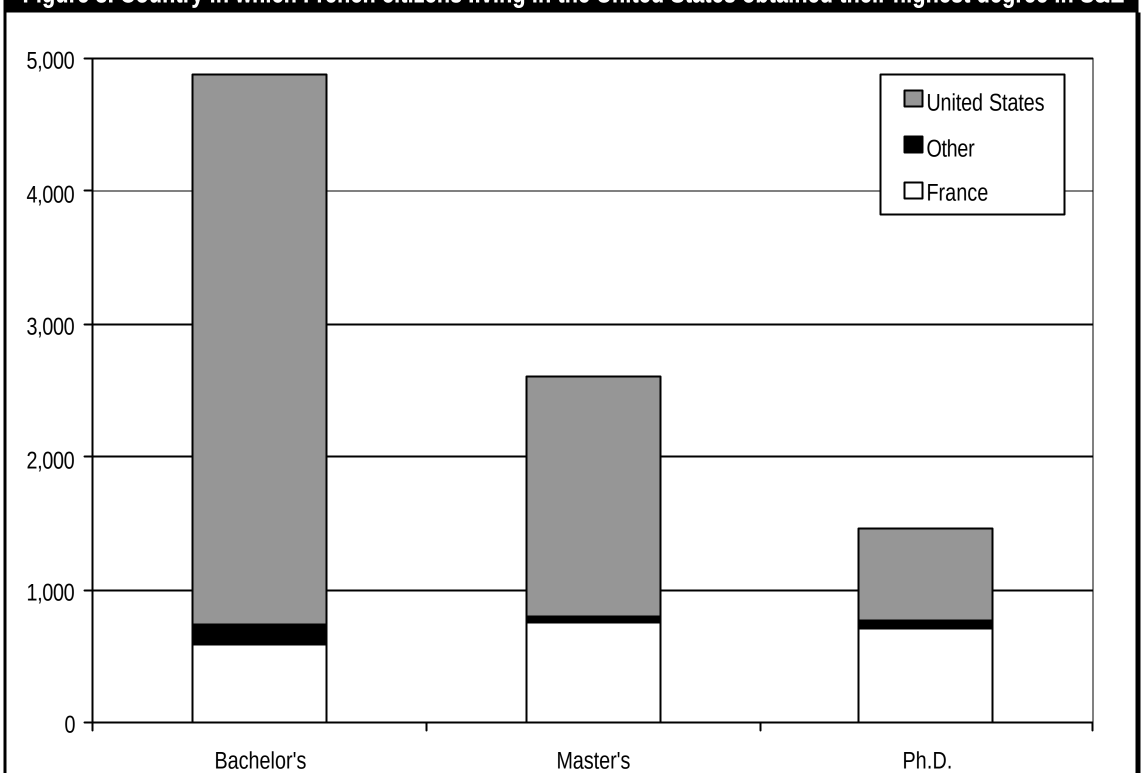
French S&E Ph.D.s in the United States. There were 1,470 French citizens with a Ph.D. from the United States, France, or elsewhere surveyed in the United States in 1990. Their distribution by place of origin of their diplomas was:

- 710 doctorates from France (48.5 percent),
- 700 doctorates from the United States (47.5 percent), and
- 60 doctorates from third countries (4 percent).

Putting aside the question of the place of origin of these degrees, it is interesting to look at the distribution by specialty (figure 4) and to compare it to the distribution of doctorates awarded by American universities (figure 5). Between 1980 and 1993, doctorates in mathematics and computer science comprised only 6 percent of all doctorates in S&E awarded in the United States. However, 19 percent of French S&E doctorate-holders living in the United States as permanent residents were in those disciplines.

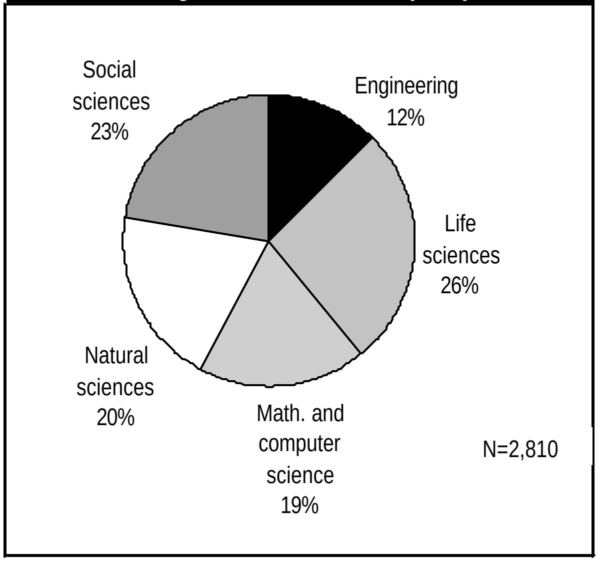
Another significant difference appears in the field of the social sciences, which represents 32 percent of the American S&E doctorates but only 23 percent of doctorates obtained by French citizens living in the United States as permanent residents.

Figure 3. Country in which French citizens living in the United States obtained their highest degree in S&E



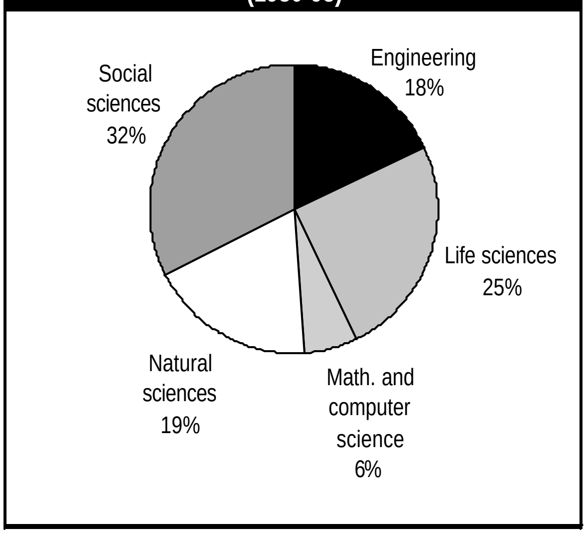
SOURCE: National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Data System (SESTAT) Integrated File, 1993.

Figure 4. Doctorates held by French people living in the United States (1993)



SOURCE: National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Data System (SESTAT) Integrated File, 1993.

Figure 5. S&E doctorates awarded by U.S. universities (1980-93)



SOURCE: National Science Foundation, Division of Science Resources Studies, Selected Data on Science and Engineering Doctorate Awards, 1996.

Conclusion. Most of the 9,000 French citizens living permanently in the United States and having a graduate degree have pursued their secondary education in the United States, and three-fourths of them obtained their highest level diploma there. However, when looking at only those with the highest level degrees, the trend is reversed. Among those 1,500 S&E doctorate-holders, almost half have French doctorates. *Of all the persons educated in France, those with doctorates represent the highest proportion of those who are "lost" to France.*

Migration of French Scientists and Engineers to the United States

The data used in this section were obtained from the U.S. Immigration and Naturalization Service (INS), the department charged with regulating immigration. An immigrant is an alien admitted to the United States as a legal resident. The INS provided NSF with data on those immigrants who declared themselves to be scientists or engineers, and whose curriculum justified that designation. Those who declared themselves to be researchers, managers, teachers, or students were not included in the figures. Neither were those who did not declare a profession. Therefore, the following figures are perforce underestimates of the actuality.

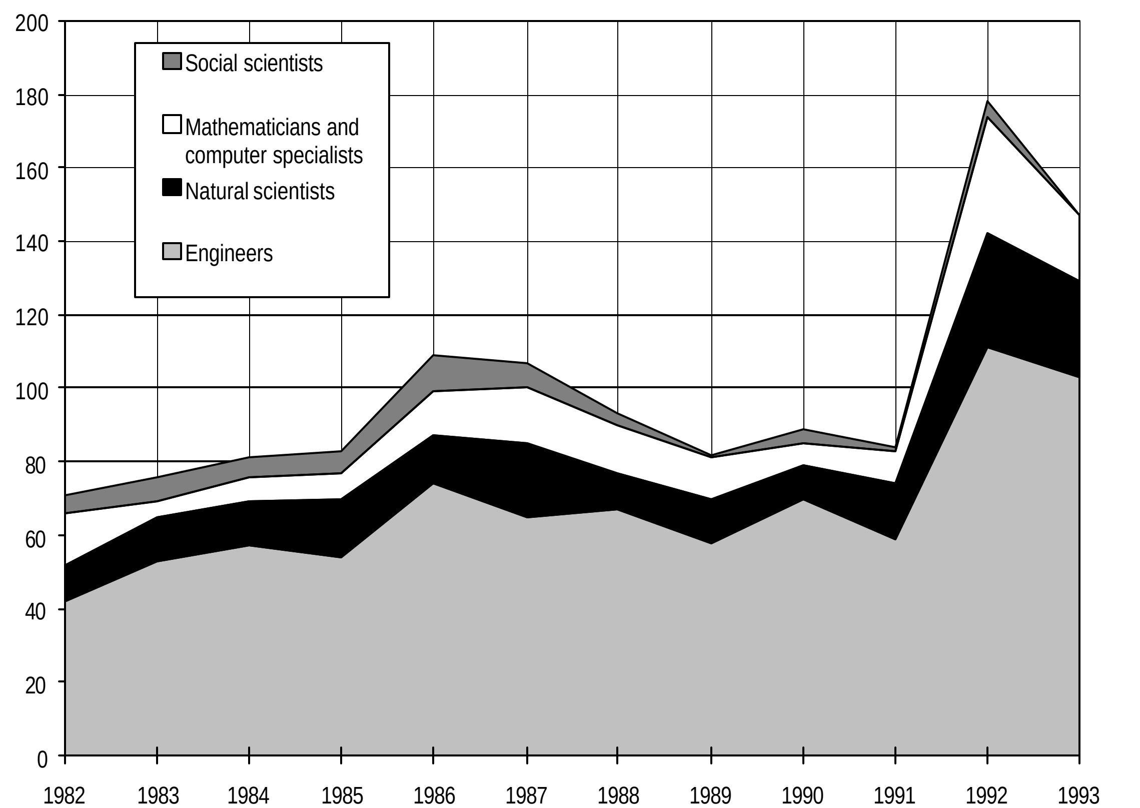
It is important to note, also, that among the French immigrants in S&E are some who have lived in the United States for several years, but on temporary visas. They may have, for example, obtained a doctorate or filled a postdoctoral position in the United States, but they will not appear in the figures from immigration until they become permanent residents.

French Scientists and Engineers Admitted to the United States as Permanent Residents. Figure 6 shows the number of French scientists and engineers admitted to the United States on permanent visas since 1982. Only those persons who declared themselves as belonging to one of the four professional categories appear in the figure.

A significant increase is readily apparent in 1992. This was the year the Immigration Act, passed in 1990, took effect. It put into place the first major changes in immigration quotas in 25 years. This law raised immigration quotas for professionals, bringing a strong increase in the number of highly qualified immigrants—among whom are engineers and scientists. (Note that the year 1992 shows as a plateau in figures 6 and 7, due to the 1990 Immigration Act.)

Scientists and Engineers Admitted to the United States Whose Last Country of Residence Was France. In this category, it is not country of origin that is chosen but country of last residence (figure 7). Of the engineers and scientists coming from France to the United States, many are French citizens and were included in the previous subsection analysis. In 1990, for example,

Figure 6. French S&E admitted to the United States on permanent visas



SOURCE: National Science Foundation, Division of Science Resources Studies; U.S. Department of Justice/Immigration and Naturalization Service, unpublished tabulations.

140 scientists and engineers came to the United States from France, and 82 of them were French citizens. That same year, 89 French scientists and engineers were registered by the INS. Seven of those, therefore, came from a country other than France. Additionally, 58 engineers and scientists who were not French citizens left France in 1990 for the United States.

Status of Scientists and Engineers From France: Work Permits. Generally, persons immigrating to the United States for professional reasons, as well as temporary, non-immigrant, workers, must obtain a labor certification from the U.S. Department of Labor. Approximately one person in three comes to the United States for professional reasons; the other two-thirds come because of family or as refugees. One in three immigrants here for professional reasons is exempted from the need for a labor certification. This exemption is most often awarded to highly qualified people, including scientists.

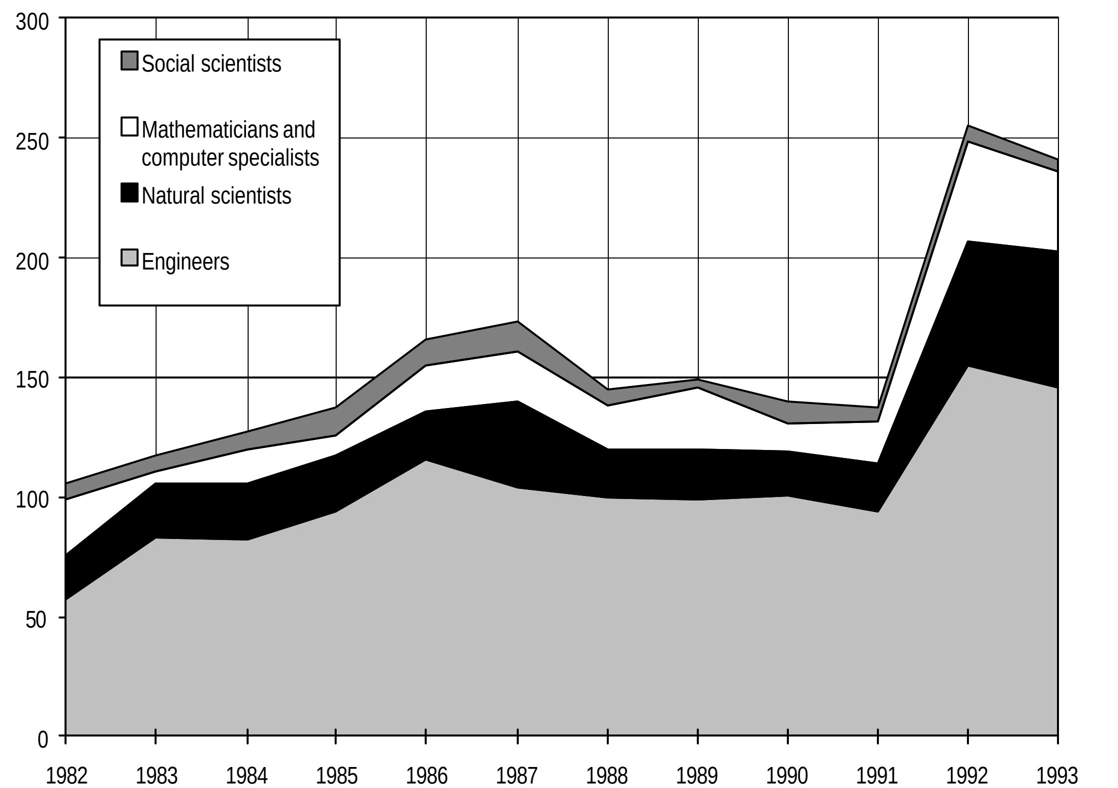
Among those scientists and engineers coming from France, only some immigrate for professional reasons; of those, not all are required to obtain a labor certification. These considerations explain the data in figure 8.

Geographic Origin of Scientists and Engineers Coming From France but Not French Citizens. Each year, scientists and engineers who are not French citizens leave France for the United States. The INS counted between 60 and 80 of them every year between 1984 and 1993. These figures are certainly underestimated, once again due to the number of immigrants whose professions are unknown. With this understood, it is still interesting to look at their distribution according to country of origin.

Figure 9 gives the aggregate of this distribution over the years 1984-93. The evolution of this distribution over time is not different enough to be significant. Overall, the scientists and engineers who lived in France before emigrating to the United States came from the Near and Middle East, the Far East, and Africa.

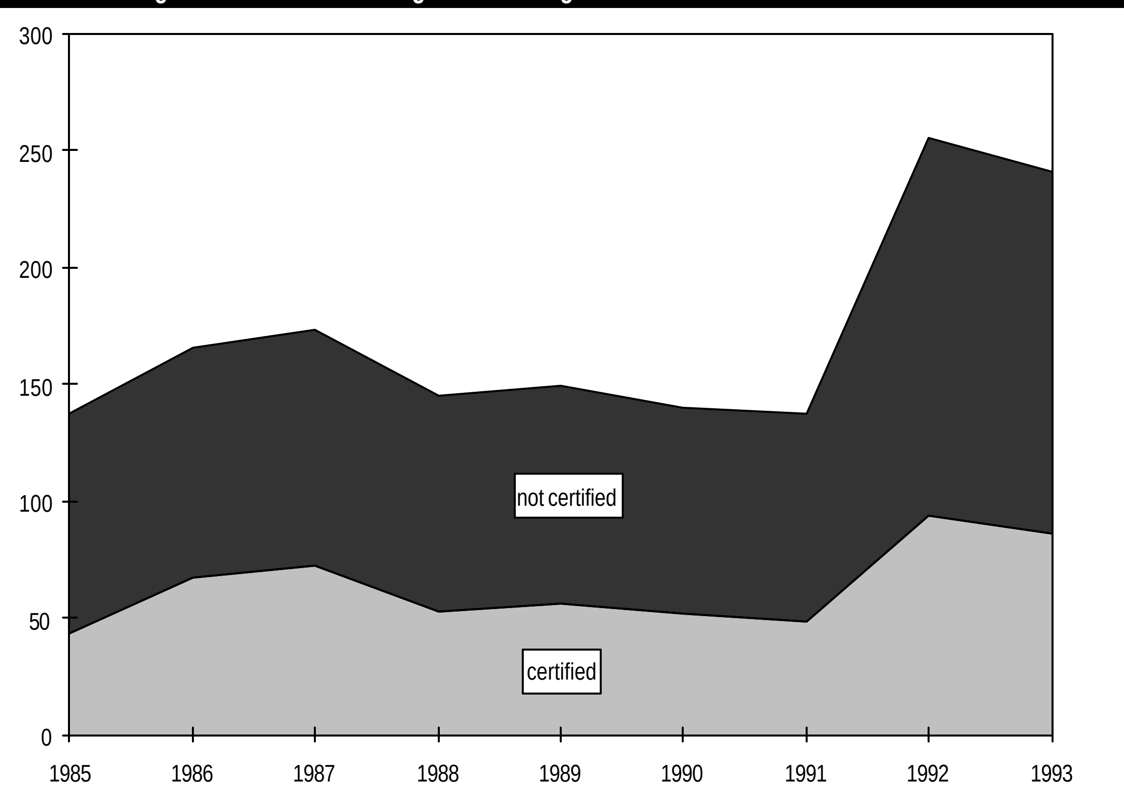
It is instructive to look at the parallels between this distribution and that of country of origin of noncitizens obtaining doctorates in France in 1995 (figure 10). Obviously, it is not advisable to make too much of this comparison because the two figures do not compare the same population. Still, it is interesting to see that Africa, which is the point of origin of more than half the noncitizens

Figure 7. S&E admitted to the United States on permanent visas, last permanent residence is France



SOURCE: National Science Foundation, Division of Science Resources Studies; U.S. Department of Justice/Immigration and Naturalization Service, unpublished tabulations.

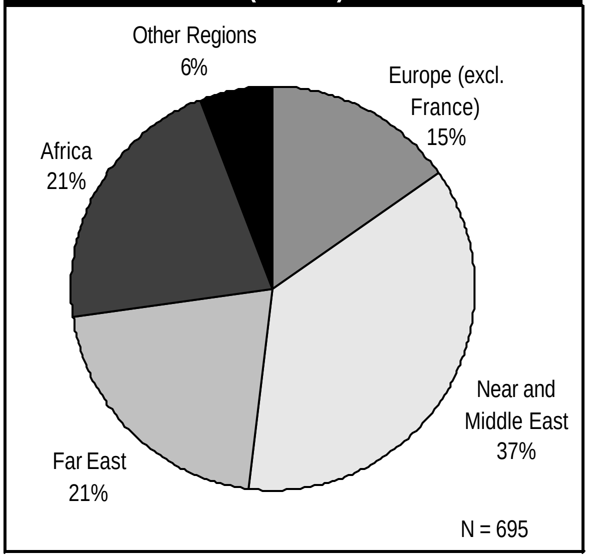
Figure 8. Scientists and engineers coming from France - Labor certification status



SOURCE: National Science Foundation, Division of Science Resources Studies; U.S. Department of Justice/Immigration and Naturalization Service, unpublished tabulations.

obtaining doctorates in France, is not disproportionately represented in the population of non-French citizens who are scientists moving from France to the United States.

Figure 9. Origin of non-French scientists and engineers leaving France to the United States (1984-93)



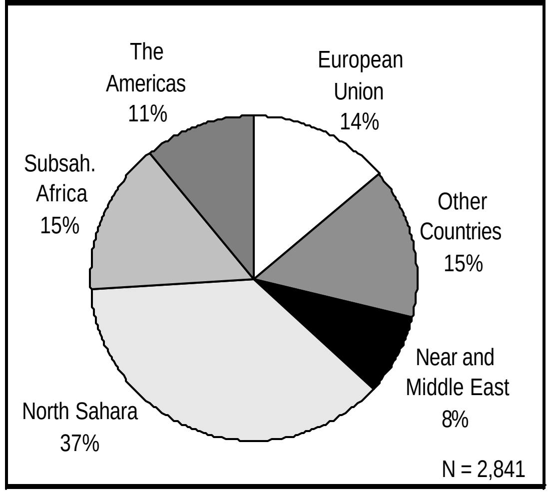
SOURCE: National Science Foundation, Division of Science Resources Studies; U.S. Department of Justice/Immigration and Naturalization Service, unpublished tabulations.

In fact, those scientists coming from the Near East and Middle East, a smaller proportion of those who get their doctorates in France (about 8 percent), leave for the United States in much higher numbers (37 percent of the immigrants coming from France but not French citizens).

French Students and University Staff in American Universities

This section is based on data found each year in the reports *Open Doors* and *Profiles,* published by the Institute of International Education. *Open Doors* presents the results of a yearly survey of the population of foreign students registered in all American universities. Depending on the year, the rate of response of these establishments varies between 90 and 98 percent. Unfortunately, not all the universities reply with the same amount of detail. For example, in the data for 1995-96, the universities registered a total of 453,800 foreign students, but those conducting the survey could only identify countries of origin for 395,000 of them, or 87.1 percent. The level of academic studies is only known for 346,000, or 76.3 percent.

Figure 10. Doctorates awarded to foreign people in France in 1995



SOURCE: French Ministry for Research, DGRT Rapport sur les études doctorales, December 1996.

In *"Profiles,"* universities are asked to furnish data that is individual in nature on their foreign students: nationality, sex, field and year of studies, major source of funding. This request for supplemental detail reduces overall participation. In 1993-94, about 70 percent of the institutions that responded with the number of foreign students provided the individualized information. This data, all together, provided information on a sample population of 258,300 students, 57 percent of the total population counted in that year's *Open Doors*. Finally, of the individual forms filled out, not all were complete, but more than 90 percent had no more than one blank box.

Taking these problems into account, the correlation between the findings of the two surveys is still very strong: the overall distribution by sex, by level and field of study, or by geographic location is very similar in both surveys. It would be reasonable to think that these two sources of data give a fairly representative picture of the population of foreign students, specifically of French students, in the United States.

French Students in the United States: General Trends. There were 5,710 French students in American universities during the academic year 1995-96. This is 2.3 percent lower than the year before. Figure 11 shows the evolution of this number over the past decade. There is a significant increase in the number between 1984-85 and 1990-91, when France went from being the 26th to the 16th in terms of countries having the largest number of students in American universities. Since 1990-91, this population has been stable—between 5,000 and 6,000 students per year. For purposes of comparison, there are currently 8,500 German students in the United States and about 7,800 British students. France ranks third among European countries.

Figure 12 shows the change in the total number of foreign students in the United States since 1984-85. The strong increase between 1984 and 1994 is mostly due to an increase in the number of students from Asia coming to the United States. There were 145,000 Asian students in the United States in 1984-85 (42 percent of the total number of foreign students), and 260,000 in 1995-96 (more than 57 percent of the total). Japan, China, and Taiwan are the most represented countries, each with between 35,000 and 45,000 students in American universities.

The distribution by level of studies of French students in the United States has changed little over time. Following are the figures for academic year 1995-96:

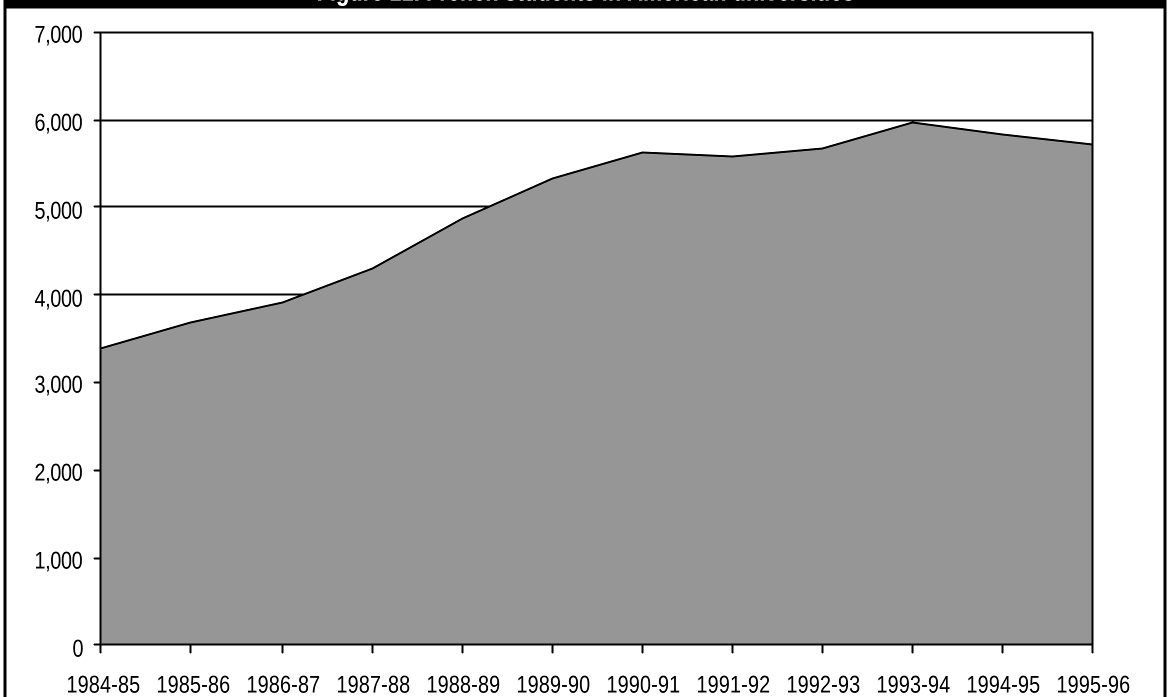
- 2,670 students (46.8 percent) in undergraduate programs (before the *maîtrise* in France);
- 2,340 students (40.9 percent) in graduate programs (after the *maîtrise*); and
- 702 students (12.3 percent) in other programs (intensive English, internships, etc.).

Distribution by Discipline of French Students in the United States. Table 11 gives the approximate distribution of French students in the United States by discipline, based on the findings of the *Profiles* survey of 1993-94. The field of study was known for 2,850 French students, a bit less than half of those counted in the *Open Doors* survey of the same year (5,980).

French Postdoctorates and Scientists at American Universities as Scholars. Despite the lack of precision in the term “scholar,” there is a consensus among universities as to how to define this category of person. The definition suggested in the *Open Doors* report is: “International scholars, being neither students nor permanent faculty, conduct research or teach or do both in a concentrated period of time, usually less than three years.” The scholar category thus includes people in postdoctoral internships as well as established scientists and academics sent “en mission” for a predetermined length of time in an American laboratory.

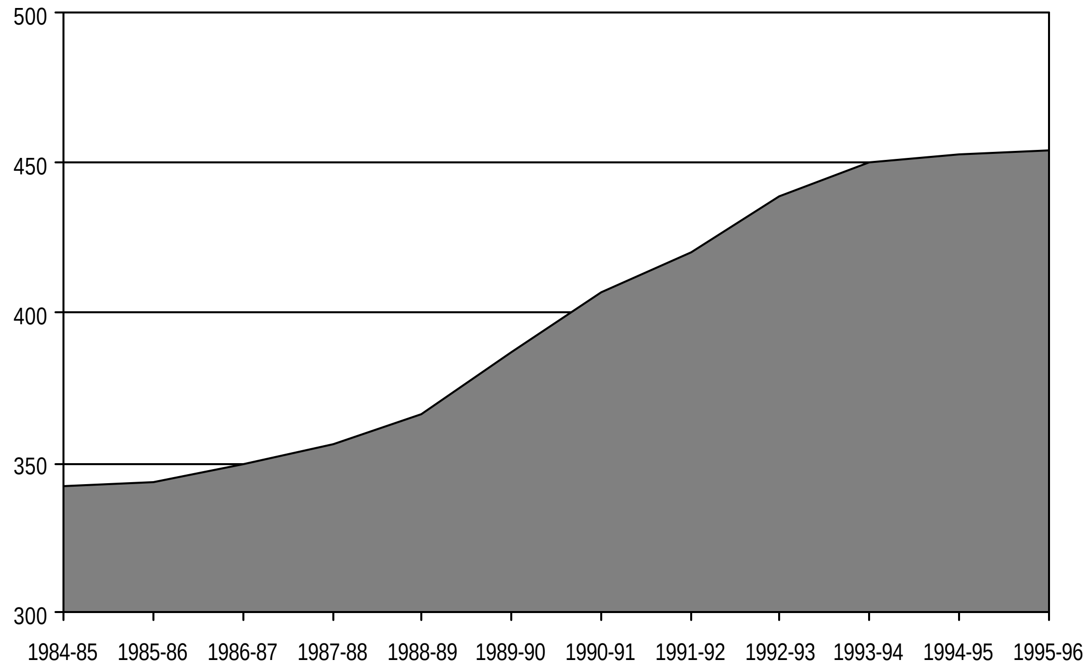
Table 12 gives an idea of the number of scholars counted in the United States over the past few years. Once again, this information comes from a survey of the

Figure 11. French students in American universities



SOURCE: Open Doors - Institute of International Education - Report on International Educational Exchange, years 1984-85 and 1995-96.

Figure 12. Foreign students in American universities (in thousands)



SOURCE: Open Doors - Institute of International Education - Report on International Educational Exchange, years 1984-85 and 1995-96.

Table 11. Distribution by discipline of French students in the United States (1993-94)

Total number of French students counted ("Open Doors")	5,976
Number of students whose discipline is known ("Profiles")	2,845
Percent of Students Whose Discipline is Known	
Commerce - Management	30.8%
Engineering	10.7%
English literature	9.6%
Social sciences	6.6%
Physical and life sciences	5.5%
Beaux-arts	3.8%
Mathematics and computer science	3.0%
Other (<3%)	14.5%
Not indicated	15.3%

SOURCE: "Profiles" - Institute of International Education, Report on International Exchange, 1994-95.

universities, with rates of return each year between 80 and 90 percent. The figures given are thus necessarily slight underestimates of reality.

While France ranks 16th in terms of numbers of citizens in American universities, it ranks 8th in terms of number of scholars in those same universities. This discrepancy is an indication of the strength of French research.

The *Open Doors* report provides information on the types of visas held by scholars, without an indication as to country of origin. Among the 58,000 scholars counted during academic year 1994-95, 76.6 percent held a J1 visa. The U.S. Information Agency office for exchange programs in teaching, research, or education issues this visa. Postdoctorates usually have this type of visa, as well as many of the scientists coming to work in American laboratories. The other type of visa scientists and academics may obtain is the H1 visa; this was issued to 16 percent of the scholars surveyed. This visa is given to highly skilled people or to those who bring a type of knowledge or ability that is not available in the United States.

Table 12. Number of French postdocs and scientists in American universities as scholars

Year	Scholars
1989-90	1,810
1991-92	2,175
1993-94	2,076
1994-95	2,410
1995-96	2,320

SOURCE: "Open Doors" report by the Institute of International Education, Report on International Exchange, 1984-85 to 1995-96.

Unfortunately, it is not possible to isolate postdoctorates from scholars from the figures available in the *Open Doors* report. Despite this, NSF estimates that the total number of foreign postdoctorates in American universities is about 17,300. Among the 58,000 foreign scholars in American universities, only about 30 percent fill postdoctoral positions. The same ratio applied to the French scholars population shows that about 700 French postdoctorates work in American universities. About 60 percent of all foreign postdoctorates in the United States, of any nationality, work in a university. By applying the general ratio of foreign scholars/postdoctorates to the number of French scholars counted, we get a total number of slightly more than 1,100 French postdoctorates in the United States.

Conclusion. American universities take in about 5,800 French students each year. Almost half of them are undergraduates (before the bachelor's degree). Studies in commerce and management attract almost one-third of the French students, and science and engineering only about one-fourth. The available data do not allow us to compare country of origin, chosen discipline, and level of studies. It is, however, reasonable to assume that there would be a much higher percentage of scientific disciplines found at the graduate level (master's and doctorate) among the French students, as is the case for students from many other countries.

The American universities surveyed counted about 2,300 French scholars per year. These scholars are temporary visitors, often holding J1 visas; postdoctorates; academics; or visiting scientists. A minority of scholars are postdoctorates.

Doctoral Candidates in the United States

The data used in this section come from the National Research Council's annual Survey on Doctorate Recipients for NSF and four other federal agencies. The information is collected via questionnaire directly from doctoral candidates just before their thesis defense. While answering the questions is not required of the candidates, most do so, finding no difference between this survey and the other administrative papers they must fill out when they get their degrees. In this way, the rate of response has consistently stayed between 92 and 94 percent over the past 10 years.

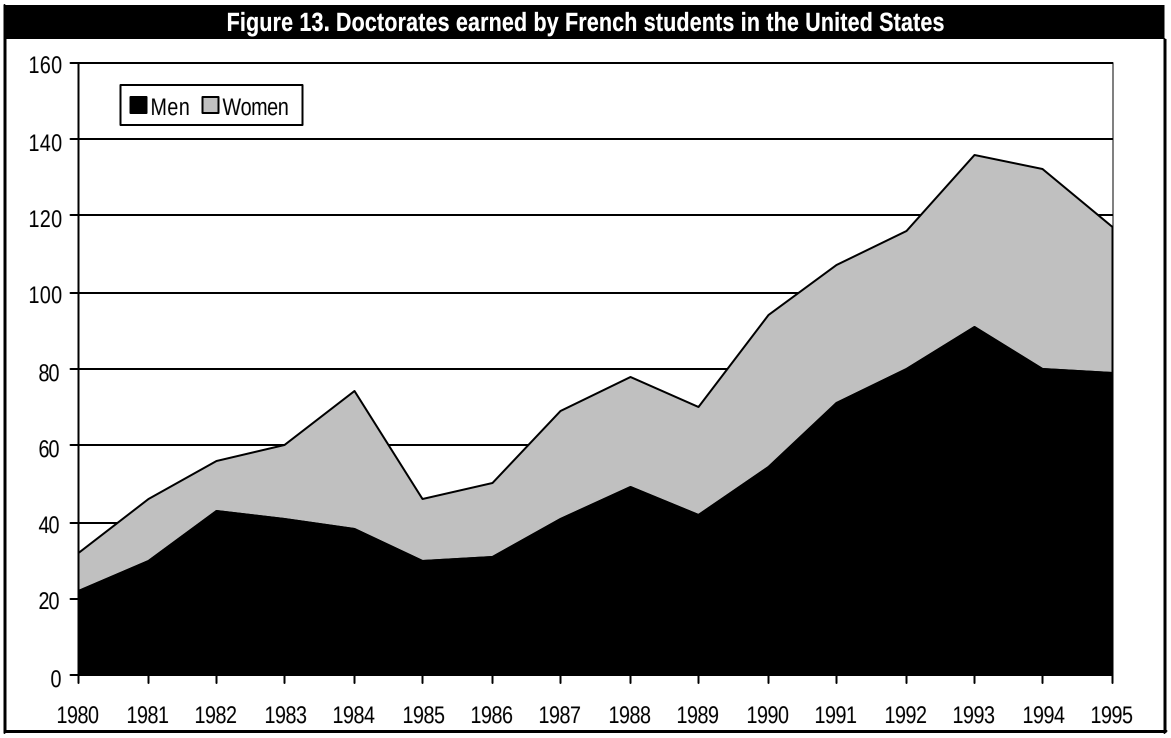
Total Number of French Doctoral Candidates in the United States, in All Fields of Study. Figure 13 shows the evolution of the number of doctorates awarded to French citizens in the United States between 1985 and 1995 in all disciplines. This population has remained relatively small, despite having more than doubled in 10 years (117 doctorates in 1995, against 46 in 1985). All categories of doctorates, encompassing those in S&E as well, are included. Distribution by sex has stayed basically the same between 1985 and 1995: about one-third of doctorates are awarded to women (35 percent in 1985, 40 percent in 1990, 32 percent in 1995, and 36 percent on average over the entire period under consideration). If only the S&E fields are examined, the proportion of women receiving doctorates is a bit lower: 23.5 percent between 1987 and 1991.

Profile of French Citizens Getting a Doctorate in the United States. Table 13 contains information presenting a profile of the 1,015 French citizens who obtained a doctorate in the United States between 1985 and 1995. During that decade, 30 percent had a permanent visa and were the most likely to remain for long periods in the United States.

The average time between getting a bachelor's degree and obtaining a Ph.D. was 7.4 years. The time spent solely in the university was 6.2 years. These averages are lower than those of all U.S. doctorate recipients in all disciplines, whose average time at the university was 7.2 years, with 10.9 years between getting the two degrees.

The 1-year difference between the university time of French citizens as compared to all doctoral candidates is related to the fact that more French students pursue disciplines requiring shorter terms of university study (engineering, for example, which attracts almost one-fourth of French doctoral candidates in the United States). The more significant difference (more than 3 years) in the total period between the bachelor's and the Ph.D. is due in part to the U.S. practice of alternating work and the pursuit of a degree or of pursuing both work and degree concurrently. The difference between the two groups also shows that French students coming to the United States for a degree do not often adopt this dual regimen; this is mostly due to a lack of opportunity, since most of the students have only temporary visas that do not allow them to work outside of the university environment.

NSF's statistical division—the Division of Science Resource Studies—is responsible for monitoring American activity in science and technology. Therefore, some



SOURCE: National Science Foundation, Division of Science Resources Studies, Survey on Earned Doctorates, unpublished tabulations, 1996.

Table 13. Profile of French citizens who obtained doctorates in the United States 1985-95

All disciplines	Number	Percent
Total number of doctorates (1985-95)	1,015	
Status		
Permanent visas	303	30
Temporary visas	712	70
Average time between the bachelor's and the Ph.D.		
Years since obtaining a bachelor's	7.4	
Years of education since obtaining a bachelor's	6.2	
Married	441	43
Planning to stay in the U.S. after getting their Ph.D	496	49
With a prospective postdoc or job	344	69
Looking for employment or a postdoc	144	29
Not specified	8	2
Science and engineering only		
Number of doctorates in science and engineering	695	
Average age of obtaining doctoral degree	29	
Plans upon receipt of doctorate		
Planning to stay in the U.S.	287	41
Planning to leave the U.S.	274	39
Not yet decided	134	19

SOURCE: National Science Foundation, Division of Science Resource Studies data, Survey on Earned Doctorates, unpublished tabulations, 1996.

of the data available at NSF from the Survey on Doctorate Recipients focus on doctorates in S&E only. An interesting figure is the average age of French recipients of American doctorates, which is 29 years. The average age of all recipients of American doctorates in S&E is 32.2 years. There is the same 3-year difference previously found in the average number of years between the undergraduate degree and the Ph.D.

The questionnaire given to doctoral candidates just prior to their thesis defense includes some questions about their plans. Great care must be taken in interpreting these responses. The French candidates filling out this questionnaire just before defending their theses know that they will need a postdoctoral position if they want to find employment with one of the public sector institutions in France. They are more predisposed, therefore, to see a short-term future in the United States. These findings, moreover, indicate only the *intentions* of future doctorate-holders; they do not actually provide any information on future careers (especially after the postdoctoral period).

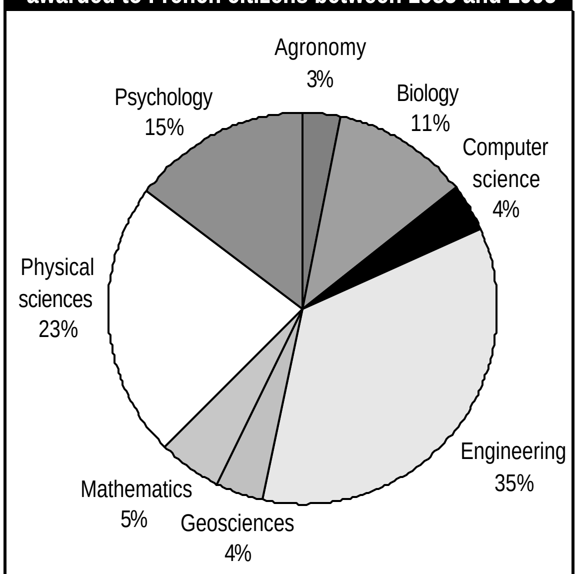
About half (49 percent) of the French doctoral candidates in the United States, in all disciplines, plan to stay in this country after obtaining their degree. Two-thirds of these have a specific position or postdoctoral position arranged. The remaining one-third consists of people planning to stay, but either without specific plans or not stating those plans. In short, some months before defending their theses, one in three French students who are candidates for Ph.D.s at American universities have specific plans to stay in the United States.

In S&E, the proportion of future doctorate-holders planning to stay in the United States, either with or without an arranged position, is a bit lower (41 percent). Details on the nature of these plans or of these persons are not available.

Distribution by S&E Discipline. Between 1985 and 1995, 695 of the 1,015 doctoral degrees obtained in the United States by French citizens were in science or engineering. The distribution of these 695 doctorates by field is given in figure 14. Engineering is an extremely significant field, awarding 240 doctorates—35 percent of the total in S&E. This predominance is recent since only 12 percent of French citizens with doctorates residing in the United States obtained their degrees in engineering (see figure 6). The other field with a large percentage of candidates is the physical sciences (physics and chemistry), which attracts 23 percent of French citizens obtaining their doctorates in American universities.

States and Universities Where French Citizens Come to Study. Two geographic areas are immediately apparent as destinations for French doctoral candidates coming to the United States:

Figure 14. Distribution by field of the Ph.D.s in S&E awarded to French citizens between 1985 and 1995



SOURCE: National Science Foundation, Division of Science Resources Studies data, Survey on Earned Doctorates, unpublished tabulations, 1996.

- California, which awarded almost one-fourth of the doctorates obtained by French S&E students; and

- the Northeastern states, including the Mid-Atlantic (New York, New Jersey, Pennsylvania) and New England (Massachusetts, Connecticut, Rhode Island), which together account for 35 percent of the total.

Table 14. Science and engineering doctorates awarded to French citizens in American universities by state and university (1980-91)

State	S&E Ph.D.s	University	S&E Ph.D.s
Total	505	Total	505
California	117	MIT	32
New York	63	Stanford	31
Massachusetts	52	Berkeley	23
Texas	41	U. of Houston	21
Illinois	30	Columbia University	18
Pennsylvania	23	UCLA	16
Colorado	16	Cornell University	14
New Jersey	14	UC San Diego	13
Connecticut	13	Northwestern Univ.	12
Indiana	13	U. of Pennsylvania	12
Michigan	12	Yale	11
Rhode Island	11	Illinois Inst. of Tech.	10
Georgia	10	Princeton University	10
Other states (<10)	90	U. of Rochester	10
		U. of Texas at Austin	10
		Other universities (<10)	262

SOURCE: National Science Foundation, Division of Science Resources Studies data, Survey on Earned Doctorates, unpublished tabulations, 1996.

These same two geographic areas are found in the survey of doctoral candidates and postdoctorates in North America, the subject of the next section.

CONCLUSION

Currently, there are 1,500 young French scientists in the United States either pursuing a doctorate or in postdoctoral positions. The often feared brain drain, if in fact it does exist, applies to a relatively small population.

While assembling information from these young scientists, it seems that many of them remain interested in France and want to return there one day for a career in higher education or public research. Their education taught them a love of purely intellectual activity that can be found only in basic research; their early experiences as researchers, as doctoral candidates, and—later—in postdoctoral positions confirmed this preference while also failing to instill an interest in the more applied research that industry offers. This categorical rejection of the value of applied research is often a problem when they seek professional positions—and leads to some bitterness with the French educational system if they have difficulties finding interesting jobs.

While the French university system can be criticized for its lack of interest in the industrial sector, industry shares the responsibility in that it has systematically given preference to students and graduates of engineering and business schools, first in internships and later when hiring.

When stated thus, the problem may seem typically French. The United States, however, is also reexamining the future of its young doctorate-holders and questioning the pertinence of graduate education. In the United States as in France, the educational system does not seem to encourage careers in the industrial sector. The postdoctoral positions are, in the United States, synonymous with uncertainty. The low unemployment rate in the United States makes the problem less urgent.

The gravity of the employment situation in France, even for the best educated, exacerbates the bitterness of these young expatriate scientists. This is particularly evident when those reactions examined in this study are compared to those evinced in the same type of survey 10 years ago. Initiatives such as the *doctoriales*—training designed to help doctorate-holders find employment in the industrial sector—are steps in the right direction. The efforts of the Association Bernard Gregory, whose mission is to find jobs for Ph.D.s in industry; and the activities of the French Office of Science and Technology in Washington that created the Forum USA, an annual job fair at which French scientists in the United States have the opportunity to meet with employers from France in three American cities, will help integrate researchers into the French private sector.

France is aware of this call from its young scientists in the United States. Their futures are tied to the health of higher education, research, innovation, and industry in France. This may be a brain drain, but it is one in which those who have left would like nothing better than a ticket home.

GERMANY

Jeroen Bartelse, Eric Beerkens, and Peter Maassen

INTRODUCTION

Germany has a binary system of higher education, consisting of a university sector and a nonuniversity sector. The university sector is by far the larger, attracting 1.8 million students. The nonuniversity sector is only a quarter this size (Baldauf 1998, p. 162). The basis of the current higher education system lies in the 1960s, but the traditions of earlier times are still very much present in the German doctoral system. Paramount in this respect is the unity of teaching and research.

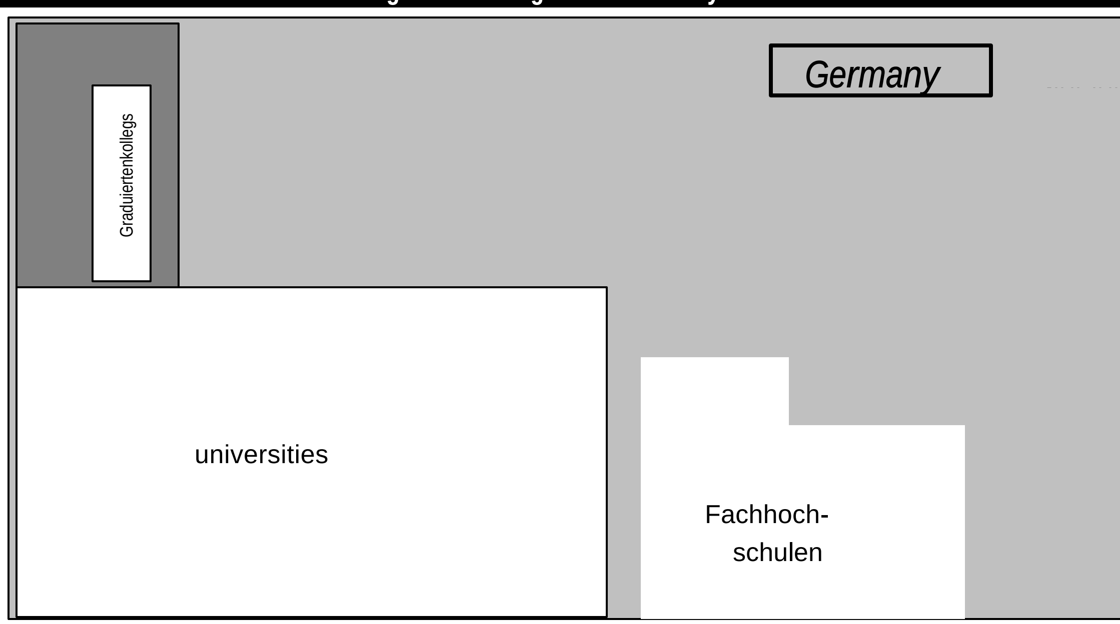
As opposed to the distinction commonly made between undergraduate and graduate studies, German university programs rather are divided into first degree programs and advanced, or postgraduate, degree programs. First degree programs have a formal duration of 4 to 4.5 years and lead to the *Staatsexamen*, *Diplom*, or *Magister*. After obtaining these degrees, graduates can continue their education in two ways: through specialized postgraduate courses leading to a variety of postgraduate certificates or by pursuing a doctorate degree. The doctorate is the highest academic degree in Germany. It can only be offered by universities. Another qualification beyond the doctorate can be obtained, although this is not considered an academic degree in its own right (Kouptsov 1994): the *Habilitation*. The *Habilitationschrift* gives proof of academic scholarship and should comprise a piece of original, independent scholarly work. The holder of a *Habilitation* qualifies for a professorship at a university.

In figure 1, a graphical overview of the German higher education system is presented. In this report, we address the doctoral stage.

TRENDS IN GRADUATE EDUCATION

It was in Prussia in the early 19th century that the idea of research training was grafted onto the context of a university. This began within a broader reform of ideas on teaching, learning, and research. A few high-ranked administrators, influenced by political events in France and by the German idealist philosophers, conceived the idea that a balanced development of state and society was only feasible with educated citizens (Gellert 1993, pp. 5-9). To achieve this aim, the university had to train students for civil jobs, in a neutral atmosphere of truth-seeking. Von Humboldt expressed the ideals of his time into plans for the foundation of a new university. In 1809, the University of Berlin was founded on the basis of Von Humboldt's principles; in the following years, other German universities reformed accordingly.

Figure 1. The higher education system



The ideal of the German university as it emerged at the beginning of the 19th century is summarized by Paulsen (1906, p. 520):

> Its principle was to be, not unity and subordination, but freedom and independence. The professors were not to be teaching and examining State officials, but independent scholars. Instruction was to be carried on not according to a prescribed order, but with a view to liberty of teaching and learning. The aim was not encyclopedic information, but genuine scientific culture. The students were not to be regarded as merely preparing for future service as state officials, but as young men to be trained in independence of thought and in intellectual and moral freedom by means of an untrammeled study of science.

In practice, these principles lent themselves to multiple interpretations (see Clark 1995, pp. 21-24). The orientation toward research led to increasing specialization and gradual departmentalization of universities into centers of specialized research. In the course of the century, the original Humboldtian doctrine with its broad humanistic orientation evolved at some places into a narrow intellectualism: an over-commitment to the advancement of knowledge (see Gellert 1993, pp. 9-11).

The institutional forms that were created for the advancement of science and breeding of scientists were the teaching-research laboratory and the research-oriented seminar (Clark 1995, pp. 24-30). The classic case of the first form is the laboratory of the chemist Justus Liebig, founded in 1826 in Giessen. Here, Liebig combined research and teaching in a way that attracted many advanced students with whom he was able to create a research environment in which innovative research was conducted. Its success motivated other German research universities to review their own training methods. Morrell (1990, pp. 51-64) points out that "the university laboratory provided for science an equivalent of the Renaissance artist's studio, in that it offered to apprentices induction into the scientific guild through pupilage in practical skills under a master-practitioner."

Another form in which research activity was combined with teaching was the research-oriented seminar. The classic and exemplifying model here is the Neumann seminar in physics established in Königsberg in 1834. Unlike other seminars of those times, Franz Neumann included "practical exercises in techniques of quantification, group review of problems, and innovative design of instruments" (Clark 1995, p. 27). The laboratories (later named "research institutes") and seminars were autonomous, relatively small, organizations headed by the chair-holding professor. These influential figures ran the institutes and seminars and were sovereign in their scientific pursuit. The institutes and seminars gave the German higher education system its esteemed reputation in the late 19th century.

The origins of German research training as described in the foregoing section have of course undergone substantial changes in the first half of the 20th century. Rapid industrialization, two world wars, and the transformation of an elite into a mass system of higher education are only a few examples of circumstances with a high impact on the higher education system. However, some of the original beliefs and institutions are still vital and reflected in doctoral training and research.

Freedom of learning has remained the paramount feature of German education and research, anchored in the Basic Law of 1949, which reads: "Art and science, research and teaching, are free."[1] Still surviving is the unity of teaching and research, which is expressed profoundly in the apprenticeship model of doctoral research: the *Doctorvater* who, in a one-to-one relationship, guides his student by way of learning by doing. The institutes form a distinct organizational characteristic of the German higher education system. Influential chair-holders function at the top of these hierarchically ordered organizations, where many doctoral candidates conduct their research. Furthermore, the seminars still exist, although they have been watered down to large-scale instructional seminars at the first degree level rather than at the doctoral level.

After World War II and up until the 1990s, individuals aspiring to a doctoral degree usually sought a junior research post. In 1989, 70 percent of doctoral candidates were employed in this way. Doctoral candidates in these positions combine their research work with teaching and other activities: this, on the one hand, provides them with professional experiences and skills; on the other hand, it lengthens completion times (Baldauf 1998). Research training at the doctoral level is not formally organized. German universities in the 1980s did "not offer doctoral programmes incorporating a minimum systematic institutional effort to qualify candidates further. It is entirely a matter of the individual master/apprentice relation between the candidate and 'his' supervisor whether he gets training and advice in his work and, if so, how much" (Huber

[1] Article 5, par. 3, as reported by Clark (1995), p. 52.

1986, p. 302). Enders (1996, p. 165) concludes that, in the 1990s, courses are increasingly being offered (for up to 50 percent of the junior staff working on a doctoral thesis), but that candidates usually perceive doctoral study as an informal learning process. In this respect, there are considerable differences across disciplines.

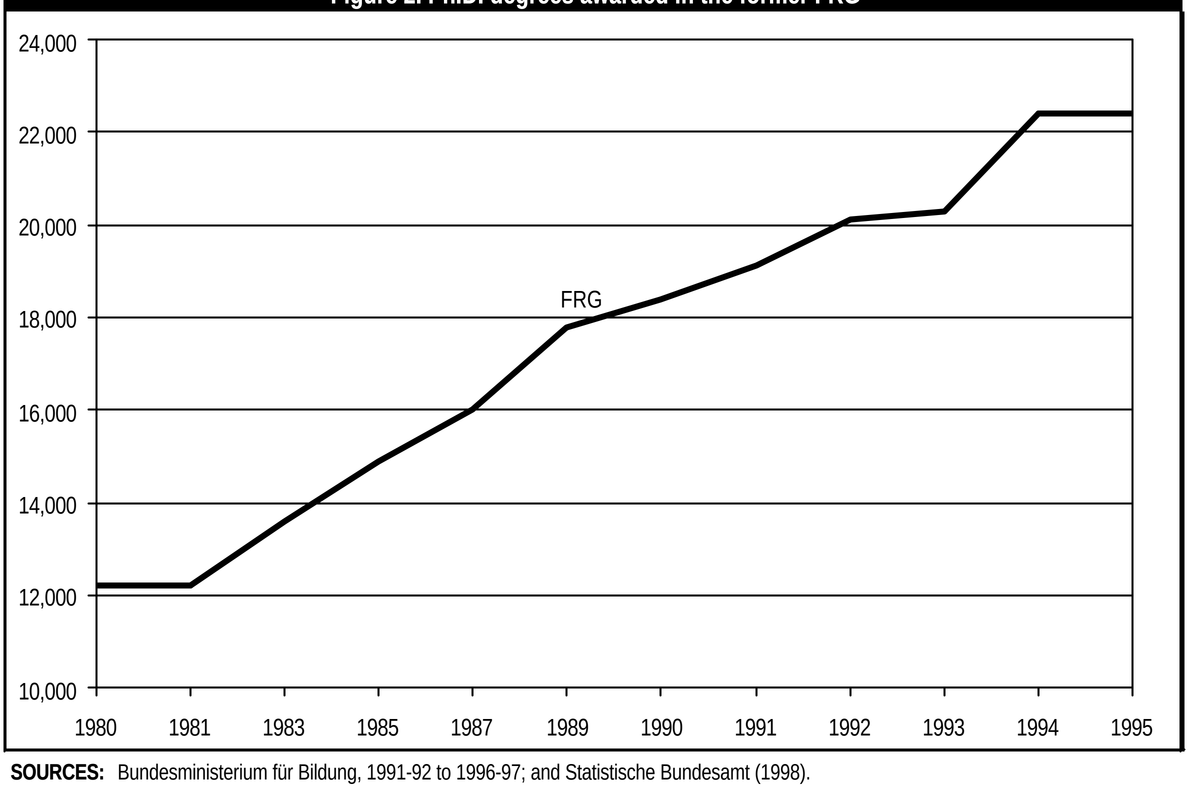
In the natural sciences, junior research posts are relatively numerous as (external) funds are more affluent. Those pursuing advanced research training usually participate in a research group at a university laboratory or an institute. These groups provide a more structured research environment. In addition to the one-to-one apprenticeship relationship, a larger group of researchers provide the doctoral candidates with the opportunity to interact more frequently and to find collegial support in their work. In this context, doctoral colloquia are commonly organized to give doctoral candidates the opportunity to present their work. Those working on a Ph.D. thesis in the social sciences and particularly the humanities miss such a research environment. Moreover, their supervision is often scant. These doctoral candidates "have little contact with universities or their supervisors; they mostly work at home" (Gellert 1993, p. 20).

The following figures show quantitative trends in German doctoral education. Note that only earned degrees are recorded in German statistics on doctoral training. Figure 2 shows the number of doctoral degrees awarded in the former Federal Republic of Germany (FRG). In figure 3, the number of awarded Ph.D. degrees are shown for the FRG, the former German Democratic Republic (GDR), and these two areas together (after 1994, these two areas are not presented separately in German statistics). Figure 4 presents the proportion of Ph.D. graduates in the various disciplines. Figure 5 shows the proportion of female Ph.D. graduates.

Doctoral Reforms

Basically, three broad developments have given an impetus to change to the German system of doctoral education (see Enders 1995,[2] pp. 247-51). First, degree programs were considered overloaded in terms of student numbers and years of study. In particular, the desire to educate students capable of doing scientific research was shifted from first degree programs to a more structured doctoral stage. Second, doctoral education itself was con-

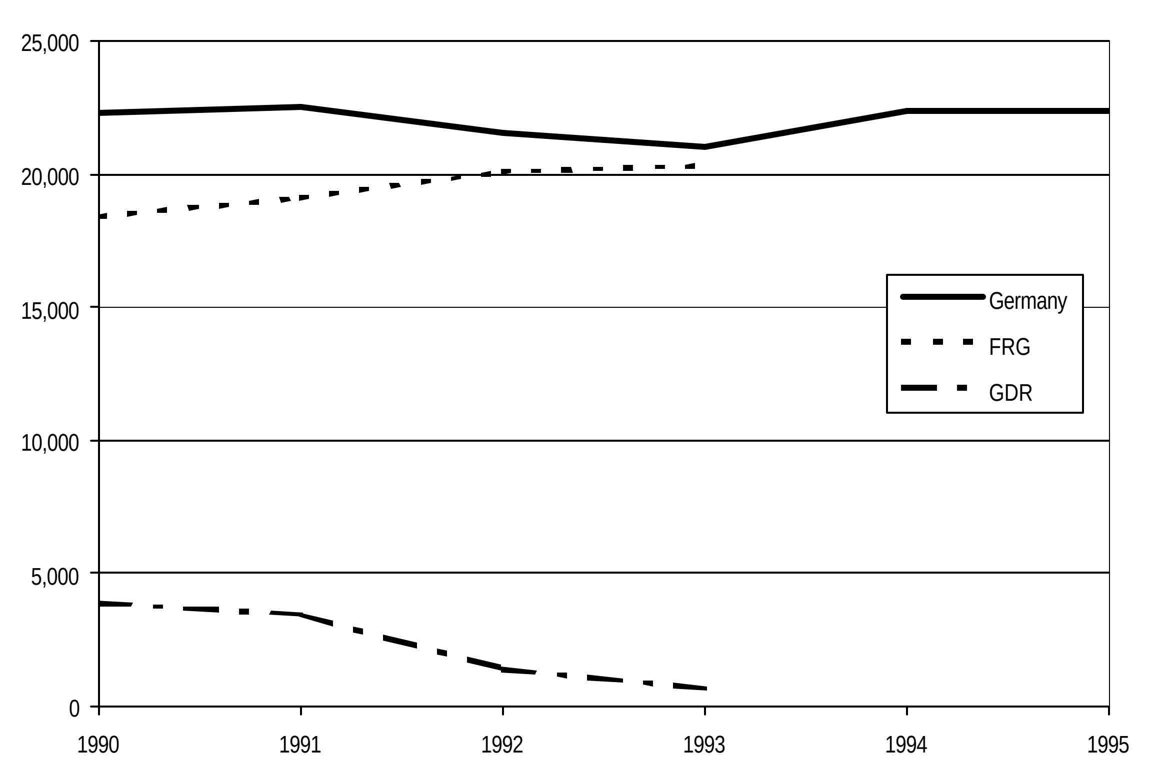
Figure 2. Ph.D. degrees awarded in the former FRG



SOURCES: Bundesministerium für Bildung, 1991-92 to 1996-97; and Statistische Bundesamt (1998).

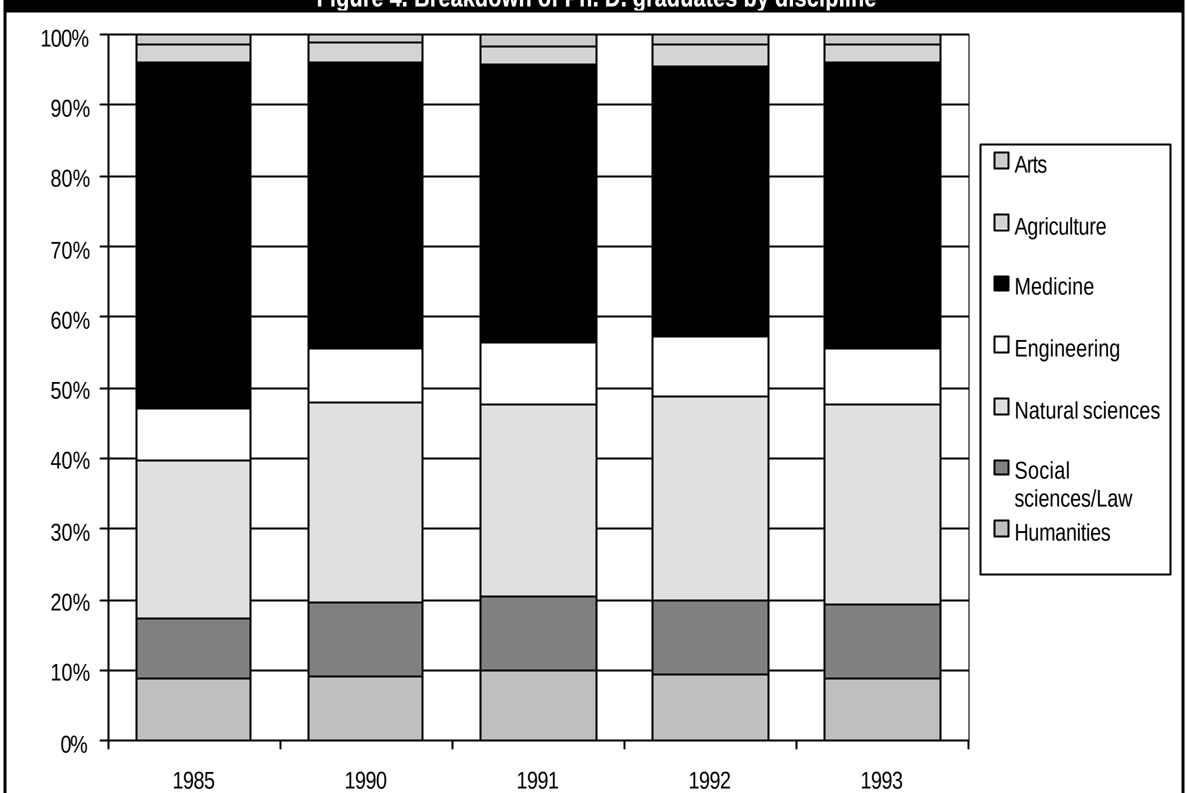
[2]This publication is a draft version of Enders (1996); the draft contains an analysis of the development of *Graduiertenkollegs* which was omitted in Enders (1996).

Figure 3. Ph. D. degrees awarded in Germany by region



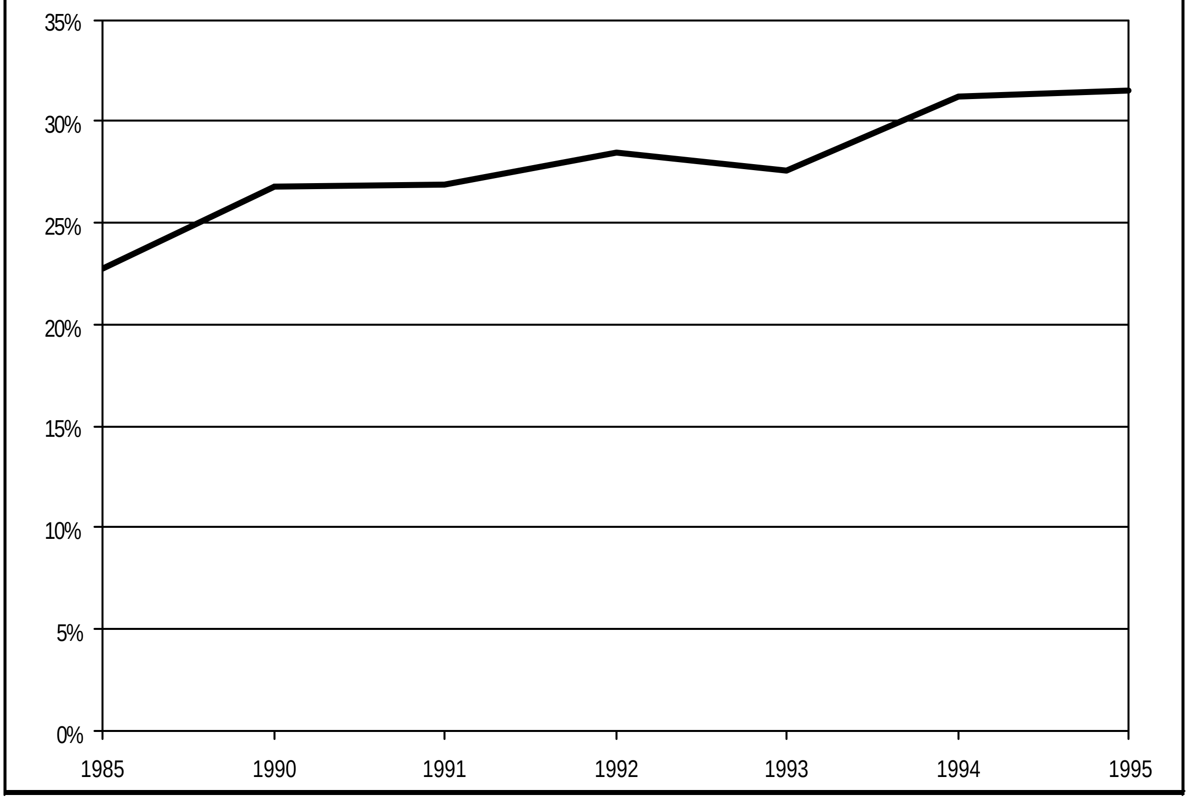
SOURCES: Bundesministerium für Bildung, 1991-92 to 1996-97; and Statistische Bundesamt (1998).

Figure 4. Breakdown of Ph. D. graduates by discipline



SOURCES: Bundesministerium für Bildung, 1991-92 to 1996-97; and Statistische Bundesamt (1998).

Figure 5. Proportion of female Ph. D. graduates



SOURCES: Bundesministerium für Bildung, 1991-92 to 1996-97; and Statistische Bundesamt (1998).

sidered to be in need of reform. Long times to degree and low completion rates, as well as the fear of not keeping pace with European developments in higher learning, stimulated the German government to initiate experiments with new structures of doctoral education in 1986 (see Nerad 1994a and De Wied 1991). Illustrative is the following statement by the Wissenschaftsrat (1988): "the present state of Ph.D. training is too long, too specialized and too isolated…" Third, research policy objectives—such as the creation of more interdisciplinary work, the stimulation of joint and transparent research planning, and the advancement of applied research—were also cited as reasons to reform graduate schools.

The most striking reform in German doctoral education regards the introduction of the system of graduate schools in 1989, the so-called *Graduiertenkollegs*. The introduction of the *Graduiertenkollegs* has not replaced the previous situation, but it certainly marks the beginning of a shift in German doctoral education.

The establishment of a system of *Graduiertenkollegs* can be considered one of the few top-down operations in the area of doctoral education. The German federal government does not have extensive power over higher education: it influences higher education primarily through budgetary policies (Frackmann and De Weert 1994, p. 141). More responsibilities over education exist at the level of the 11 *Länder* that must comply with the Framework Act on Higher Education (HRG). But doctoral education in the German higher education system has remained a rather autonomous area, only lightly touched on in the margin of research policies and reforms of first degree education. The HRG authorizes universities and faculties to establish their own regulations in accordance with the law of the *Land*. The government of the *Land* should formally approve such regulations (Baldauf 1998, p. 171). Although the idea of the graduate school developed in close cooperation with representatives of the academic world, the program for the stimulation of graduate schools is strongly backed and shaped by (semi-) governmental organizations.

In 1986, the Wissenschaftsrat, which is the leading advisory board in scientific affairs, recommended the creation of graduate schools. The German federal government and the *Länder* governments accepted the recommendations of the Wissenschaftsrat. In December 1989, the federal government and the governments of the *Länder* signed an agreement on joint support for *Graduiertenkollegs*.

The implementation of the entire program was assigned to the Deutsche Forschungs Gemeinschaft (DFG). The DFG describes the *Graduiertenkollegs* as: "university institutions devoted to the promotion of young graduates. They are designed to enable Ph.D. students to work on their theses within the framework of a systematic and mostly interdisciplinary program of study and in cooperation with various research groups working on allied topics" (DFG 1993, pp. 1-2). The DFG has formulated the following objectives for the system of *Graduiertenkollegs*, which are supported by the Wissenschaftsrat (DFG 1996b, p. 1; and Wissenschaftsrat 1994, p. 15):[3]

1. To engage doctoral candidates in joint research activities of the participating institutions and thus move beyond the supervision of a single professor.

2. To strengthen supervision both qualitatively and organizationally through guest professors, research seminars, and the like.

3. To prevent overspecialization through a research-oriented study program.

4. To stimulate mobility and other forms of support for Ph.D. candidates that might foster educative opportunities.

5. To provide participating professors with the opportunity to cooperate with qualified young academics.

6. To open up possibilities for institutions to choose priority areas for research and research training.

7. To contribute to the restructuring of higher education in general.

The first reactions to the idea of the *Graduiertenkolleg* were ambiguous. Some institutions feared they would lose their traditional monopolies. The faculties of philosophy, for example, were reluctant to alter the *Doktorvater* system; and the West German Rektorenkonferenz expressed its concerns regarding the financial consequences of the *Graduiertenkollegs* for universities. Other organizations feared that the schools would create a new elite education at the expense of high-quality first degree studies (Müller 1993, p. 31). Nevertheless, in several fields, a strong interest was expressed in establishing *Graduiertenkollegs*; by 1988, 15 experimental *Graduiertenkollegs* were established, funded by the Thyssen and Volkswagen Foundations. In 1990, the Programm zur förderung von Graduiertenkollegs officially started.

A proposal to establish a *Graduiertenkolleg* is drawn up by the engaged scientists and submitted to the respective departments of education in the *Land* where the university is established. After approval, the application is forwarded to the DFG. At the DFG, several academic committees assess the proposals on a number of criteria. If the proposal is approved and selected, then the *Graduiertenkolleg* receives funds for a 3-year period. After 3 years, the school is evaluated and may receive funds for another 3 years. The idea is that no further grants are provided after 9 years—the perceived full life-cycle of a *Graduiertenkolleg*.

Between 1990 and 1993, 512 applications for the establishment of a *Graduiertenkolleg* were submitted to the DFG; of these, 199 were granted. Three years later, in May 1996, the number of approved and established *Graduiertenkollegs* increased to 214, and in 1997 reached 280 (see table 1). Eventually, the number of *Graduiertenkollegs* is expected to stabilize at around 300, a number that is not only determined by financial reasons but also based in the idea that excellence in research and research training can only be achieved through selectivity. The DFG has therefore declined proposals to expand the number of *Graduiertenkollegs* to 600 or 1,000. In these *Graduiertenkollegs*, 4,936 *Nachwuchswissenschaftler*[4] and 2,401 professors were engaged. The number of doctoral candidates residing in *Graduiertenkollegs* is 4,385; of these, 2,500 candidates were funded by the DFG. In 1996, the average number of doctoral candidates participating in a *Graduiertenkolleg* was 21.

Table 1. Number of *Graduiertenkollegs* by discipline

Discipline	1993	1994	1995	1996	1997
Total	175	199	203	214	280
Social sciences and humanities	57	64	63	64	81
Biology and medicine	37	44	45	51	72
Natural sciences	61	69	72	71	90
Technical sciences	20	22	23	28	37

SOURCE: Deutsche Forschungsgemeinschaft. *Entwicklung und Stand des Programms "Graduiertenkollegs" (Graduate schools).* Bonn: DFG (1997), p. 3.

[3]Translation by authors.

[4]*Nachwuchswissenschaftlern* are doctoral candidates as well as postdoctorates.

PATTERNS OF SUPPORT

Funding for doctoral work is generally acquired in four ways: (1) in junior positions at universities, (2) in junior positions at research organizations outside universities, (3) through grants from various institutions, and (4) through self-support (Wissenschaftsrat 1995, pp. 23-36). These categories are detailed below.

- **Junior positions at universities.** Universities employ roughly 7 out of 10 doctoral candidates in junior positions (usually called *wissenschaftliche Mitarbeiter*). Often, the contracts are on a temporary basis, and doctoral candidates may complete several of these contracts during their doctoral work. Mainly because of the growth in contract research, the number of *wissenschaftliche Mitarbeiter* grew between 10 and 15 percent in the 1990s (Baldauf 1998, p. 169). Salaries vary from DM1800 to DM2000 for part-time contracts and from DM3000 to DM3200 for full-time contracts (after taxes and health insurance payments).

- **Junior positions at research organizations outside universities.** Research institutions outside the universities employ another 4,500 doctoral candidates, usually on 3-year contracts.

- **Various grants.** Doctoral work is also funded by grants. Around 8,500 stipends are provided by a number of organizations. The most important of these are mentioned here. The *Länder* grant around 2,500 stipends yearly (*Graduiertenförderung der Länder*). The DFG funds around 2,300 through its graduate school program (discussed earlier). A number of other institutions, such as political parties, churches, and trade unions (*Begabtenförderungswerke*), provide around 2,700 doctoral grants under strict conditions. The level of the scholarships varies, but the stipends provided by the DFG are DM1400 (DM1700 for technical subjects).

- **Self-support.** About 1 out of 10 doctoral candidates is believed to prepare a dissertation without any of the above-mentioned types of funding (Wissenschaftsrat 1995, p. 36).

Table 2 and figure 6 present the proportions and absolute numbers of doctoral candidates using the various sources of support.

Table 2. Sources of support in 1995 (estimated)

Source of support	Percent	Number
Total	100	63,000
Junior staff at universities	70	44,000
Junior staff at research institutes	7	4,500
Grants *lander*	4	2,500
Grants DFG	4	2,300
Grants *begabten*	4	2,700
Grants other	2	1,000
Self-financed	10	6,000

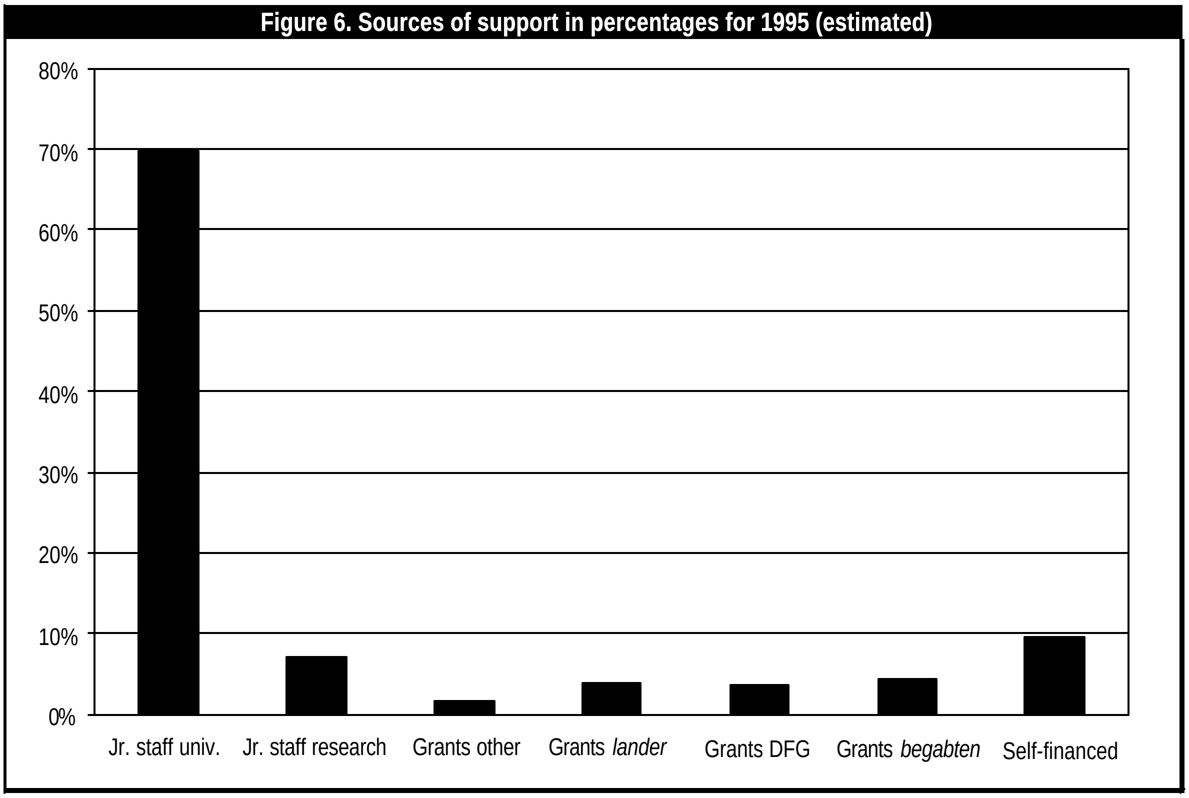
SOURCES: Wissenschaftsrat (1995), pp. 23-36 and Baldauf (1998), p.169.

There are considerable differences in both the sources and levels of support for doctoral candidates. The majority of Ph.D. candidates in junior positions are involved in research, teaching, and contract work. They gain valuable professional experience throughout their doctoral work. A disadvantage of this situation, however, is the lengthening completion times that occur due to the dovetailing of doctoral studies and professional work (Baldauf 1998, p. 170). In this regard, work at research institutions outside universities provides a more favorable environment: around 70 percent of the candidates here complete a dissertation in 3 years. At these institutions, doctoral work is more closely supervised and thesis-related, and candidates are well funded for their work (Nerad 1994a).

Another area of concern is the difference between DFG stipends and alternative sources of support, which seems to discourage student participation in *Graduiertenkollegs*. This contrasts strongly with the goal that *Graduiertenkollegs* should attract the most talented candidates. In a study on the institutionalization of graduate schools in Germany, a respondent commented on this issue (Bartelse 1999, p. 147): "Of course, we would all like the best students to enroll in our programs. But in a number of disciplines, it is not a matter of strict selection. The grants of the DFG are relatively low, which makes it difficult to attract doctoral candidates."

EMPLOYMENT PATTERNS

Investigations into the labor market situation of doctoral degree-holders are few. Baldauf (1998) mentions that most studies are small scale or date back to the mid-1980s. There is a strong need for research into this area, and, as a matter of fact, the Wissenschaftlichees Zentrum für Berufs- und Hochschulforschung at the University of



SOURCES: Wissenschaftsrat (1995), pp. 23-36 and Baldauf (1998), p.169.

Kassel is conducting a research project on this issue. For quantitative information on employment patterns, we must await the outcomes of this study.

The material available on the labor market situation of Ph.D.s in Germany suggests a mixed picture. Depending on the discipline, the orientation of the individual doctorate-holder will be toward an academic research position, industrial research position, or job in policy and management. Outside academia, the doctorate seems to be esteemed. The number of doctoral degree-holders in top positions in German businesses is disproportionate, reflecting the high status of the doctorate in the German private sector. Several authors indicate that doctoral degree-holders will increasingly move out of the university sector. A study on junior staff working on their doctoral theses concludes that:

> Data show that the academic work and further qualifications of doctoral staff cannot be interpreted as the preparation for an academic career, but must also be interpreted as preparation for future employment outside higher education. The majority of doctoral staff do not intend to continue an academic career and…nearly all of these junior staff members in all fields expect that they will have to leave their university and the area of higher education (Enders and Teichler 1994, p. 31).

The issue of the labor market position of Ph.D.s is rather controversial (Baldauf 1998, p. 176). Even within the broad discussions of the *Graduiertenkollegs*, the subject is barely touched upon. The *Graduiertenkolleg* is meant to prevent doctoral candidates from conducting their work in isolation and specialization. But despite the introduction of more breadth, the labor market orientation of doctoral research in a *Graduiertenkolleg* remains focused on the university and research. As such, no challenge to the existing situation is imposed. There is no explicit broader labor market perspective required for the establishment of a school. A representative from the Wissenschaftsrat commented on this (Bartelse 1999, p. 148): "Currently, the issue of a broader employability perspective is slowly gaining ground in the discussions on doctoral education. However, I do not believe that it was on our minds at the outset of the system of *Graduiertenkollegs*."

PATTERNS OF INTERNATIONAL MOBILITY

Doctoral education has always been international, and the area now known as Germany has been an important place for research training. In medieval times, students traveled all over Europe in search of knowledge and a good education. Throughout the course of history, these journeys sometimes abated due to political tensions or for protectionist reasons. But during the heyday of the German research universities, voyages for knowledge were commonplace. In reaction to these travels, doctoral programs were established on the other side of the Atlantic to keep young American scholars home.

In the post-war decades, international exchange often took place on the basis of personal contacts between individual professors. Recent visions of the European Union and of several European governments see these exchanges as insufficient (Blume 1993). The scope of European Community action in the field of education is defined in article 126(1) of the Maastricht Treaty (EU 1992): "The Community shall contribute to the development of quality education by encouraging cooperation between member states, while fully respecting the responsibility of the member states for the content of teaching and the organization of education systems and their cultural and linguistic diversity." Efforts to cooperate in the area of research training so far focus on mobility of researchers, particularly through the Training and Mobility of Researchers program, which is part of the European Commission's Framework Programmes. There have been suggestions to create a European doctorate[5] and to establish international, or rather, European centers for research training. As yet, however, these suggestions have not led to more extensive forms of cooperation in the area of doctoral training.

Another initiative to foster international exchange in the area of doctoral training involves a letter of interest signed between Belgium, Denmark, France, Germany, and the Netherlands in January 1996. These countries have committed themselves to support the exchange of doctoral candidates and inform each other on developments regarding doctoral programs and graduate schools.

The data available for Germany on international mobility in doctoral education and citizenship of doctoral candidates are scant. Figure 7 presents the absolute numbers of doctoral graduates with German citizenship, as compared to the number of doctoral graduates with foreign citizenship. Figure 8 reflects these data in percentages. A gradual increase of foreign doctoral degree recipients can be observed (from 5.5 percent in 1990 to 6.5 percent in 1993).

Through the *Graduiertenkollegs*, the internationalization of research and research training is supported by funding. The *Graduiertenkollegs* regard joint international projects and the exchange of doctoral candidates and research staff as important aspects of their function (DFG 1997). In 1995, 67 *Graduiertenkollegs* (33 percent) were involved in these international activities; by 1996, the number had risen to 81 *Graduiertenkollegs* (37 percent); and in 1997, to 133 *Graduiertenkollegs* (47.5 percent). The majority (53 percent) of these projects are with West European partners (53 percent); in 23 percent of the cases, cooperation is with U.S. or Canadian partners; 15 percent involve cooperation with Eastern Europe; and 9 percent with other countries.

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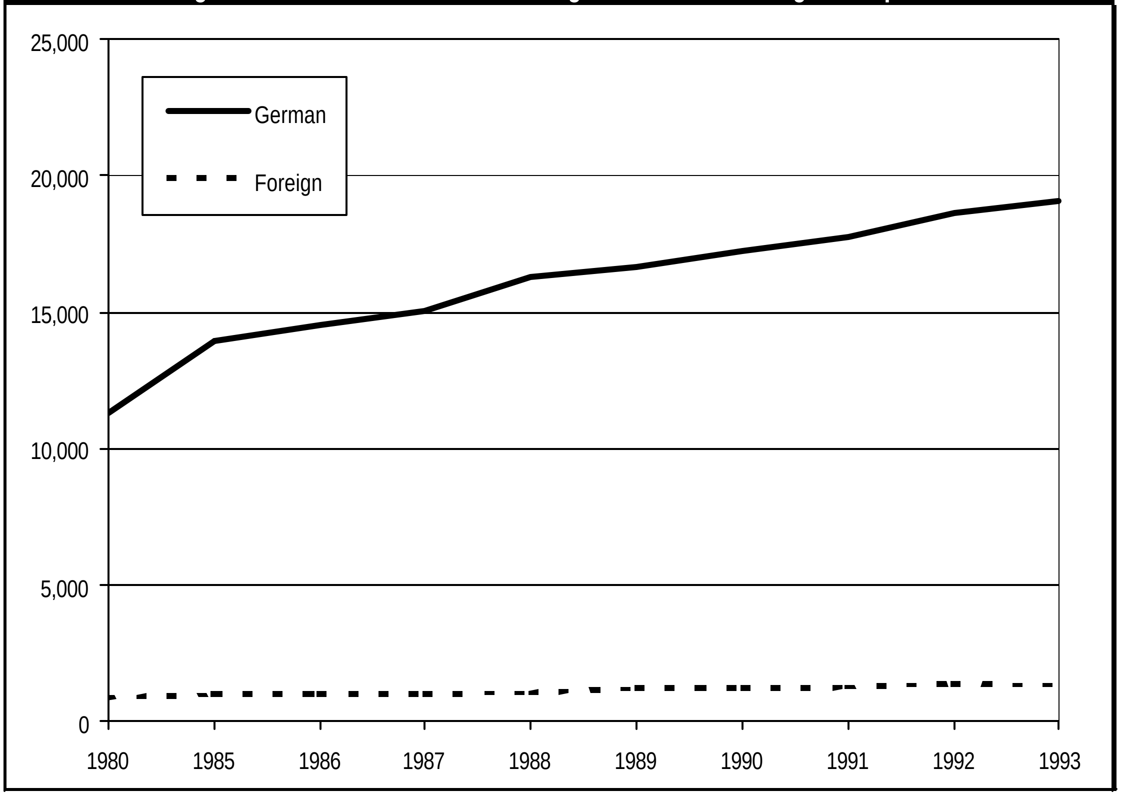
[5] See EC (1995). The European doctorate will be accorded under the following conditions:

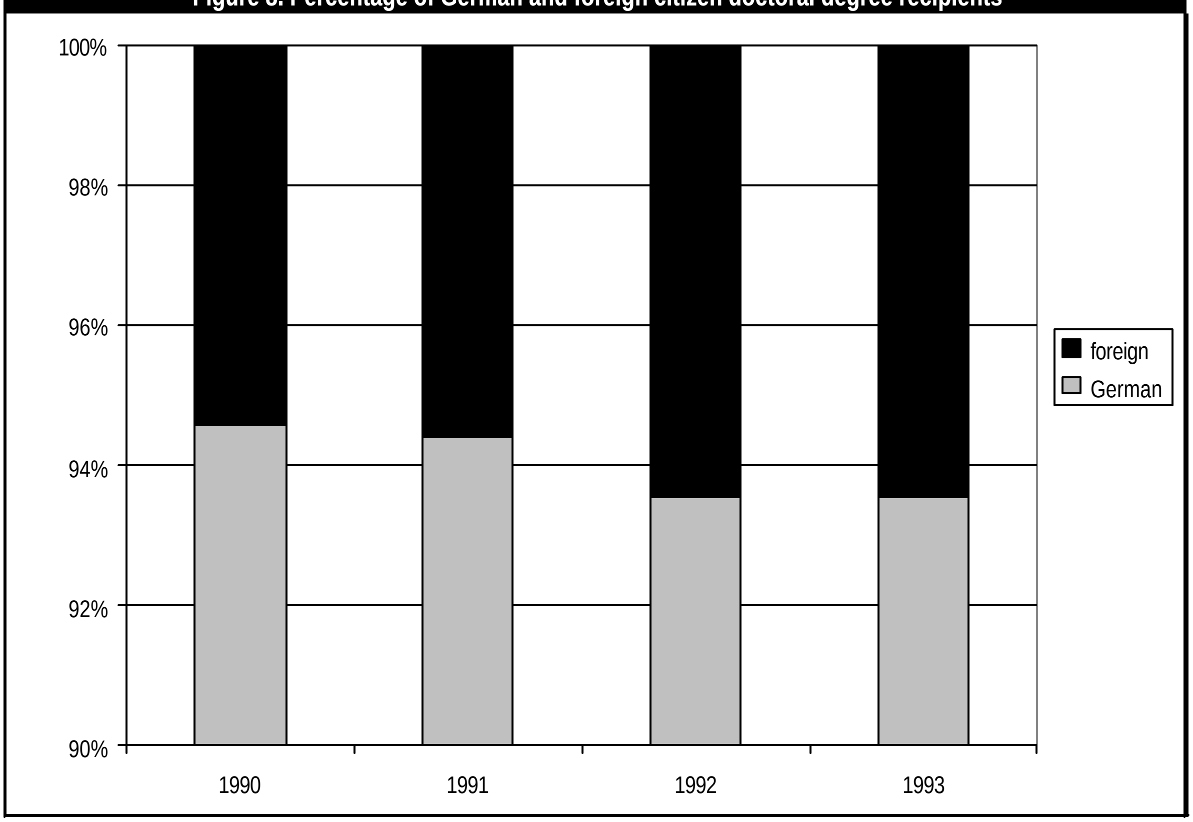
- If at least two professors from two higher education institutions of two European countries, other than the one where the Ph.D. thesis will be defended, have given their judgment.
- If at least one member of the jury comes from a higher education institution in European countries, other than the one where the Ph.D. thesis will be defended.
- If part of the defense takes place in one of the official languages, other than the one(s) of the country where the Ph.D. thesis will be defended.
- If the Ph.D. thesis has been prepared partly as a result of a period of research of at least one trimester spent in another European country.

Figure 7. Number of German and foreign citizen doctoral degree recipients



SOURCE: Bundesministerium für Bildung, 1991-92 to 1996-97.

Figure 8. Percentage of German and foreign citizen doctoral degree recipients



SOURCE: Bundesministerium für Bildung, 1991-92 to 1996-97.

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NETHERLANDS

Jeroen Bartelse, Eric Beerkens, and Peter Maassen

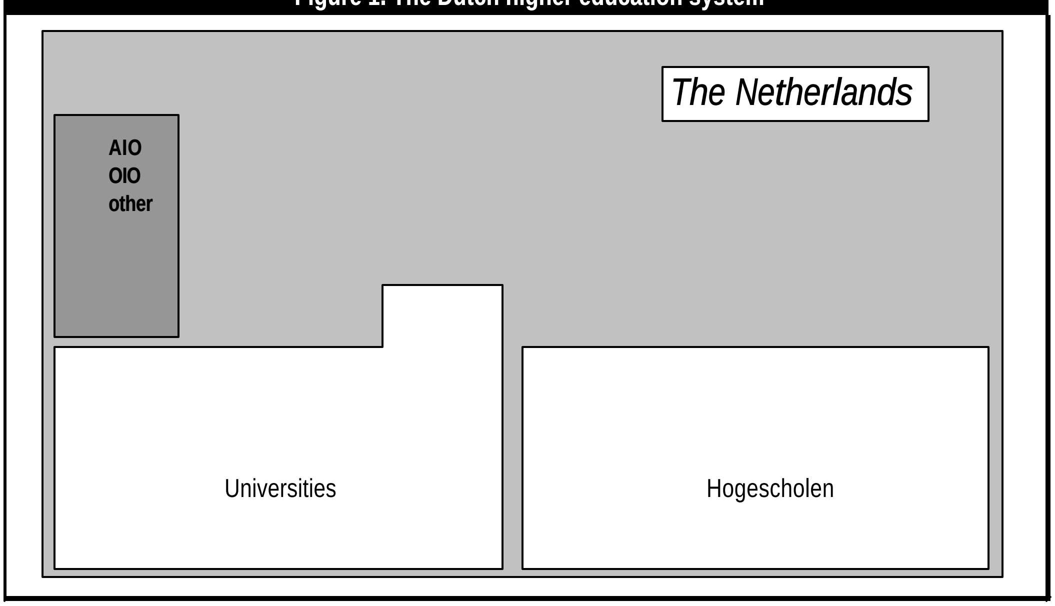
INTRODUCTION

The Netherlands has a binary system of higher education: a university sector and a nonuniversity sector primarily consisting of the *hogescholen*. In the *hogescholen*, advanced professional education is offered, comparable to that provided by the former British polytechnics. Around 80 *hogescholen* provide 4-year programs. Thirteen universities have been established that offer 4- to 5-year programs leading to the *doctorandus* degree. This degree roughly equates to the master's degree (Goedegebuure et al. 1994, p. 192). The *doctorandus* (which literally means "one who is entitled to become a doctor") degree is usually the minimal requirement for doctoral degree matriculation, although it is at the discretion of the universities to admit *hogeschool* graduates. Doctoral candidates may have a normal research or teaching position at universities or other research institutes, or they may hold a distinct doctoral position called the AiO or OiO.[1] At the initial postgraduate education level, both universities and *hogescholen* offer a variety of programs that lead to recognized degrees and generally have a market orientation. Figure 1 graphically presents the Dutch higher education system. In this report, we focus on the Dutch system of doctoral education.

TRENDS IN GRADUATE EDUCATION

In 1644, the University of Utrecht was the first to employ the title *Philosophiae Doctor et Liberalium Artium Magister* (literally, doctor of philosophy and master of a liberal art) (Hesseling 1986, p. 25). In those days, a dissertation could be either of two types of products, each with a distinct academic tradition of defense. The first type was the *disputatio sub praeside*, where the candidate defended a set of printed propositions—later a short essay—under the direction of the professor. The second type was the *dissertatio pro gradu doctoratus*, where the candidate had to defend a thesis against the opposition of a larger academic audience of students, doctors, and magisters. The public defense often featured an extensive ritual, such as the one at the University of Leiden, which involved an elaborate processional, speeches lauding the successful candidate, a recessional, and a graduation dinner. At present, many of these rituals are still featured at Dutch universities. In the 17th and 18th centuries, the doctorate represented a "vocational" degree rather than a research degree; the holder was entitled to teach.

Figure 1. The Dutch higher education system



SOURCE: D. De Wied, Postgraduate Research Training Today: Emerging Structures for a Changing Europe, The Hague: Netherlands Ministry of Education and Science, 1991.

[1]These positions are described later in this paper.

In the course of the 19th and early 20th centuries, the process of obtaining the doctorate gradually changed. Although Dutch universities remained institutions of education (Wachelder 1992, p. 28), the research ethos gained importance. The functions of the degree changed under the influence of the research imperative of the German universities and laboratories. The doctorate became proof of one's capabilities to conduct independent research. In the sciences in particular, renowned scholars formed research groups where research was conducted in master-apprentice relationships. Although inspired by German universities, the Dutch doctoral system has developed within its own distinct societal and academic context, and is sometimes not comparable to the German example.[2]

After World War II and up until the 1980s, an individual pursuing a Ph.D. was usually employed as faculty staff—sometimes in the position of a research assistant, but also as regular (senior) staff. Apart from being a profound rite of passage, the writing of a doctoral dissertation was an informal endeavor. The process was not a fixed series of tasks dictated by university or government standards. Usually, it had the characteristics of the apprentice model: a doctoral candidate working under the guidance of a professor. Yet, unlike the German situation, the role of the supervisor or chair-holder was less authoritative. The writing of the dissertation was primarily the responsibility of the person desiring the degree. There were, of course, strong differences by discipline.

In the natural sciences, research was conducted in laboratories through collaborative effort. As early as the 1950s, preparation of a dissertation in the sciences had shifted from individual work to an educational process supervised by senior staff and a supervisor. This, together with a clear demand for qualified researchers from outside the university, led to the concentration of larger groups of doctoral candidates in university laboratories (Beenakker 1990, pp. 321-22). A representative from this field once described this situation as follows (Bartelse 1999, p. 91):

> In the natural sciences there has always been a high degree of organization. The research team conducted a control function for the quality and proceedings of those working on a dissertation. The role of the professor can be compared as a coach: he gives intense guidance to the doctoral candidates without actually conducting the specialized research himself.

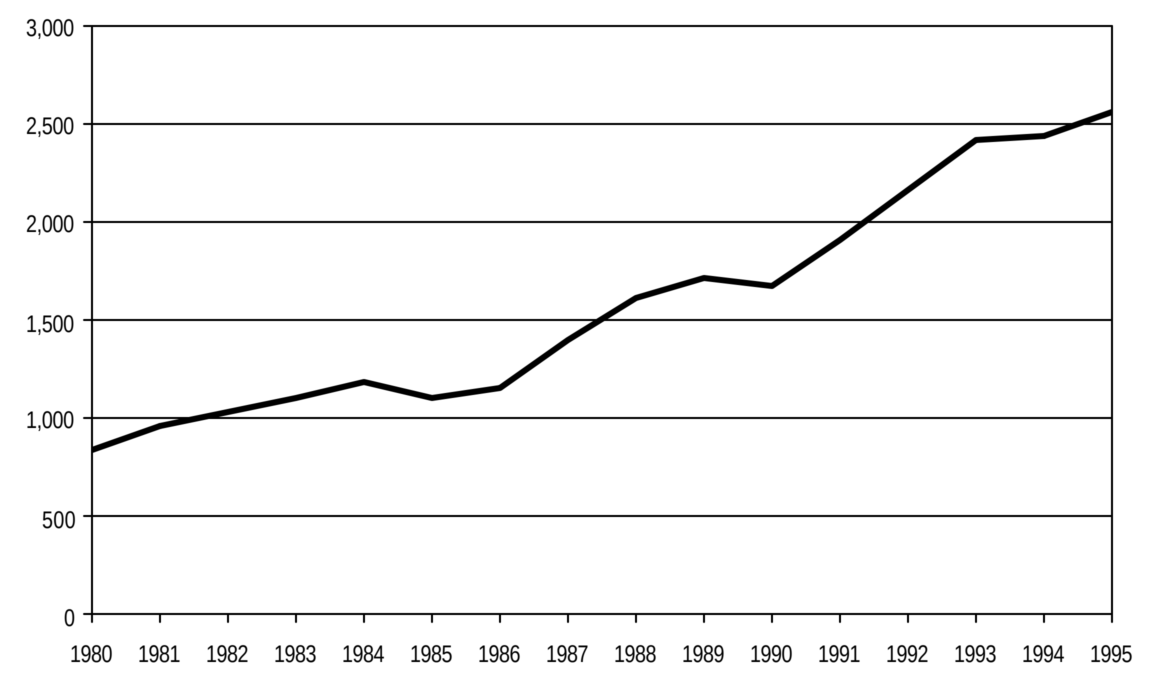
In contrast to the natural sciences, the role of the dissertation featured less prominently in the social sciences and humanities. The disjointed organization of research in the humanities and social sciences stimulated individual undertakings. The dissertation was written in relative isolation, in addition to fulfilling teaching and research responsibilities. Caught between the demands of regular teaching and research loads and high ambitions, the thesis frequently became for these researchers a lifelong *magnum opus*. In addition, and unlike the natural sciences, a clear labor market demand for doctors in the social sciences never developed. Hence, these fields did not experience a structuring influence on the doctoral process from the outside. The role of the supervisor was also different than in the sciences. The candidate's supervisor was actually more of a colleague who, once in a while, commented on the work in progress.

Since the 1960s, the Dutch government has moved into the area of research training. In a series of policy statements and laws, attempts have been made to adjust or reform doctoral training according to varying objectives. These are addressed in the next section. In the remainder of this section, we provide some quantitative trends on doctoral education.

As said, doctoral work can be conducted while serving in one of two junior positions that were created for doctoral candidates in 1986. Thus, a candidate can be an assistant in education (*assistent in opleiding*—AiO) if employed by a university, or a researcher in education (OiO) if employed by the Netherlands Organization for Scientific Research (NWO). Dissertations are also prepared while employed in normal research positions at universities or in a candidate's spare time. About this latter group of doctoral candidates, the available information is less detailed and less accurate. Figure 2 presents the number of Ph.D. degrees awarded between 1980 and 1995. The number of Ph.D. graduates has risen from 700 in 1980 to 2,600 in 1996. Since 1990—4 years after the introduction of the AiO system—the increase in awarded Ph.D.s is striking. Figure 3 shows a proportional breakdown of Ph.D. degrees by discipline.

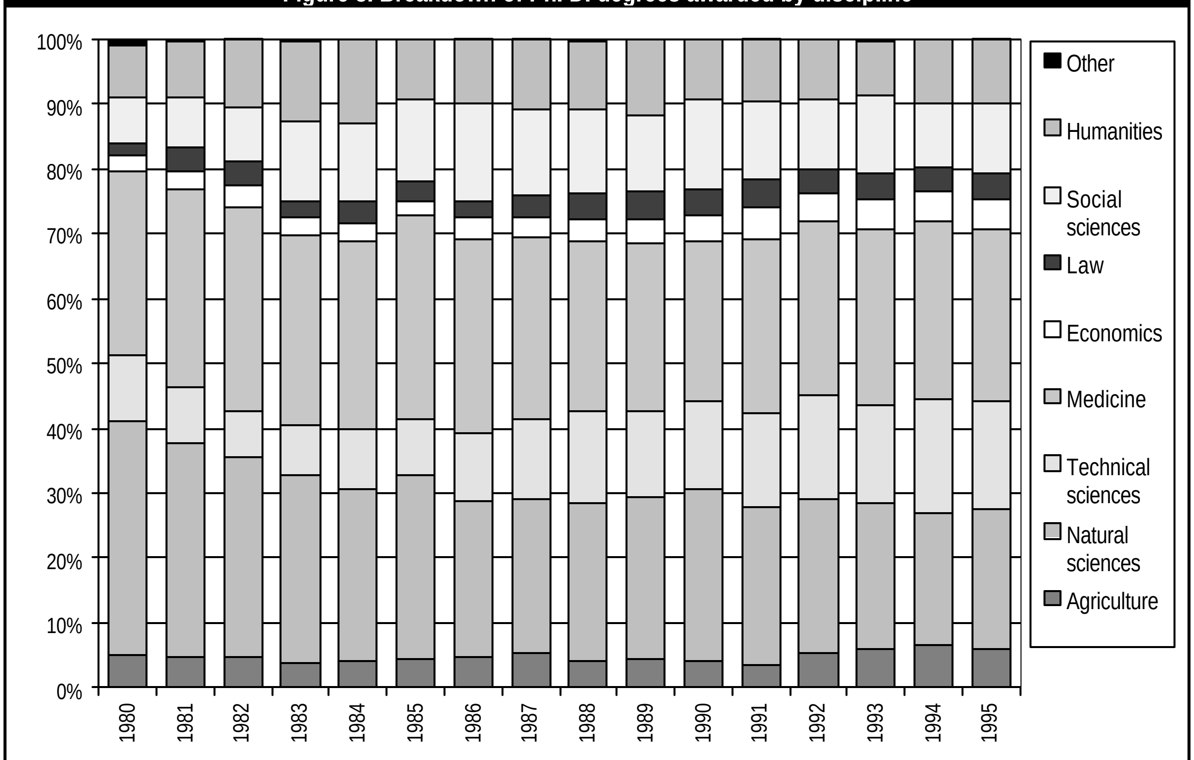
[2] Moreover, the German example did not provide an ambiguous model upon which to base a uniform research practice. For an elaboration of this point, see Wachelder (1992), pp. 27-22, and Clark (1995).

Figure 2. Number of Ph. D. degrees awarded, 1980-95



SOURCE: Vereniging van Samenwerkende Nederlandse Universiteiten (VSNU), *Kengetallen Universitair Onderzoek 1996/1997.* Utrecht.

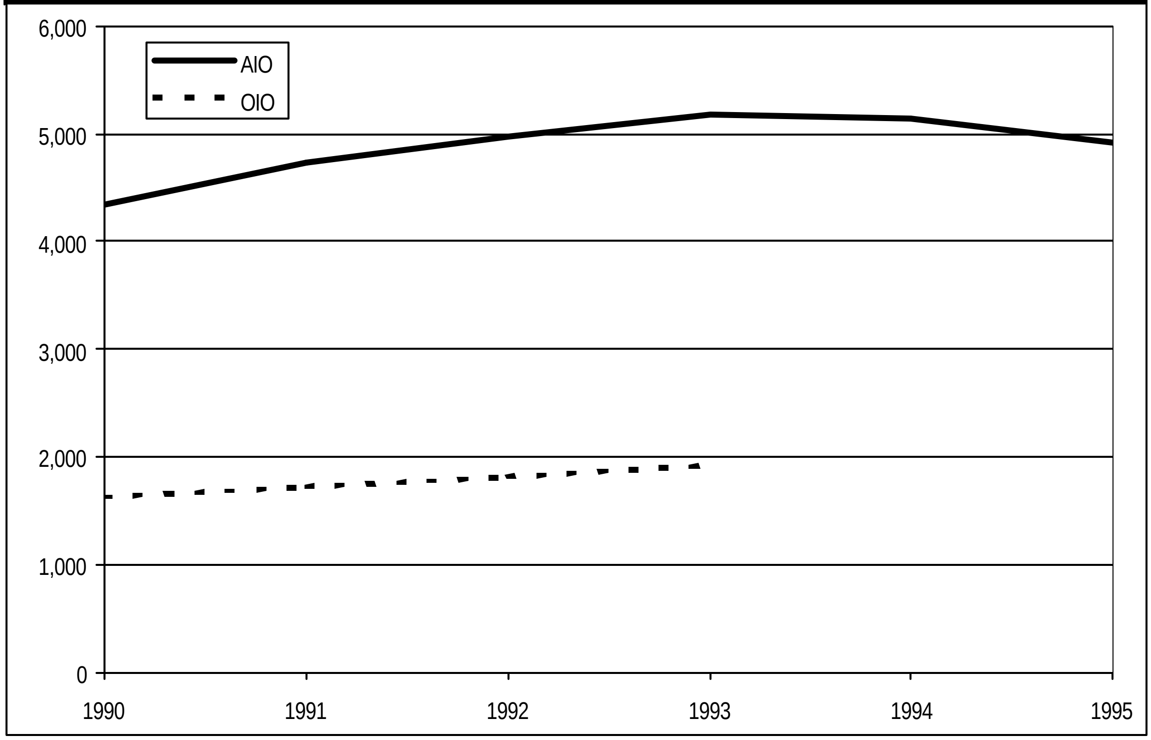
Figure 3. Breakdown of Ph. D. degrees awarded by discipline



SOURCE: Vereniging van Samenwerkende Nederlandse Universiteiten (VSNU), *Kengetallen Universitair Onderzoek 1996/1997.* Utrecht.

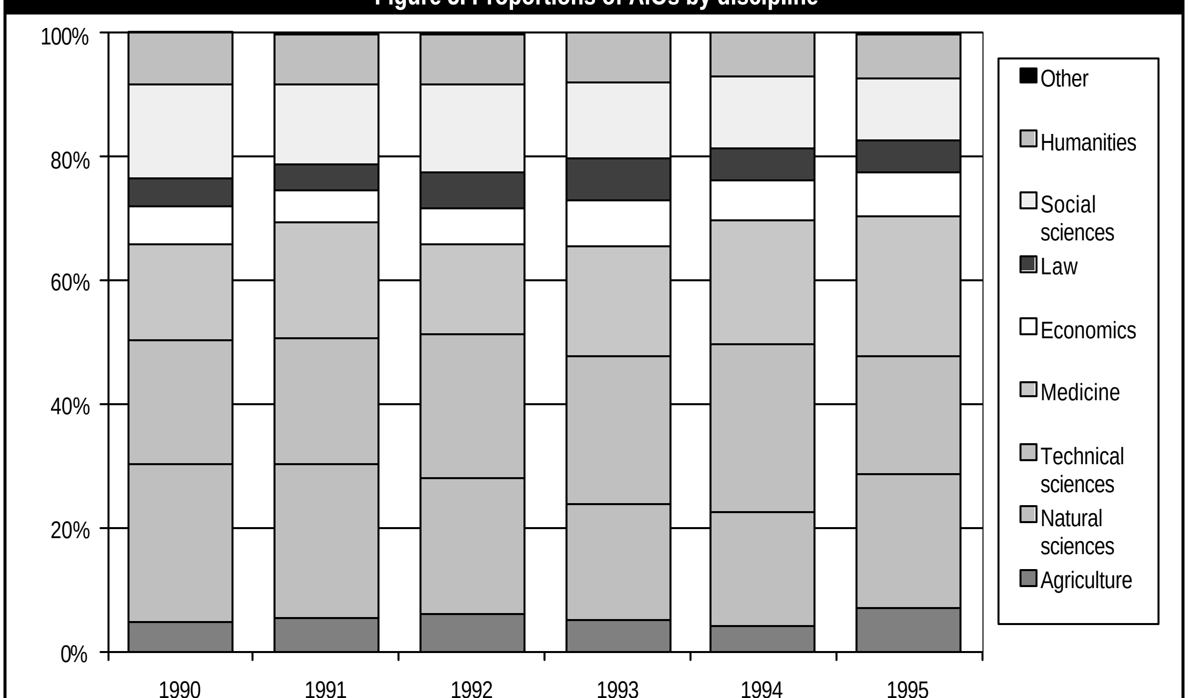
Figure 4 presents the number of doctoral students by type (AiO and OiO). Figure 5 shows the proportion of AiOs in various disciplinary fields. Female participation in doctoral education is reflected in figure 6: the participation of women in AiO positions has gradually increased from 29 percent in 1990 to 35 percent in 1995.

Figure 4. Number of doctoral students by type



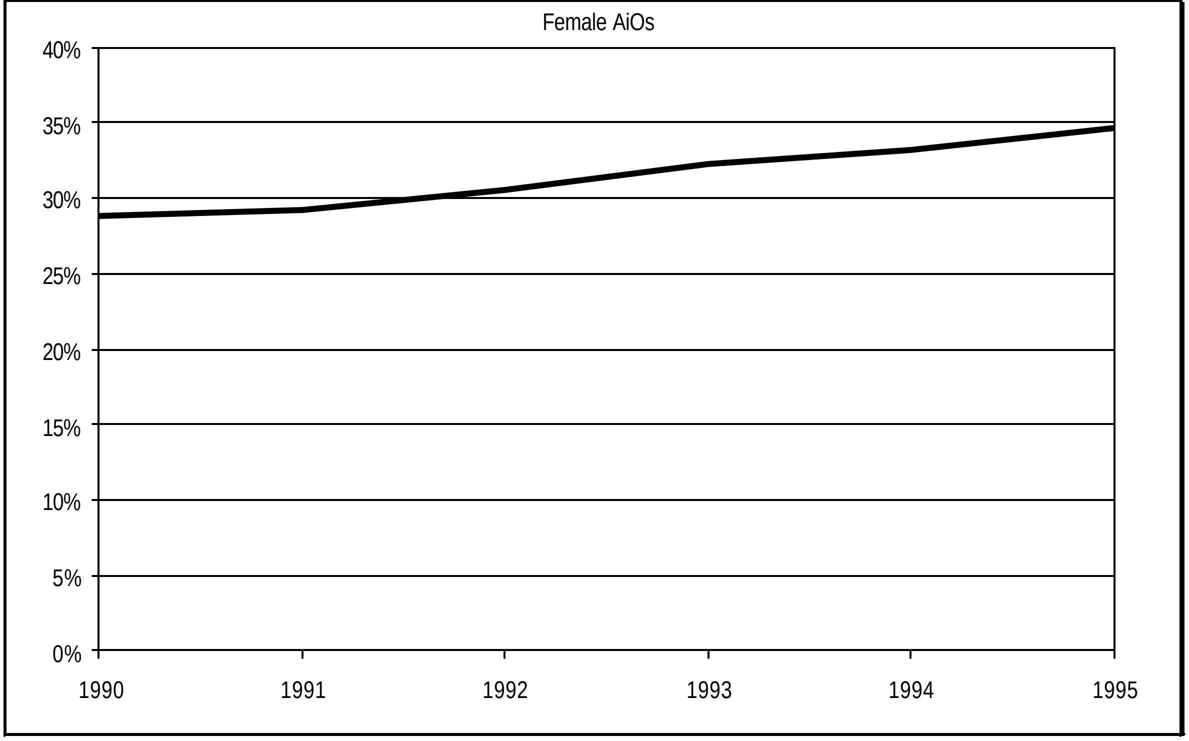
SOURCE: Vereniging van Samenwerkende Nederlandse Universiteiten (VSNU), *Kengetallen Universitair Onderzoek 1996/1997.* Utrecht.

Figure 5. Proportions of AiOs by discipline



SOURCE: Vereniging van Samenwerkende Nederlandse Universiteiten (VSNU), *Kengetallen Universitair Onderzoek 1996/1997.* Utrecht.

Figure 6. Female participation in doctoral education



SOURCE: Vereniging van Samenwerkende Nederlandse Universiteiten (VSNU), *Kengetallen Universitair Onderzoek 1996/1997.* Utrecht.

In the Netherlands, 7 percent of all Ph.D. candidates finish their degree within the nominal time of 4 years; after 5 years, this proportion is 35 percent; after 6 years, 55 percent. Eventually, 80 to 85 percent of Dutch candidates obtain a doctoral degree (VSNU 1996).

Doctoral Reforms

As mentioned in the previous section, government has moved into the business of doctoral education since the 1960s. It goes beyond the scope of this paper to describe the various policy developments that have occurred since then. We present here the main points of discussion that can be considered important impetuses to change in the doctoral system in the Netherlands.

The Function of Doctoral Training and the Doctorate

As university education massified and began to cater to a wide range of labor market positions, a discussion emerged to accommodate research training in a separate program. This implies a break with the traditional view, particularly in the social sciences and humanities, of the doctorate as a life-long masterwork. Instead, the doctorate becomes a proof of one's abilities to conduct independent research. Still, the criteria used to judge a doctorate (an original piece of research usually written as a monograph) stem from the early tradition and not from this new conception of doctoral training.

Structure and Duration of Training

Van Hout (1988) notes that two different models of doctoral training underlie the Dutch policy discussions. The first involves a 3- to 4-year period of work on a dissertation as a temporary staff member at a university. The second model consists of two stages, a 1-year student assistantship and a 2- to 3-year temporary assignment to write a dissertation. These models reflect disparate opinions as to what the time to degree should be. Until the introduction of the AiO system (see below), time to degree did not drop considerably, although the sciences were better able to restrict time to degree than the social sciences and humanities.

The Employed Educational Concept

Two educational models can be distinguished in the history of Dutch doctoral education. The idea of learning by doing (the apprenticeship model) prevails in early policy documents and laws. The professional model features more explicitly in the policy documents of the 1980s. The incorporation of coursework elements is motivated by the desire to shorten time to degree, to bring down attrition, and to be attuned to international developments.

Accessibility of Graduate Education and Selection of Candidates

As research training became a separate tier in university education, the issue of selection came to the fore. Usually, selection was considered to be based on individual competencies—although more random approaches have been proposed in the interest of greater egalitarianism (Sonneveld 1996, p. 34). The appropriate amount of first tier students to enter second tier education (more or less), and the selection procedures employed (open competition with equal chances or institutionally based competition less subject to objective criteria), were subject to discussion during almost all policy phases.

We here discuss two important, relatively recent, reforms in the Dutch doctoral system. The first regards the introduction of the AiO system in 1986; the second, the introduction of a system of graduate schools in 1991.

AiO System. Up until 1984, policy discussions on research training were almost a side effect of discussions on the organization of university education in general, rather than arising from perceived problems or systemic analysis of doctoral education. In 1984, a policy paper on doctoral education (Parliamentary Proceedings 1983-84, pp. 9-13) stated that the implementation of the second tier in general faced a number of problems. Concerns were expressed about the implementation of the so-called second tier as if it were a continuation of the first tier (i.e., first degree) education; about the lack of coherence in second tier program offerings; about inappropriate accessibility and selection mechanisms; and about the high expenditures in the second tier. With regard to research training specifically, the document expressed doubts about the value of the 1-year *onderzoekersopleiding* (the researcher-student) to the labor market. The policy paper suggested providing advanced research training by way of active participation of the candidates in university research and, to a limited extent (less than 25 percent), in teaching and administration. The idea was expressed of creating a separate employment position for the doctoral candidate. This position would comprise a 4-year appointment as a research trainee; this was the genesis of the above-mentioned AiO and OiO positions.

In the act that followed the policy, the AiO was introduced as a distinct academic position.[3] Regulations proscribing the position were published a year later. In summary, these comprised the following (Staatsblad 1986; see also Van Hout 1988, p. 15):

- The AiO has a temporary appointment in order to receive advanced scientific education.

- The objectives of the appointment are determined explicitly.

- The AiO usually holds his or her position for 4 years.

- The AiO conducts scientific research and records the results in a dissertation; the extent of this work, including instruction and supervision time, consumes at least 75 percent of his/her appointment.

- An instruction and supervision plan is drawn up for the AiO, and this plan is evaluated and adjusted after a year. In this plan is specified (1) what knowledge and skills are to be acquired and how, (2) who supervises the AiO, and (3) the number of hours the AiO is entitled to receive in personal supervision.

- After a year, an evaluation is conducted on the basis of the instruction and supervision plan. The university boards determine the evaluation procedures and criteria to be employed.

- At the end of the contract time, the AiO receives a certificate that reflects an overview of his/her publications, the education received, and his/her contributions to teaching.

- For the part of the appointment for which the AiO receives instruction and supervision (and thus does not conduct "productive labor"), he/she does not receive salary. This is specified for all AiOs in fixed percentages.

[3] AiOs are employed by the universities. The Dutch Research Council [not the same term used earlier in text] also employs doctoral candidates, under slightly different employment conditions; these are called researchers in training [not the same term used earlier in text] (OiO).

Although it is still possible to write a dissertation outside the AiO system, the regulatory framework uniformly structures the position of the doctoral candidate for all disciplinary fields. Of note is the status of the instruction and supervision plan: instruction—in addition to "learning by doing"—now occupies an important, formal place in the process leading to the doctorate.

Graduate Schools. The AiO system as such did not provide adequate mechanisms to shape the second tier of higher education satisfactorily. In March 1990, the Dutch minister of Education and Sciences established the Committee Rinnooy Kan (named after its chairman). This committee was tasked with investigating the creation of research schools. On the committee's establishment, the minister formulated five reasons for the development of research schools (Parliamentary Proceedings, 1990-91, p. 5; AWT 1994).

- There is a need for more structured research training. The introduction of the two-tier structure resulted in an accessible first tier limited in duration to 4 years, and a selective second tier that is expected to provide high-quality research training. As the AiO is expected to complete a dissertation in 4 years' time, a structured and well-supervised training trajectory is necessary.

- The Dutch society and economy are developing into a knowledge-intensive system. As a consequence, there is a need, both in the private and public sectors, for highly educated people—not only for first-tier-trained individuals, but also for those who have received further (research) training.

- Although research has always been an internationally oriented activity, it is expected that the internationalization of research will continued to grow. Researchers will become more mobile, and excellent centers of research will attract these researchers across borders. This calls for a reinforcement of the Dutch infrastructure.

- In order to operate internationally, sparse and scattered research capacity must be concentrated and fragmentation avoided. It is necessary to generate critical mass through cooperation among universities and other research institutions.

- Current governmental arrangements do not guarantee selectivity, which is the prerequisite for ensuring quality of research, researchers, and research training. More emphasis on selectivity in the research system is needed.

As expressed in these five points, the reason to establish research schools not only lay in the desire to give shape to research training—although this can be seen as the original motive (Ritzen 1990, p. 315; and Hazeu 1991, p. 112). The research school was also seen as a vehicle for stimulating the emergence of research centers of excellence to operate on an international scale.

In its report, *Vorming in Vorsen* (1990), the Rinnooy Kan Committee recommends a heterogeneous system of research schools, which would allow the different disciplines to retain their specific characters. The committee sees the university as the primary institution responsible for the research school. The universities serve as gatekeepers for the multitude of initiatives that may emerge at the faculty and departmental levels. Nevertheless, the committee also expects that a large number of research schools will develop ("between 50-150"). These schools should compete for resources from science foundations, industry, and European funds. Although the committee rejects to a large extent the concept of uniformity, it does formulate characteristics "that should be typical of all research schools" (Rinnooy Kan Committee 1990, p. 6). According to these characteristics, a research school should:

1. train individuals to become independent researchers;

2. be a high-quality research center;

3. be an independent organizational unit with budget responsibilities;

4. be affiliated with at least one university, but usually with more (university) institutions;

5. be of adequate size, so as to benefit from economies of scale;

6. carefully select research proposals and research assistants;

7. guarantee supervision and outstanding educational quality;

8. formulate a policy on postdoctorate positions;
9. have a good nexus with the first tier; and
10. be accountable and conduct evaluations.

The report explicitly reflects the initial call to create a satisfying structure of research training, but it also foresees the development of *topinstituten* (centers of excellence) as a means of securing high-quality research in selected areas. This latter aspect is captured in a proposal (the Snellius Program) to select two to three excellent research schools each year. These schools would receive extra financial support for a period of 5 years.

From the governmental standpoint, research schools are defined as centers of high-quality research in which structured training is offered to young researchers (Parliamentary Proceedings 1990-91). The reasoning behind this is that good training of researchers can only be conducted in an environment of high-quality research. The system of research schools should give impetus to high-quality research and education. Therefore, the minister decided to stimulate the development of a broad, yet selective, system of research schools, from which—eventually—should develop a limited number of centers of excellence. The government standpoint agrees in its main points with the advice of the Rinnooy Kan Committee. The government envisages a diverse system of research schools that share a number of common characteristics. The characteristics suggested by the Rinnooy Kan Committee are endorsed, but complemented on a few points. The minister acknowledges the importance of sufficient critical mass; he adds, however, that this consideration should not prevail over functional coherence. Therefore, the scale criterion is complemented with the condition that the school should have a sufficiently homogeneous training and research program. Another aspect in which the government standpoint adds to the committee's criteria regards the need for researchers in the labor market. In this respect, the minister stresses the importance of postdoctoral positions in a research school. Furthermore, the government stipulates that research schools should have budget responsibility; to this end, sufficient funds are to be allocated from the hosting universities to the research schools.

The government subscribes to the idea that research schools should be developed bottom-up. In order to allow this, yet to ensure quality, the government proposes a two-step procedure for the establishment of recognized research schools. At the faculty level, initiatives are undertaken to establish a research school. The executive board of a university—or boards, if more than one university is involved—determines whether such an initiative complies with the aforementioned criteria and may give the research school a legal foundation as a research institute. Also, the university boards sign a contract as to the resources available for the school for a period of at least 5 years. The next step toward recognition lies outside the university context. The minister has delegated the task of formal recognition of research schools to the Royal Dutch Academy of Sciences (KNAW). For this task, an independent committee (organizationally linked to the KNAW) named *Erkenningscomissie Onderzoekscholen* (Commission for the Recognition of Research Schools—ECOS) has been assigned. ECOS has designed, on the basis of the 10 characteristics identified by the Rinnooy Kan Committee, a protocol designating a procedure with which research schools should comply in order to achieve formal recognition.

By March 1998, 119 research schools had been registered in virtually all disciplinary fields (VSNU 1998, p. 6). ECOS has recognized 107 of these schools (table 1). Although the system of research schools is envisaged to include all doctoral candidates, participation rates differ by field. There is also variation in the level of development of the schools across these fields. The total number of AiOs and OiOs participating in research schools is around 7,460 (as of March 1998).[4]

PATTERNS OF SUPPORT

Dutch doctoral candidates are basically funded by three different sources, called first, second, and third money flows (Koelman, Vossensteyn, and Jongbloed 1998). The first flow is supplied by the Ministry of Education, Science, and Culture to the universities. The universities pay their academic staff and AiOs from these funds. The second flow of funds is allocated through the NWO. From these funds, the OiOs are paid. The third flow of funds is acquired through contracts with government, nonprofit organizations, private companies, charitable boards, and the European Community. In addition to these sources of support, doctorates can be financed by other employers or on their own.

[4]Ten research schools did not submit quantitative information on this matter.

Table 1. ECOS-recognized research schools in the Netherlands						
Discipline	1992	1993	1994	1995	1996	1997
Total	19	24	62	86	98	107
Agriculture	0	1	2	5	5	5
Economics	1	1	1	1	2	3
Health sciences	5	6	12	13	15	15
Humanities	1	1	6	11	14	14
Law	0	0	0	1	1	2
Natural sciences	7	8	21	25	27	28
Social sciences	1	2	10	15	17	18
Technical sciences	4	5	10	15	17	22

SOURCE: Vereniging van Samenwerkende Nederlandse Universiteiten (VSNU), *Kengetallen Universitair Onderzoek 1998.* Utrecht.

Table 2 gives an overview of the sources of funding for doctoral candidates by money flow type (that is, the proportions of doctoral students using different sources of support). Table 3 shows the sources of support by field of study. These data should be taken as indicative rather than precise. The figures are taken from a study by Hulshof, Verrijt, and Kruijthoff (1996, p. 66) and reflect the characteristics of a survey population of 2,652 respondents.

Table 2. Funding sources for doctoral candidates (percentages)					
Funding source	Total	AiO	OiO	Doctoral univ	Doctoral ext
1st flow	46	81	6	47	9
2nd flow	29	12	88	29	25
3rd flow	27	21	8	31	17
Research inst.	11	4	7	14	8
Other empl	7	2	4	3	39
Private	10	2	1	8	41
Total respondents	2,652	862	455	1,086	248

SOURCE: Hulshof, Verrijt, and Kruijthoff (1996), p. 66.

AiOs and OiOs receive salaries according to a special salary scale. In the first years of their appointments, salaries are cut back to compensate for the training they receive. Table 4 shows the monthly incomes for each year of their appointments (as of January 1, 1998).

Table 4. Monthly incomes of AiOs and OiOs	
Year of appointment	Salary
1st year	DFL 2.184,--
2nd year	DFL 2.495,--
3rd year	DFL 3.053,--
4th year	DFL 3.899,--

SOURCE: Hulshof, Verrijt, and Kruijthoff (1996), p. 66.

Recently, the labor market situation forced universities to change their financial support of AiOs. In 1995, a number of Ph.D.s coming out of the AiO system could no longer be absorbed by the (academic) labor market. The universities were, however, obliged to make unemployment payments, which signified an important financial loss. Some universities decided to introduce Ph.D. grants instead of employment. This would discharge them of the responsibility of making unemployment payments. The results for doctoral candidates can be imagined: lower incomes, poorer benefits, and a feeling of being unappreciated for their work.

In the following years, however, the labor market situation for academics improved considerably. Almost all universities abandoned the grant system, which is now only in place for Ph.D. programs that aim to attract international candidates. Instead, as AiO positions became difficult to fill, universities have started to complement AiO salaries to a level comparable to that for other academic staff members. This phenomenon is particularly commonplace at the universities of technology.

Table 3. Funding sources by field (percentages)								
Funding source	Agriculture	Natural science	Tech. science	Medicine	Economics	Law	Social science	Humanities
Total respondents	108	868	327	447	137	85	401	278
1st flow	37	42	47	36	69	81	58	52
2nd flow	34	44	30	31	18	20	26	31
3rd flow	33	16	35	41	12	6	20	8
Research inst.	15	8	9	15	7	6	8	5
Other empl	5	5	11	6	8	1	6	4
Private	3	2	4	9	13	8	14	21

SOURCE: Hulshof, Verrijt, and Kruijthoff (1996), p. 66.

The recent developments in conditions of support illustrate the ambiguity that exists around this issue. AiOs and OiOs basically occupy a hybrid position at Dutch universities. On the one hand, they are students who receive training and supervision. On the other hand, they are considered the engine of scientific work. The financial support structure that was introduced in the framework of the AiO system basically reflects this hybrid position. But external forces, such as the labor market and the internationalization of postgraduate training, are increasingly putting pressure on this situation.

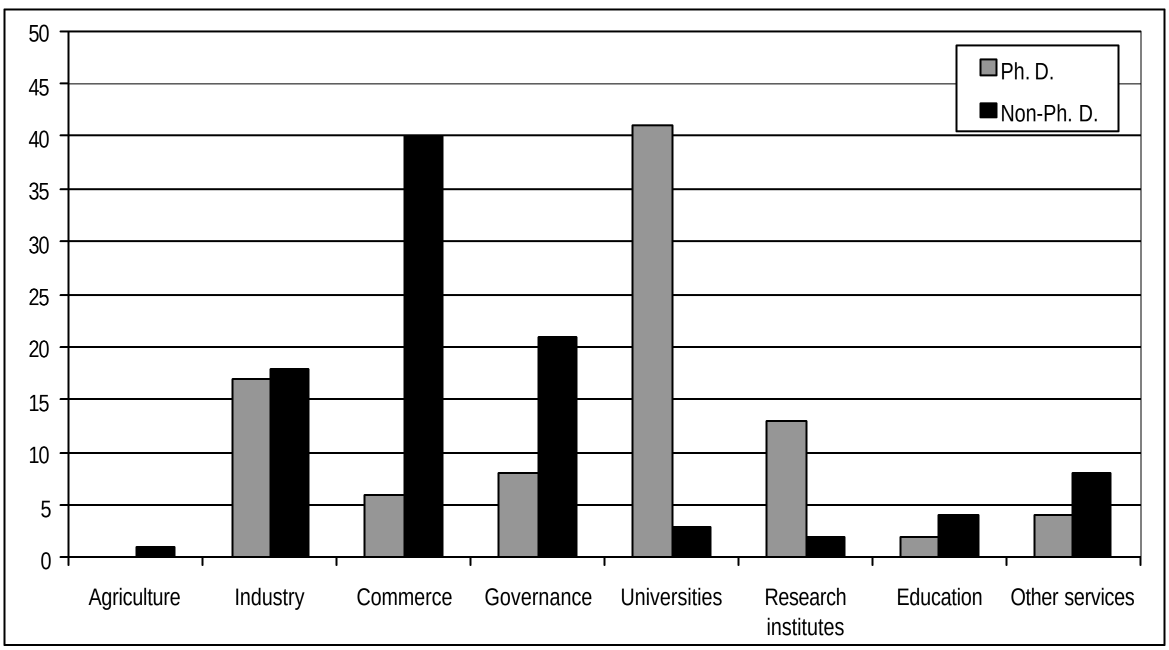
Employment Patterns

The labor market position of doctoral degree-holders has been the subject of discussion since the mid-1990s. The Dutch academic labor market was perceived as being unable to absorb the increasing number of young doctoral degree-holders aspiring to an academic career. At discussion seminars on this topic, doctoral candidates tended to refer to themselves as a "lost generation." In 1996, the Ministry of Education, Culture, and Science commissioned a study of the labor market situation for doctoral candidates (Hulshof, Verrijt, and Kruijthoff 1996).

Unemployment among doctorate-holders appeared to be less than among non-Ph.D.s: 6 percent versus 14 percent. For those Ph.D.s who obtained their degree through an AiO or OiO position, the unemployment figure is slightly higher: for AiOs, 9 percent; for OiOs, 12 percent (Hulshof, Verrijt, and Kruijthoff 1996, p. 51). This picture, as compared to the Dutch labor force overall, is not negative. However, employment conditions in terms of salaries and job security are generally less favorable for Ph.D.s.

Figure 7 shows the labor market destinations of Ph.D.s as compared to non-Ph.D.s. Clearly, most doctorate-holders find work in research and teaching positions at universities or research institutes (54 percent) or in industry (16 percent). There is, however, a move away from academia and into other positions. In 1983, 70 percent of Ph.D.s worked at universities; in 1995, only 38 percent were employed by a university. Although 70 percent of doctorate-holders have a research job—a figure that has been quite stable since 1983—most Ph.D.s exchange this type of work for another at some point along their career path.

Figure 7. Labor market destinations of Ph. D.s and non-Ph. D.s (percentages)



SOURCE: Hulshof, Verrijt, and Kruijthoff (1996), pp. 65-66.

Ongoing discussions of the labor market for Ph.D.s have gradually become less informed by pressing labor market issues, which allows for a more fundamental discussion of the labor market itself. There is a move toward discussing the consequences of a broader labor market orientation for doctoral education. If replenishment of the professorate is not the main labor market objective for the Ph.D. degree, then how should doctoral education (which is still very much focused on academic work after doctorate award) meet the societal needs of highly educated professionals? This issue fundamentally affects the orientation of doctoral education: toward the market or toward academia (see Bartelse and Hulshof 1996)? Subsequently, the question is being asked as to what implications this changing orientation will have for the process of acquiring a doctorate. If a broader labor market orientation is accepted, then the qualifications required for a Ph.D. graduate may need to be reconsidered. There are a few experiments with the "professional doctorate"—i.e., degrees for employed professionals—but the issue is still a sensitive one.

Patterns of International Mobility

Systematic data on the number of foreign doctoral students in the Netherlands and the number of foreign doctoral degrees earned by Dutch citizens are not available so far. Our impression is that Dutch universities increasingly attempt to attract foreign Ph.D. students. Particularly in the sciences, which face difficulties in filling vacant doctoral positions, the number of foreign doctoral students is increasing.

At the national and supra-national levels, several initiatives have been developed to stimulate international mobility of doctoral candidates (see also the German country report included in this volume). At the initiative of the Dutch Minister of Education and Science, Belgium, France, Germany, the Netherlands, and—later—Denmark established an international advisory committee on new organizational forms of graduate research training. The committee was established with the following terms of reference: to provide an opinion on the proposal of the Dutch Committee on Graduate Schools, particularly in light of European and international aspects; "to consider and compare the new organizational forms of graduate research training on a doctoral level currently emerging in many European countries…to provide indications and recommendations that allow for more cooperation at the level of graduate training; and to sketch ideas for the further evolution of these new systems of graduate training" (De Wied 1991, p. 9). The cooperation that evolved from this initiative has led to a letter of interest signed by Belgium, Denmark, France, Germany, and the Netherlands in January 1996. These countries have committed themselves to support the exchange of doctoral candidates and to inform each other of developments regarding doctoral programs and graduate schools.

The European Union is stimulating international cooperation in the area of doctoral training. In the post-war decades, international exchange often took place on the basis of personal contacts between individual professors. Recent visions of the European Union and of several European governments see these exchanges as insufficient (Blume 1993). The scope of European Community action in the field of education is defined in article 126(1) of the Maastricht Treaty (EU 1992): "The Community shall contribute to the development of quality education by encouraging cooperation between member states, while fully respecting the responsibility of the member states for the content of teaching and the organization of education systems and their cultural and linguistic diversity." Efforts to cooperate in the area of research training so far focus on mobility of researchers, particularly through the Training and Mobility of Researchers program, which is part of the European Commission's Framework Programmes. There have been suggestions to create a European doctorate[5] and to establish international, or rather, European centers for research training. As yet, however, these suggestions have not led to more extensive forms of cooperation in the area of doctoral training.

[5]See EC (1995). The European doctorate will be accorded under the following conditions:

- If at least two professors from two higher education institutions of two European countries, other than the one where the Ph.D. thesis will be defended, have given their judgment.
- If at least one member of the jury comes from a higher education institution in European countries, other than the one where the Ph.D. thesis will be defended.
- If part of the defense takes place in one of the official languages, other than the one(s) of the country where the Ph.D. thesis will be defended.
- If the Ph.D. thesis has been prepared partly as a result of a period of research of at least one trimester spent in another European country.

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SWEDEN

Jeroen Bartelse, Eric Beerkens, and Peter Maassen

INTRODUCTION

The Swedish higher education system before 1977 can be characterized as heterogeneous and centralized. After the Second World War, a large variety of schools, colleges, and courses existed. Labor market and economic forces stimulated the government to introduce an ambitious policy and administrative measures that would expand the whole education system above grade 7. These measures led to an expansion of higher education that was probably faster than in any other Organisation for Economic Co-operation and Development country (Svanfeldt 1994). This expansion occurred mainly in the 1960s: at the end of this decade, there were about three times as many students in higher education as at the start of the decade. The capacity of the existing institutions was not sufficient to accommodate the student explosion. This resulted in the establishment of a parliamentary committee in 1968. The report by this committee, published in 1973, led to thorough reforms of the entire Swedish higher education system in 1977. Under these reforms, all higher education institutions became integrated into one system of tertiary-level education called the *högskola*. This is the Swedish collective name for higher education, encompassing not only traditional university studies but also those at the various professional institutes and university colleges, as well as a number of programs previously taught in other forms of the educational system. Most of the programs included in the broadened definition of higher education are under the jurisdiction of the Ministry of Education and Science, others are under the Ministry of Agriculture, and paramedical programs are under the county councils.

Between 1977 and 1993, a system of national programs existed in the Swedish higher education sector. The state determined the curricula, program length, overall aims, etc., of all higher education programs offered. The educational system was organized into general study programs, local study programs, and single subject courses. In 1993, the government decided to loosen requirements in order to allow for more variation at the local level, and thus more correspondence with the labor market. Under these reforms, institutions were allowed to develop their own programs.

With the 1993 reform of higher education, institutions were given increased autonomy in the organization of their studies, admissions, use of resources, and general organization. Under the present system, the government only specifies program lengths of degrees. Different degrees correspond to the number of "study points" needed to complete them. In figure 1, a graphical overview is presented of the Swedish higher education system. Three types of undergraduate degrees are offered. After 2 years, students earn 80 points and are eligible to receive a diploma (*Högskole*). Completion of a three-year program (120 points) is rewarded with a bachelor's degree (*Kandidat*), and students who complete 4 years (160 points) receive a master's degree (*Magister*). The Swedish system also offers two types of postgraduate degrees: the licentiate and the doctorate.[1] These are addressed in detail below. The total number of higher education students in 1996-97 was 300,380, of whom 16,550 were active postgraduate students. In this academic year, 840 licentiate degrees and 1,720 Ph.D.s were awarded (Högskoleverket 1998a). Professional degrees are also offered. The program lengths for these professional degrees vary from 1 to 5.5 years.

TRENDS IN GRADUATE EDUCATION

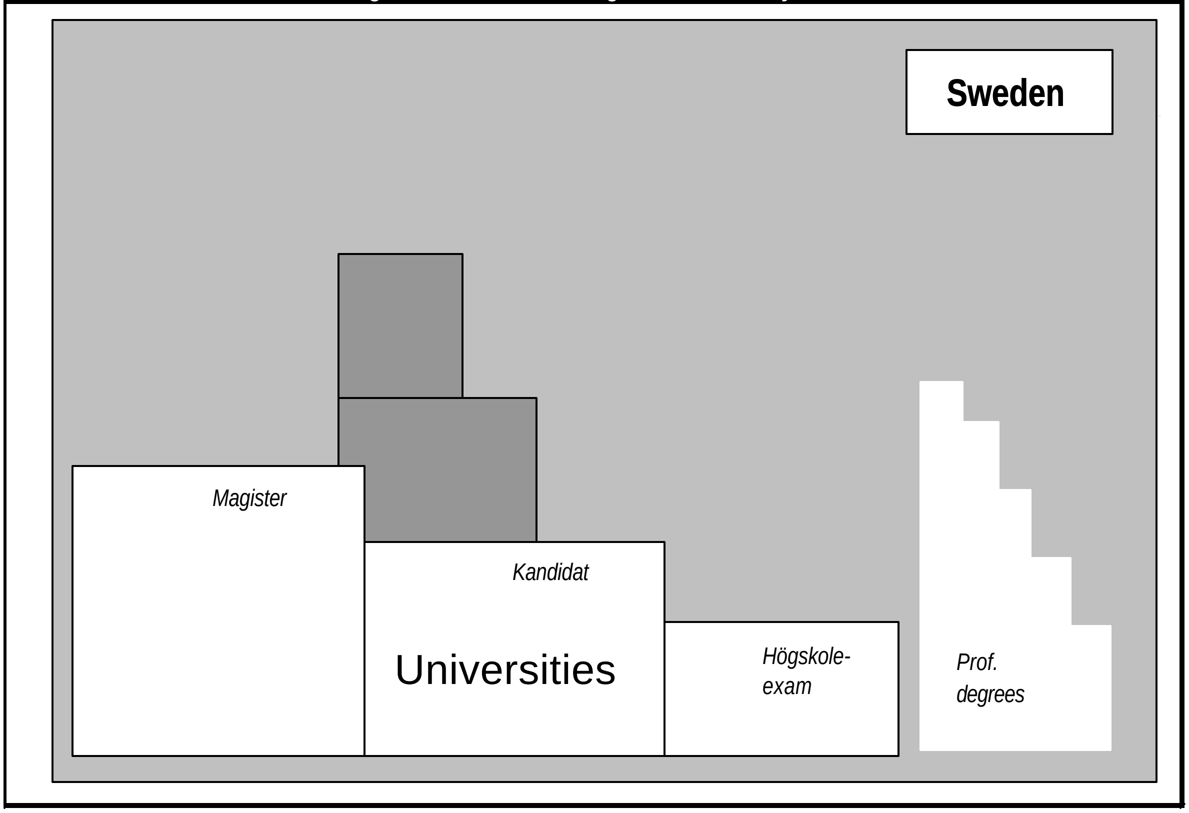
Until 1969, Sweden had a *Licentiatexamen* and a traditional doctorate. The median time of study from the *kandidatexamen* or *magisterexamen* to the licentiate was about 5 to 6 years, and the time from the licentiate to the doctorate was about 5 years. This means that, after completion of the undergraduate degree, the time to completion of the doctoral program was 10 years or more.

During the research training reforms of 1969, these degrees were replaced by the *doktorsexamen* with a time restriction and compulsory courses. The new postgraduate education system that was launched in 1969 had two main purposes (Zetterblom 1993):

- to shorten the time spent in graduate studies by introducing courses instead of literature studies, improving supervision of thesis work, and reduc-

[1]Throughout this report, we use the term "postgraduate" to refer to students in either licentiate or doctorate programs.

Figure 1. The Swedish higher education system



SOURCE: Statistica Centralbyrån (1997). *Universitet och hogskolor Forskarutbildning: Nyantagna, registrerade och examinerade lasaret 1993/94, 1995/96, and 1996/97. Örebro.*

ing demands on the thesis so that completion of the dissertation was seen as a career step instead of a life-long project; and

- to bring graduate education in Sweden closer to what was considered an international norm: the Anglo-Saxon Ph.D.

Since the 1969 reforms, the formal length of the program from enrollment to completion of dissertation has been 4 years. The average length of study, however, is still higher. For those who took the *doktorsexamen* in 1994, the program took an average of 7 years from admission to research training to thesis defense (Kyvik and Tvede 1998).

Across different faculties, however, there are large differences between lengths of study. The average duration of study in the humanities and social sciences, for instance, is considerably longer than in engineering, the natural sciences, and medicine.

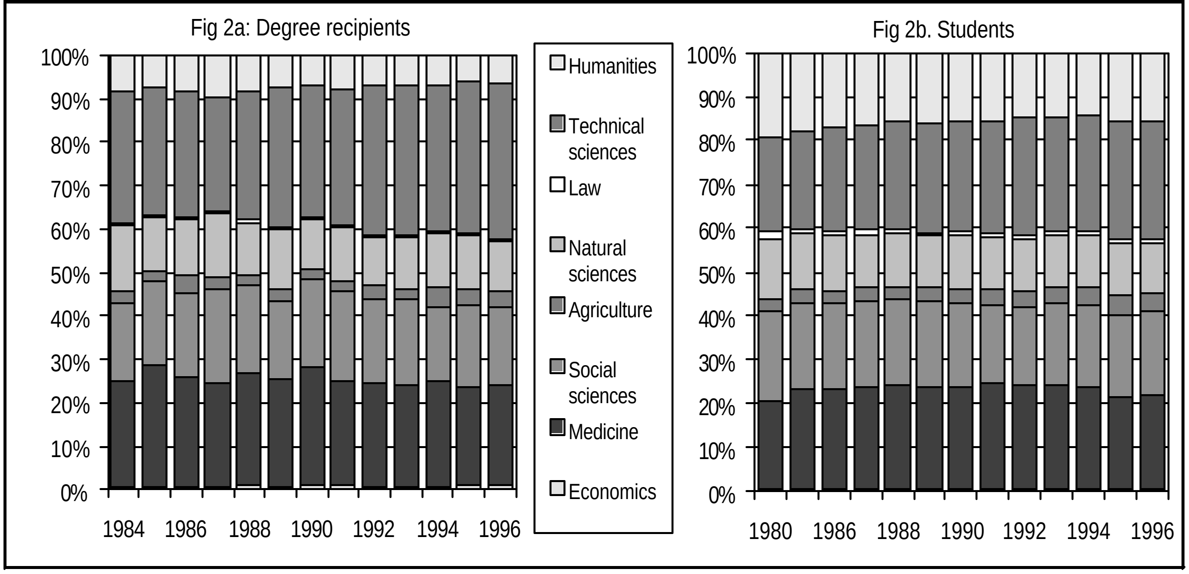
In figure 2, the numbers of postgraduate students and degree recipients are presented by discipline from 1980 until 1996. The large difference between the proportion of students and the proportion of graduates in certain fields indicates that a high percentage of graduate students do not complete the program or complete it more slowly; for example, compare the data for students in the social sciences versus those in the natural sciences.

Since the mid-1980s, the licentiate degree has been reintroduced as an intermediate qualification in postgraduate education. The standard time for completing this new degree is 2 years. The request for the new licentiate came primarily from engineering faculty, in which field a licentiate can be regarded as adequate preparation for work in industry. Most holders of licentiate degrees are in the technical sciences (computer science, mechanics, engineering, architecture, etc.) (figure 3).

As shown in figure 4, the number of licentiate and doctoral students has gone up considerably since the early 1980s. Also, although there is still a big difference between the number of students who enroll and the number of students who actually complete postgraduate studies, the difference has declined relatively.

The doctoral degree program in the current higher education system officially takes approximately 4 years

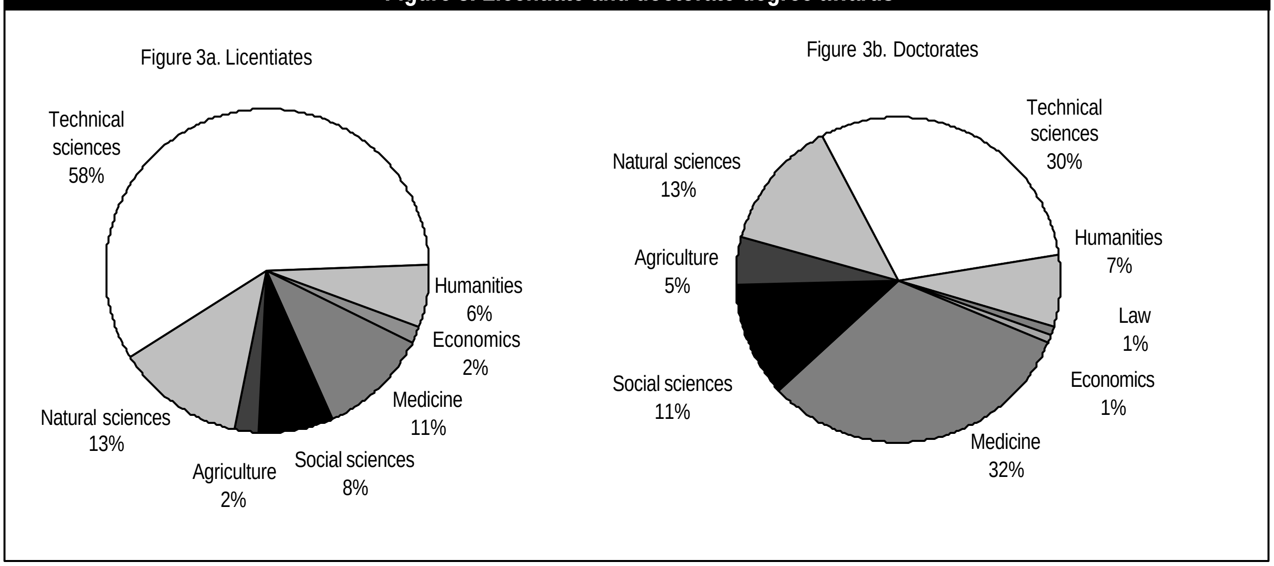
Figure 2. Postgraduate students and degree recipients by discipline



NOTES: Natural sciences includes physical, chemical, biological, and mathematical sciences. Technical sciences include engineering, mechanics, computer sciences, and architecture.

SOURCE: Statistica Centralbyrån (1997). Universitet och hogskolor Forskarutbildning: Nyantagna, registrerade och examinerade lasaret 1993/94, 1995/96, and 1996/97. Örebro.

Figure 3. Licentiate and doctorate degree awards

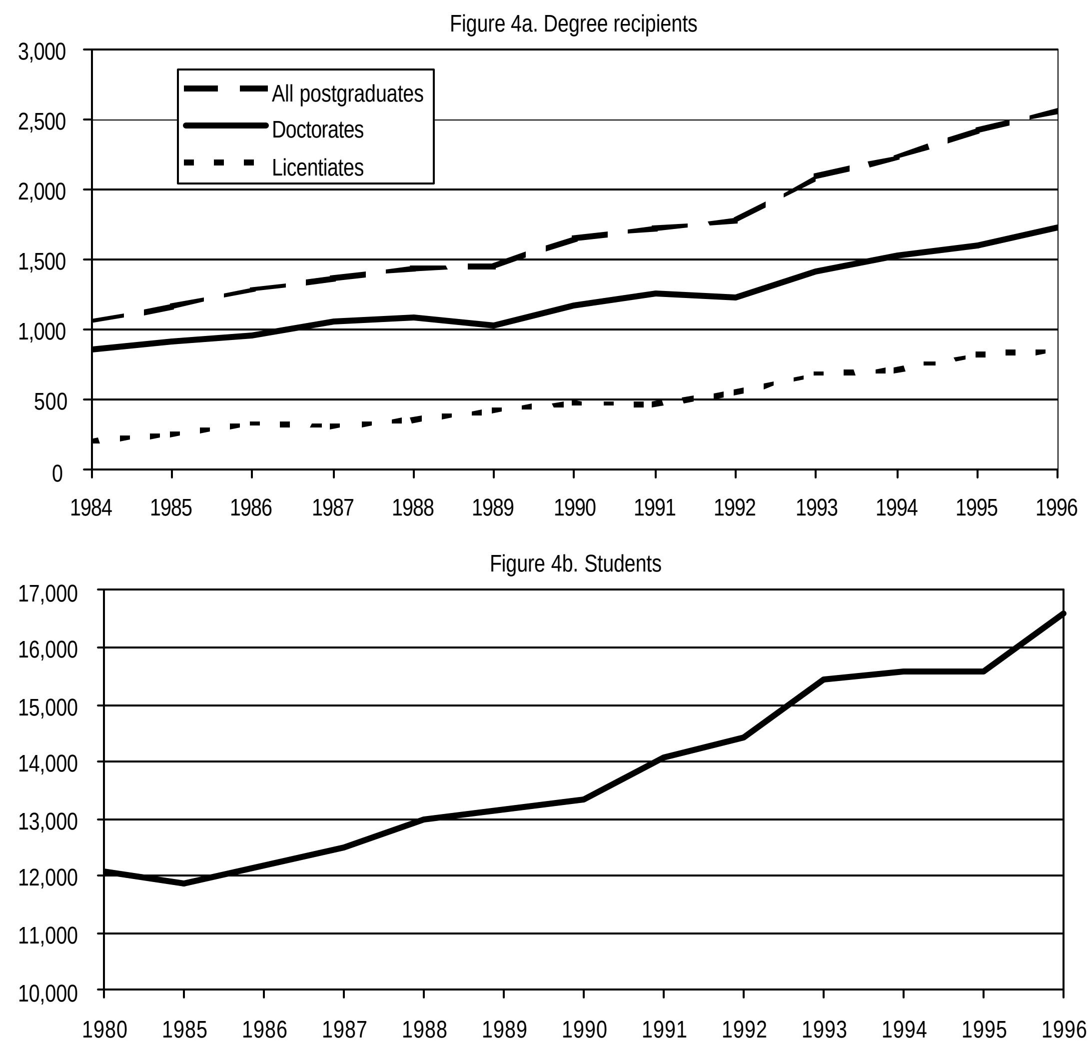


NOTES: Natural sciences includes physical, chemical, biological, and mathematical sciences. Technical sciences include engineering, mechanics, computer sciences, and architecture.

SOURCE: Statistica Centralbyrån (1997). Universitet och hogskolor Forskarutbildning: Nyantagna, registrerade och examinerade lasaret 1993/94, 1995/96, and 1996/97. Örebro.

to complete, which equals 160 study points. All graduate programs provide in-depth study in the field, training in methodology, and research experience. Required courses take about 1.5 years (60 points). The student, together with an advisor, decides upon a study plan and a topic for the dissertation during the first year; this must be approved by the department. Doctoral dissertations are usually written in Swedish or English, but may also be written in other languages. All postgraduate students receive individual tutoring. Dissertations must be defended in public before a committee. The thesis may be published as a monograph or as a composite dissertation consisting of a number of research papers and a summary.

Figure 4. Total number of postgraduate degree recipients and students



SOURCE: Statistica Centralbyrån (1997). *Universitet och hogskolor Forskarutbildning: Nyantagna, registrerade och examinerade lasaret 1993/94, 1995/96, and 1996/97. Örebro.*

The participation of women in graduate education in Sweden shows a consistent growth during the last decades, although the proportion of female students is higher than the proportion of female graduates (figure 5 and table 1).

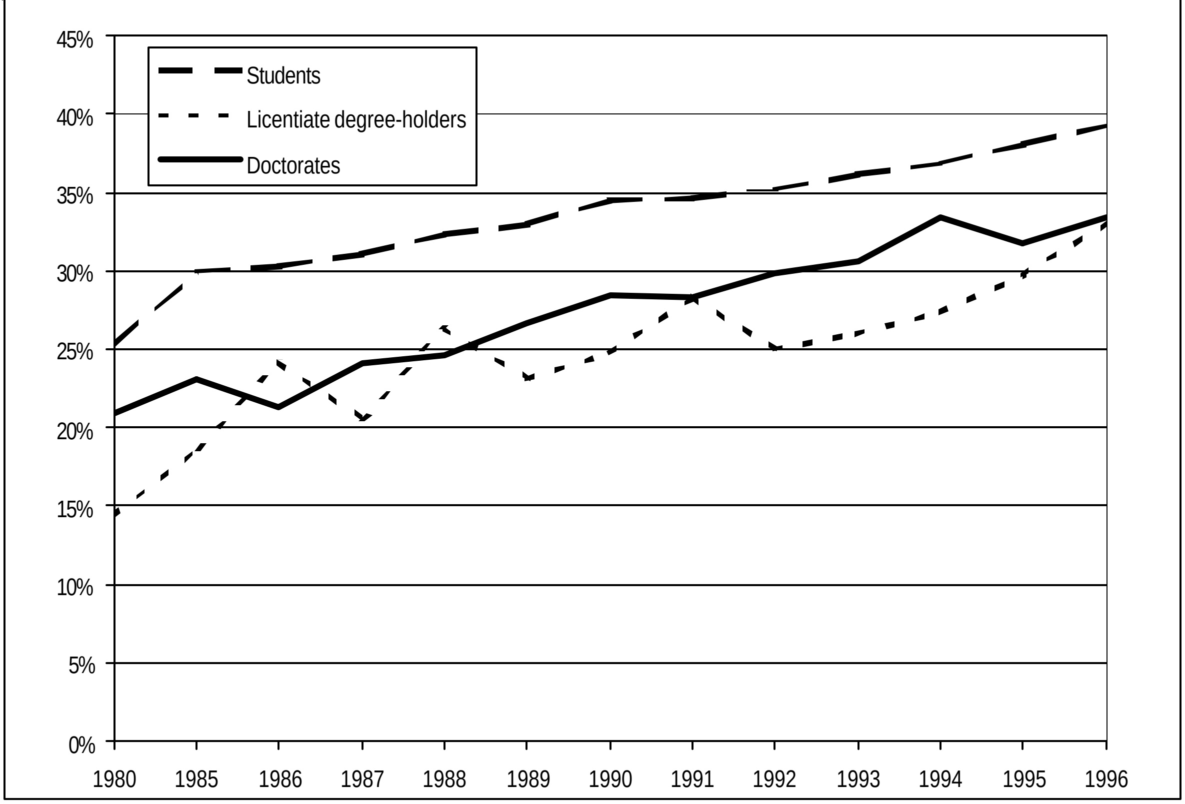
In the 1980s, the balance of the two main activities of the education sector—providing undergraduate education and conducting research—has shifted more toward research. During this decade, government appropriations for undergraduate education decreased from 40 to 30 percent of the total budget for universities and university colleges. During the same period, government grants for research and postgraduate education increased; even greater increases were seen in the funding from other sources.

In comparing the Swedish model with other systems of postgraduate education, a shift can be discerned from the apprenticeship model (e.g., of Germany) to the professional model (e.g., of the United States). Since the reforms of 1969, a considerable proportion of the current licentiate and doctoral programs have consisted of coursework and participation in seminars in the field or related areas. Research and dissertation work are mainly carried out in the final stages of the program.

Doctoral Reforms

As part of larger reforms in higher education in its entirety, graduate education has changed considerably since the Second World War. The doctoral education program introduced in 1969 was designed to boost the num-

Figure 5. Proportions of female postgraduate degree-holders and female postgraduate students, 1980-96



SOURCE: Statistica Centralbyrån (1997). *Universitet och hogskolor Forskarutbildning: Nyantagna, registrerade och examinerade lasaret 1993/94, 1995/96, and 1996/97. Örebro.*

Table 1. Number and percent of new female postgraduate students by major field

Field	1986-87		1989-90		1992-93		1995-96	
	Total number	Percent of women	Total number	Percent of Women	Total number	Percent of Women	Total number	Percent of Women
Total	2,260	32	2,450	34	3,470	35	3,100	40
Humanities	280	43	270	45	410	48	340	53
Social sciences	340	38	370	34	560	41	470	46
Medicine	490	37	560	38	760	41	780	48
Mathematics/natural sciences	220	27	300	35	390	38	310	39
Technology	570	21	570	20	780	24	760	24
Technology/natural sciences	120	28	120	26	160	32	150	32

SOURCE: Högskoleverket (1998b). *Women and Men in Higher Education.* Högskoleverkets Reports 1998:13 R.

ber of candidates, lower the average age of the candidates, and increase completion rates. This policy, however, did not lead to the expected results. In the 1980s, there were increasing concerns about the quality of Ph.D. education in Sweden. This resulted in a strategy focusing more strongly on quality and loosening the rigid formal requirements that gave priority to quantitative performance (Bleiklie 1993). In this period, government grants for Ph.D. education were increased, and doctoral students were provided an additional year of government support. The basis of most current reforms in postgraduate education can be traced back to the change of government in 1991. In the 1990s, education at all levels has become more decentralized. The new research policies introduced in 1993 involve changes designed to increase flexibility, efficiency, and competitiveness. Traditionally, Swedish researchers were supported by the government through basic research grants given to universities, personal grants from research councils, and grants from various applied science funding organizations. Additional sources of funding have been introduced to increase opportunities for supporting research in areas that are already on their way to becoming world class. Instead of focusing on specific fields, support is concentrated on specially gifted individuals and outstanding research environments.

The priorities of the new research policies, as described in the *1993 White Paper on Research* (Swedish Ministry of Education and Science 1993, p. 170), are:

- to strengthen links between universities and industries, and
- to increase efforts to promote concentrated and major world-class research projects.

Strengthening Links Between Universities and Industries

A major share of government spending on research is directed to universities, and not to specific research institutes. This university-focused orientation may cause problems in the exchange of knowledge between the university and business sectors. Therefore, a program to widen and deepen contacts between universities and industry is being introduced. This program consists of, among other things, an increase in the number of Ph.D.s in industry, the establishment of special research companies connected to the universities, and the introduction of special postgraduate programs in industry. The new research policies adopted in 1993 state that the new projects should include the training of young researchers.

Promoting Concentrated and Major Research Projects

For efforts to promote concentrated and major research projects, 10 billion SEK—to be used over a period of 15 years—has been allocated to promote internationally competitive research programs. This sum has been divided among three areas: 60 percent to strategic research (support for technical, scientific, and medical research); 25 percent to strategic environmental research; and 15 percent to research in the humanities and social sciences (Swedish Ministry of Education and Science 1993). Furthermore, special "centers of excellence" have been established at universities and university colleges. These centers are financed by the Swedish Industrial and Technical Development Administration.

Further policy measures focus on flexibility, recruitment, and internationalization. Flexibility is considered necessary to develop creative research environments and to cope with the rapid advancement of knowledge. Increased autonomy and pluralism within the university system should create opportunities to achieve this. The recruitment of additional researchers is important both for the development of Swedish industry and for the promotion of quality in university education and research. A specific program has been introduced to support the recruitment of women into higher education and research. Finally, a number of measures have been undertaken to extend international relations in Swedish research.

During the 1980s, there were discussions as to whether there was a need for a special agency at the faculty level for planning and leading research training on the model of American graduate schools. However, these suggestions didn't receive strong support at the universities, and some institutions have developed their own agencies for research training. The discussion about an agency at the university or faculty level was renewed by the *1993 White Paper on Research*.

The reforms presented above should lead to the creation of a higher education structure that can deal with future challenges. Following the creation of such a structure, the transformation of Sweden's educational and research systems is to be carried out in a project entitled "Agenda 2000, Knowledge and Competence for the Next Century." This project maps out a strategy to link together policies for schools, universities, and research. It is based on the belief that governments and parliaments should not interfere with educational and research systems by regulating and deciding on minor details, but should concentrate instead on encouraging individuals to strive for excellence.

Patterns of Support

Before the 1980s, postgraduate students were financed out of the research appropriation to which each university faculty was entitled. The way the money was spent was decided by the faculty board of the individual institution. The board could decide to spend it on positions for postgraduate studies or on fellowships. The students with posts were to spend the majority of their time on research, but could combine this with teaching. Fellowship-holders could combine research studies with a job on a research project or a part-time job as a teaching or administrative assistant. Another possibility for financing postgraduate studies was to combine one's studies with research on a project funded by external sources or by one of the research councils. Some educational institutions required that students participate in teaching and administration. Although there were great differences across faculties in the application of the regulations, postgraduates typically were either required to work as teaching assistants or volunteered to use about 20 percent of their time for teaching. This was paid work in addition to the normal sources of financial support they received.

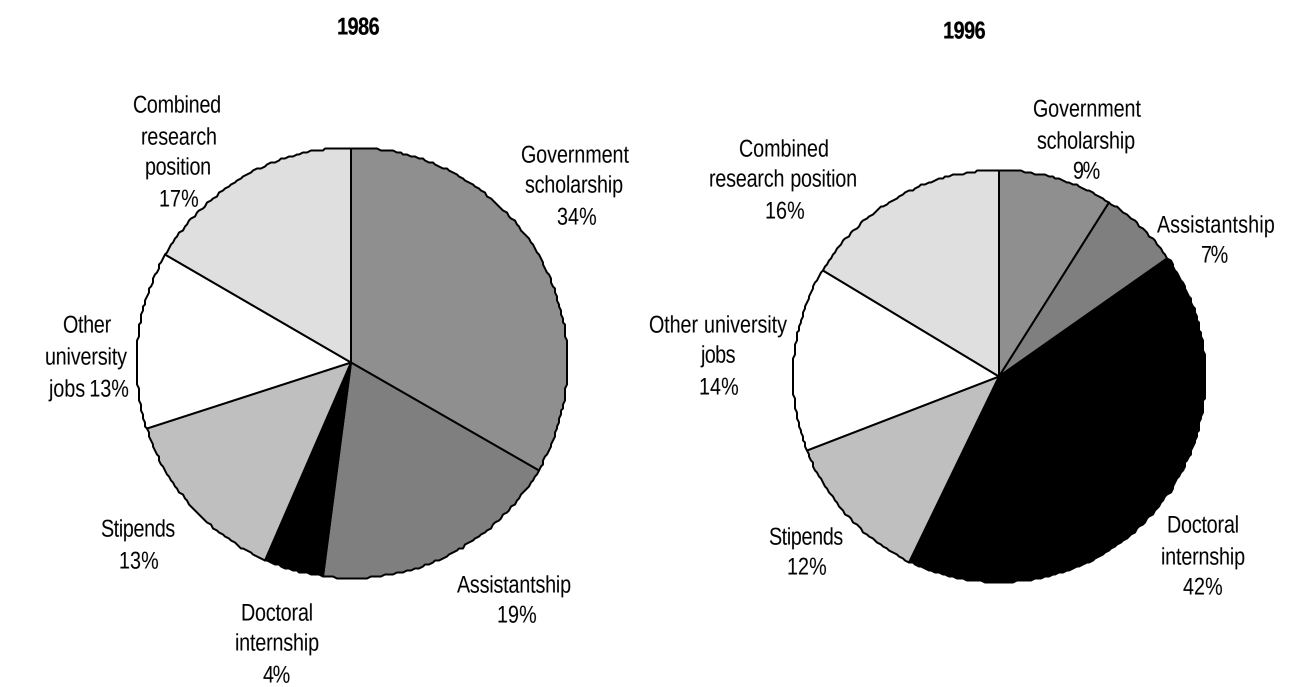
In 1982, the system for financial support of postgraduate students was changed from study grants to what is called *doktorandjänster*. These are doctoral internships by which students are temporarily employed at the university with full benefits and a salary corresponding to a starting salary in the public sector. Another way of funding students is the *utbildningsbidrag* (stipend), which gives students a lower gross income and poor benefits. In addition, some students finance their studies through work, loans, or scholarships. In 1994, of those who received funding for doctoral studies, 59 percent had a *doktorandjänst*, 16 percent had an *utbildningbidrag*, and 25 percent used another funding mechanism. Figure 6 shows that the proportion of postgraduate students supported by a *doktorandjänst* has grown rapidly from 1986-96, mainly at the expense of government scholarships and assistantships.

The availability of financial support varies by discipline. In figure 7, different types of financial support are presented for the different disciplines.

Funding has had a considerable impact on postgraduate completion rates (Zetterblom 1993). Completion rates differ greatly across groups of postgraduate students with different amounts of financial support. In the fields with the lowest rates of completion, the humanities and social sciences, about half of the students received no financial support from the university. In the natural sciences, the corresponding figure is only a fourth. With the exception of students in the clinical subjects of medicine, the completion rates were low among students who received no support. In the humanities and social sciences, the completion rate of this nonsupported group was about 5 percent; for the group most favored with study support, this proportion was 40 percent (table 2).

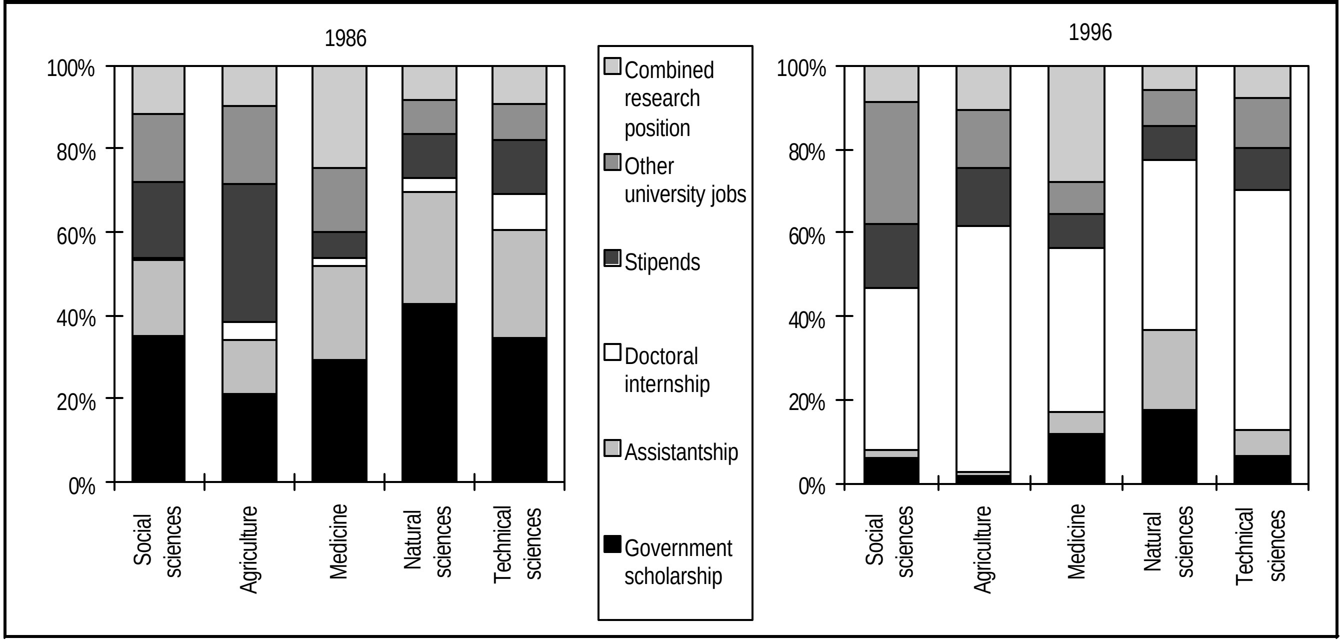
Various reasons may explain the differences in completion rates between groups with different amounts of study support. Of great importance seems to be the opportunity to perform research work on a full-time basis. In addition, the requirement of yearly applications for grants or assistantships stimulates substantial progress in their studies.

Figure 6. Support patterns, 1986 and 1996



SOURCE: Statistica Centralbyrån (1997). *Universitet och hogskolor Forskarutbildning: Nyantagna, registrerade och examinerade lasaret 1993/94, 1995/96, and 1996/97. Örebro.*

Figure 7. Availability of financial support by discipline, 1986 and 1996



SOURCE: Statistica Centralbyrån (1997). *Universitet och hogskolor Forskarutbildning: Nyantagna, registrerade och examinerade lasaret 1993/94, 1995/96, and 1996/97. Örebro.*

Table 2. Proportion of students with a doctoral degree after 13 years (admitted in cohorts of 1972-73 to 1977-78), by field

Field	Regular support ≥ 3 year	Regular support < 3 years	No study support	Total
Humanities	41	24	6	18
Social sciences	40	23	5	19
Natural sciences	71	39	20	50
Medicine, theoretical	82	45	56	67
Medicine, clinical	70	66	59	63
Engineering	57	27	18	36

SOURCE: Zetterblom, G. The Development in Graduate Eduacation in Sweden. Paper presented at the Sixth CHER Conference, July 1-3, 1993, Stockholm.

In 1998, the rules for funding postgraduate studies were modified. Now, only applicants employed in a postgraduate post or awarded a study grant may be admitted to postgraduate training. In other cases, the applicant must have guaranteed study funding for the whole period of study.

Employment Patterns

The rapid growth of postgraduate students in the 1960s raised concerns about the opportunities for graduates to find suitable employment in the future. A government committee set up to develop a system for quantitative planning proposed an elaborate system for balancing supply and demand in postgraduate education. The plans to implement such a system, however, were cancelled, as the rising growth of postgraduate students appeared to be temporary. In the 1980s, the attention given to the relation between the labor market and postgraduate education was based on more qualitative considerations. In the last decade, government policy has mainly been directed at stimulating cooperation between industry and research to train high-quality researchers.

There is little quantitative information available on employment of Ph.D.s in Sweden. We therefore give some rudimentary figures. Statistics show that almost all of the new doctoral degree-holders from 1991-92 were employed in 1994 (Kyvik and Tvede 1998). Fourteen percent were unemployed during parts of this period from 1991-94. There are large differences in the percentages of postgraduates from different disciplines who are employed by universities. Around 1980, over 50 percent of all Ph.D.s in the social sciences were employed by a university. The corresponding rates for recipients of doctorates in the humanities and natural sciences are between 40 and 50 percent. The smallest proportion of postgraduate degree-holders employed in universities can be found within the clinical subjects of medicine (Zetterblom 1993).

Patterns of International Mobility

In the 1980s, most Swedish universities developed their own plans of action to set priorities for internationalizing curricula and research networks. In 1993, however, the Royal Swedish Academy of Sciences stated that too few researchers—including postgraduate students—engaged in research stays abroad and that this situation should be changed. The government supported this view and recommended the use of existing bilateral agreements, programs, and networks; it also advised that special attention be given to the development of shorter courses, summer schools, etc. In addition, the universities themselves were expected to be responsible for enhancing the internationalization of research training.

A general trend toward the internationalization of education and research can be detected in Sweden. For example, the proportion of Ph.D. graduates in Sweden with a first degree from another country grew from 3 percent in 1973-74 to 19 percent in 1993-94. In 1994, there were almost 1,000 incoming people—both temporary and permanent residents—with postgraduate education in Sweden, compared to 340 persons outgoing. For outgoing students, the United States seem to be the most popular country to stay abroad. In addition to language reasons, students claim that the best research environments in their fields are in the United States. In Europe, the United Kingdom, Germany, and France are the most popular countries. Only 3 percent of the students going abroad chose to study in Africa, Asia, or Latin America.

With respect to the internationalization of research training, the regional cooperation between the Nordic countries in postgraduate education is especially remarkable. In 1990, the various Scandinavian countries tried to further their cooperation by establishing the Nordic Academy for Advanced Study. This organization currently funds approximately 6,000 research students and researchers involved in cooperative Nordic projects. The objective of this cooperation is that the Nordic countries function as one common research training region. Graduate students will thus have the opportunity to make use of courses in countries other than their home country.

Acknowledgments

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United Kingdom

Jeroen Bartelse, Eric Beerkens, and Peter Maassen

Introduction

In the post-war period, the British higher education system experienced a major expansion. By the end of the 1950s, however, it became clear that the route pursued was not going to yield the expansion the system actually required. This was mainly because universities raised their entry requirements to cope with increased demand, rather than accommodate larger groups of students within the existing infrastructure. These growing tensions resulted in the establishment of the Robbins Committee to inquire into the future of higher education. The report published by this committee stated that "all young persons qualified by ability and attainment to pursue a full time course in higher education should have the opportunity to do so" (Committee on Higher Education 1963, p. 49). This reflection provided a guide for the development of the British higher education system thereafter. During the 1960s, several new universities and a wholly new sector of higher education were established. Despite the recommendations of the Robbins Committee, further expansion of higher education did not take place in the universities but mainly in the newly established public sector in higher education: the polytechnics and colleges. This binary system lasted until 1992, when the polytechnics were granted university titles.

Virtually all institutions in British higher education offer the 3-year bachelor's degree program; most also offer postgraduate degrees leading to master and doctoral qualifications. Undergraduate education consists of 3-year programs. These can be concluded at different levels: the lowest level is the bachelor "pass-degree," and the highest level is the bachelor "first-class honors degree." Overcrowding in the undergraduate programs and a decrease in standards have resulted in an inadequate inflow into graduate education—and, consequently, have led to a discussion about extension of undergraduate programs to 4 years. Following undergraduate education, three types of graduate programs are offered leading to three types of qualifications: postgraduate diplomas; master's degrees (the so-called "taught master's," which are curriculum based, and the research master's degrees); and doctoral degrees (figure 1). This country report discusses graduate education in the United Kingdom and focuses specifically on the doctoral degree.

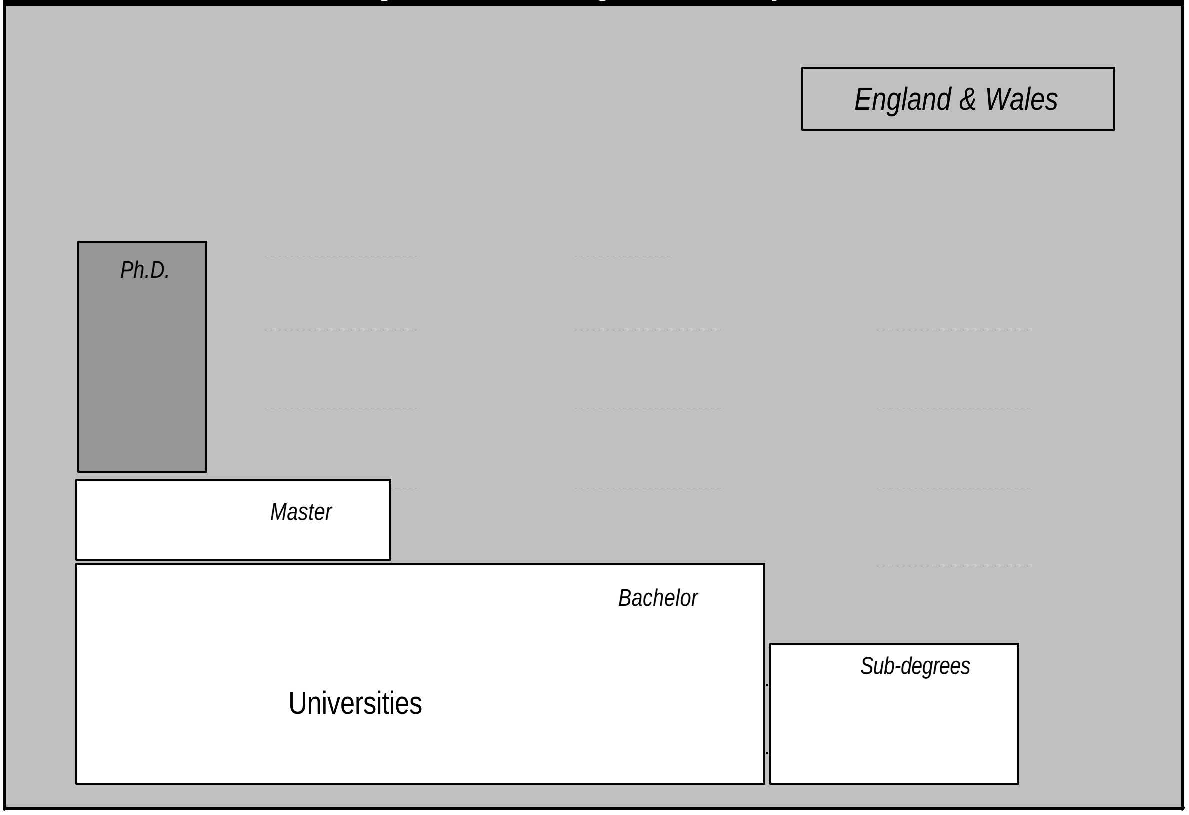
The next section discusses trends in graduate education in the United Kingdom. This discussion is limited to policy developments up until the late 1980s and the effects of these policies on the current number and division of graduate students. Following this, the various policy papers issued in the 1980s and 1990s are discussed. These papers form the basis of the actual reforms that are still ongoing at this time. Finally, support patterns, employment patterns, and international mobility are discussed.

Trends in Graduate Education

In the binary higher education system of the United Kingdom, universities were supposed to maintain their traditional academic role, including basic research; while public sector institutions were meant to develop vocational types of higher education. The polytechnics, however, took a more complex view of their role in the system, striving to become more equal to, and less different from, the universities. After the polytechnics were granted university titles in 1992, the binary system practically changed into a unitary system: 74 universities enroll 90 percent of all students in higher education, and 143 other institutions provide education for the remaining 10 percent (Brennan and Shah 1994).

In general, the British higher education system, both in the past and in the present, can be characterized as specialized, elitist, small-scale, and focused on first degree provision (Becher 1993). Two universities, Oxford and Cambridge, monopolized higher learning in England for six centuries, until the foundation of the Universities of London and Durham in the second quarter of the 19th century. In 1917, Oxford was the first British university to introduce the Ph.D., largely to attract American scholars away from Britain's wartime enemy, Germany (Simpson 1983). Professors had begun to incorporate research work into their own activities, but still research was considered subordinate to teaching activities, rather than the basis of professorial orientation and university organization. This might account for the moderate integration of the Ph.D. degree in the British system. In 1938, there were only 3,000 postgraduates in British universities; these represented only 6 percent of the full-time total student population.

Figure 1. The British higher education system



Although the number of doctoral graduates has grown rapidly during the several decades following the Second World War, its growth was considerably slower than in most other countries in Europe. In the *Robbins Report* of 1963, therefore, expansion of participation in graduate education was recommended. The committee gave two reasons why these increases were needed. First of all, there should be more graduate students in order to provide more teachers for the rapidly expanding system of higher education. Second, more students were needed to keep up with the fast pace of change in the scientific and technological revolution. It was assumed that the demand for people with graduate degrees would increase with supply.

The *Robbins Report* proposed a new structure for graduate degrees, in which a 3-year Ph.D. would follow a 1-year master's degree program. The reforms proposed in this report emphasized the importance of a close relationship between graduate education and the labor market. It was envisioned that American graduate schools would be copied in terms of training through formal instruction and seminars. This way, doctoral students would no longer be dependent on a single supervisor. After the *Robbins Report*, governmental statements on graduate education were largely absent. In 1982, the Association of British Research Councils published the *Report of the Working Party on Postgraduate Education*, better known as the *Swinnerton-Dyer Report*. This report called for labor market information and employment trends to be taken into consideration when deciding upon the number of grants to be allocated by the research councils. Like the *Robbins Report*, the *Swinnerton-Dyer Report* also recommended the inclusion of coursework as part of the doctoral program.

In the late 1980s, there was a shift in power concerning research and science policy from leading academies, the funding bodies, and the research councils to the government. The British government started to play a more definitive role in the setting of research objectives. These developments and the various papers issued in the 1990s (discussed later in this report) form the basis of the current graduate education system.

The commitment to personal teacher-student relationships still exists in this system. The British approach to university organization does not focus on research as a primary university activity, prevailing over teaching and study, as it does in Germany. The orientation toward research came rather late and was mainly a reaction to scientific progress and improvement in research training and research in other countries. Research gradually developed into a standard and subsidized component of faculty activity.

Nonetheless, in terms of number of students, the training component in research has remained relatively underemphasized in British universities. It generally involves a few carefully chosen students who conduct research in a close relationship with their mentors. This has resulted in a doctoral program with little or no curricular provision. Most graduate students register for the Ph.D., which normally requires 3 years of full-time study. Some students register with the intention of obtaining a master's degree, usually either a master of arts or a master of science taken full time in 1 year, or a master of philosophy taken full time in 2 years.

In the current system, only students who achieve a bachelor first-class or upper second-class honors degree are admitted to a graduate program, although exceptions are made for people with relevant professional experience. Admittance to a graduate program occurs in two stages. The first stage is the provision of a studentship (scholarship) by the British Academy or a research council, in which the results of the undergraduate career are taken into account. Second, the student has to be accepted by the department. Expectations regarding time to completion of the program and chances of success of the research proposal are leading criteria for admission by the institutions (Kaiser, Hezemans, and Vossensteyn 1994).

Small size, selectivity, and high quality go together along with personal relations between teacher and student. This apprenticeship model has been a major characteristic of the British system and has the advantage of being easy to operate, with clear lines of responsibility between student and supervisor. The theses produced are made publicly available and consist of a monograph or series of selected papers in learned journals.

Within the various disciplines, there are important differences in this traditional model. In the natural sciences, a graduate student joins a research team and works on a research thesis while contributing to the overall efforts of the group. In the humanities and social sciences, however, students normally select their own topics and work independently. Formal contact is much greater in science departments.

As a result of the reforms in the higher education system in the early 1990s, the number of university graduate students boomed between 1993 and 1994. As the polytechnics were awarded the university title, the number of taught master's degrees, in particular, showed a large increase (figure 2). With the expansion of the number of universities, and therefore of the number of accrediting institutions, taught master's degrees are being offered in more institutions than before the 1993 reforms.

Figure 3 shows the enrollment of graduate students in various disciplines, broken down by year. The differences on either side of 1993 can be explained by the higher education reforms implemented at that time. Figure 4 shows the differences in enrollment across various disciplines for taught (curriculum-based) programs and research-based programs.

The enrollment of women in graduate education shows a steady increase in the past decade (figure 5). Currently, the numbers of male and female graduate students are practically equal.

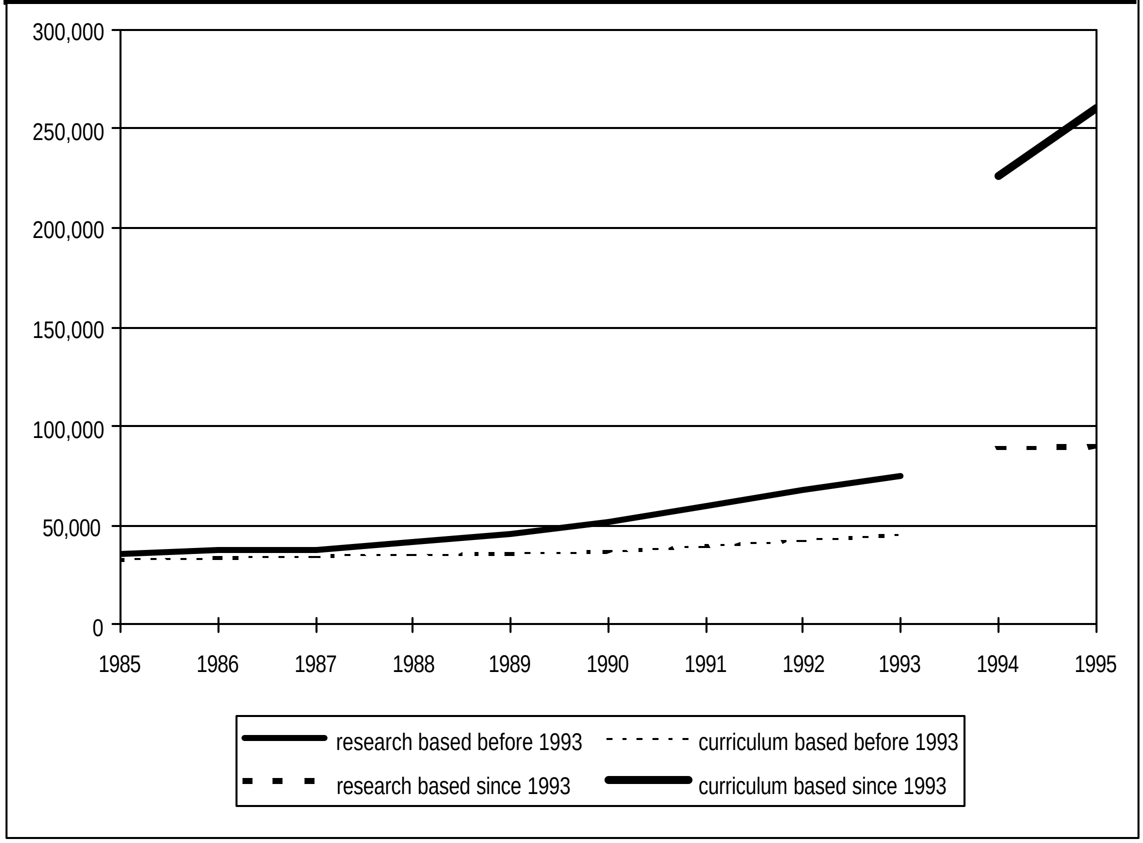
In figure 6, doctoral degrees and total graduate degrees awarded in 1994 are presented by discipline. Figure 7 shows number of doctorates by discipline.

Doctoral Reforms

While government interference was relatively absent between the publication of the *Robbins Report* in 1963 and the *Swinnerton-Dyer Report* in 1982, the role of government in graduate education increased considerably at the end of the 1980s. Until 1993, this was mainly through references to graduate education in general papers about higher education. The policy statements show a consistent interest in linking the number of graduate students to labor market demands. Therefore, an interest in the content of graduate education and its relevance to the needs of industry and commerce were incorporated in the policymaking process. At the same time, the relevance of basic research, which contributes to fundamental knowledge, was recognized. In this section, the reforms in British graduate education—which are still going on—are examined on the basis of the various policy documents issued in the 1980s and 1990s.

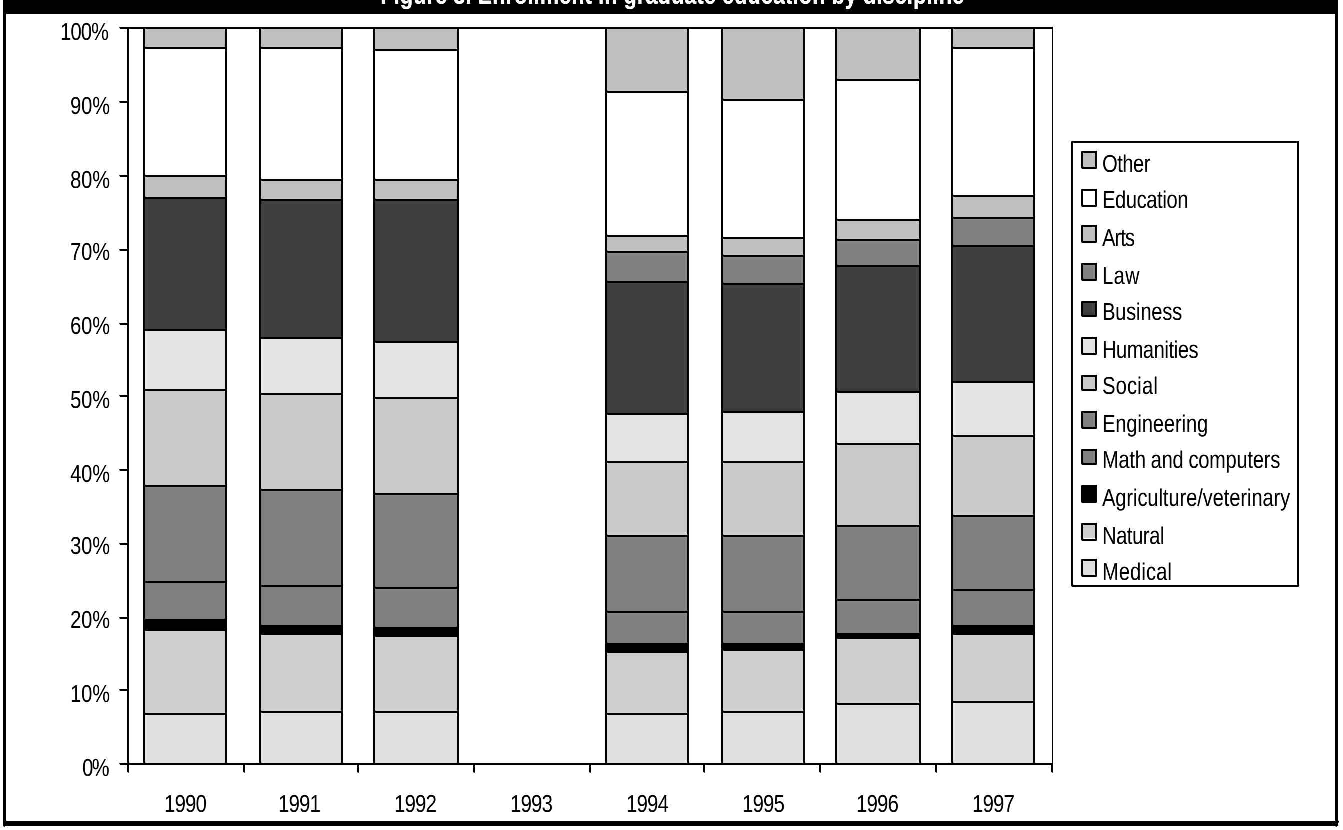
Many of the changes to the British traditional apprenticeship model have been inspired by the American graduate education system. This latter system places more emphasis on teaching as a means of introducing substantial elements of training. Furthermore, it is a system in which teams of academics act as advisors for Ph.D. projects. Some of these practices have recently appeared

Figure 2. Enrollment in graduate education



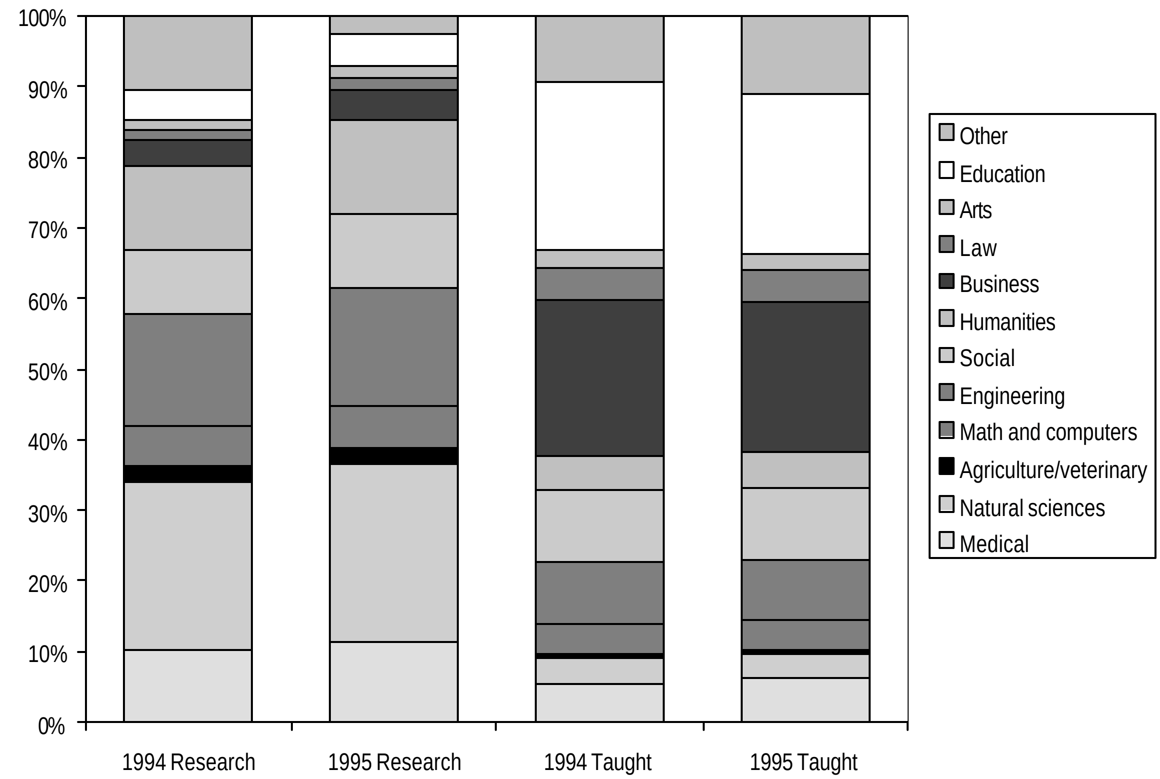
SOURCE: Higher Education Statistical Agency.

Figure 3. Enrollment in graduate education by discipline



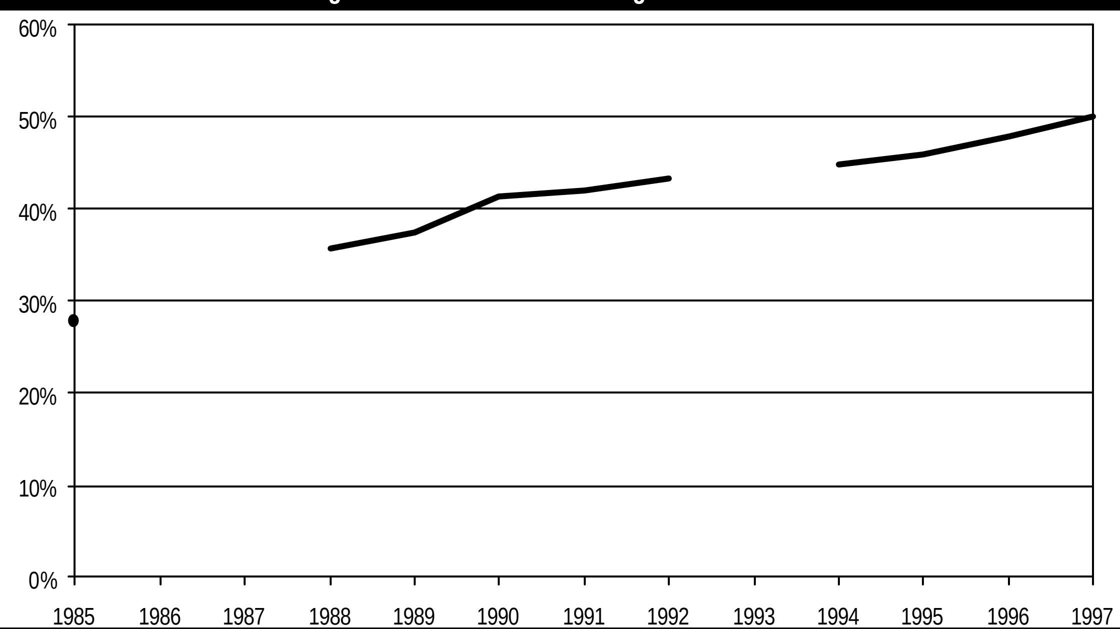
SOURCE: Higher Education Statistical Agency.

Figure 4. Postgraduate enrollment by course and discipline in 1994 and 1995



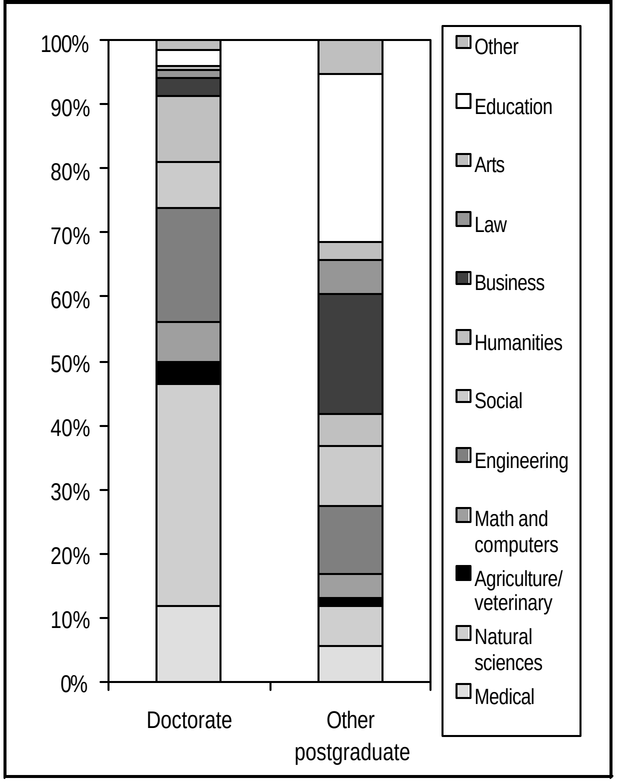
SOURCE: Higher Education Statistical Agency.

Figure 5. Female enrollment in graduate education



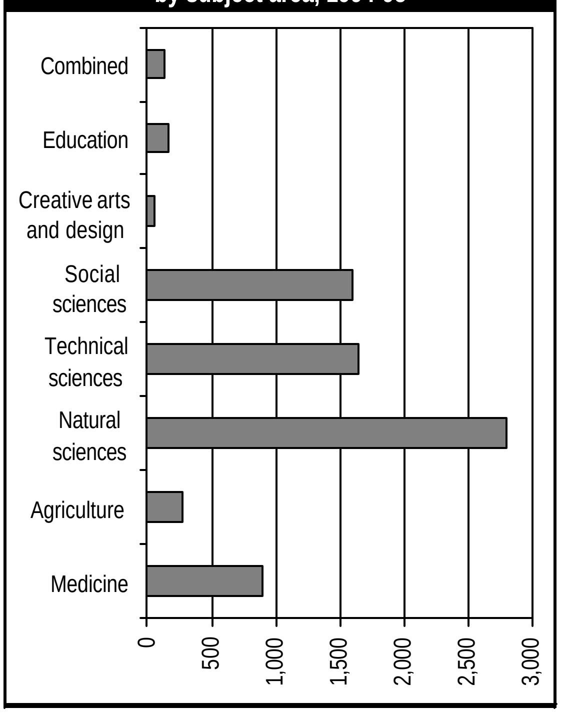
SOURCE: Higher Education Statistical Agency.

Figure 6. Degrees awarded in 1994 by discipline



SOURCE: Higher Education Statistical Agency.

Figure 7. Number of doctorates awarded by subject area, 1994-95



SOURCE: Higher Education Statistical Agency (1998c).

in the United Kingdom, as efforts have been made to incorporate coursework into the Ph.D. program. These courses are designed to broaden students' perceptions of their disciplines, but also to teach the research skills needed to complete a research thesis. Since the *Swinnerton-Dyer Report*, the debate about research training—and hence the criticism about the traditional model—has mainly been about the length of time to degree and the poor submission rates of Ph.D. theses, and about the elements of training to be incorporated into the Ph.D. program. These are addressed below.

Submission Rates and Program Length

In its report, the Advisory Board of Research Councils recommended that full-time Ph.D. students should complete their program within 4 years. The traditional Ph.D. was being criticized as overly ambitious, and the board suggested that topics should be defined so that completion within a 4-year period would become feasible. The reasons the report gave for poor completion rates were as follows (ABRC 1982):

- poor supervision, especially in the early stages;
- lack of adequate knowledge of research techniques; and
- low student motivation.

Since the publication of the report, the research councils have introduced a sanctions policy to improve national submission rates by disqualifying departments or universities with a low number of students submitting a thesis within 4 years of receiving financial support. The attention to submission rates was caused by reasons concerning funding of graduate education and by the future employment prospects of Ph.D.s (Burgess et al. 1995). Concern has been expressed about the large amount of government funding used to support research students for 3 years of full-time study when the return on this investment, in terms of completed Ph.D.s, is low. Furthermore, it was recognized that, in an environment of limited job opportunities in higher education, it was in the students' best interest to complete as quickly as possible.

Training Process in the Ph.D. Program

The question of whether the education and training process in the Ph.D. program should be emphasized has been a much-debated issue. According to the Committee of Vice Chancellors and Principals of British universities, the Ph.D. should be both a *product*—an original contribution to knowledge—and a *process*, involving the training of a researcher. The only way to accomplish this goal within 4 years is to define the thesis topic carefully and to accept the notion of a Ph.D. program with formal training elements complementing the original research work. This structure was regarded as a way of broadening the narrow, traditional Ph.D., while helping to improve completion rates. Critics of this approach note that it is difficult to combine both formal training elements and research into a coherent package. There have also been suggestions that the Ph.D. thesis should be replaced by a series of research papers on a variety of topics linked to a central theme. However, the idea of a single thesis making a substantial contribution to a discipline is considered a powerful concept which seems likely to remain dominant (ABRC 1982).

The main participants in this debate were the funding councils and the higher education institutions. Much of the pressure to reform the graduate research training process in the 1980s came from agencies responsible for funding training rather than from the universities that provided the training. There was considerable opposition within universities to the introduction of the research councils' sanctions policy and considerable argument about the nature of the Ph.D. Now that a consensus has been reached over the fundamental requirements of the Ph.D. (an original contribution to knowledge carried out as part of a research training process in a fixed period of time), the debate has moved on to the functioning of institutional policies and practices. Questions have been raised as to whether these policies sufficiently contribute to the production of trained researchers. The academic structures of most institutions were developed primarily to cater to undergraduates. Graduate education is mainly still managed as an extension of undergraduate programs, often without the necessary resources. In addition to its structure, the size of graduate training programs might create problems. Many departments are too small to support a doctoral program with a thriving graduate community (Burgess et al. 1995).

After the release of the *Swinnerton-Dyer Report*, the government remained rather quiet about graduate education until the early 1990s. In a 1993 White Paper on Research, *Realising Our Potential*, the Technology Foresight Initiative was announced; its intent was to bring together the industrial community and the communities of science and engineering. In this report, attention is paid to the relationship between higher education and the research base. Part of the Technology Foresight Program was a wide-ranging consultation of panels representing key sectors of the economy. Although many issues raised by this consultation have a general rather than a specific relevance to graduate education, some of the wider concerns might have implications for graduates in terms of funding structures and priorities for research topics. The specific objectives of the Technology Foresight Program were as follows:

- to encourage close interaction and networking between the science, engineering, academic, business, and government communities;
- to build a common understanding between these communities of the challenges, concerns, and emerging opportunities in markets and technologies; and
- to provide guidance on priority areas of the 1993 white paper.

In the mid-1990s, two committees were key in the development of graduate education. Their reports were named after their chairmen: the *Harris Report* (HEFCE, CVCP, and SCOP 1996) and the *Dearing Report* (National Committee of Inquiry Into Higher Education 1997). The *Harris Report* focused solely on graduate education and recommended a framework of degrees, specifying the length, level, and title of each program; it also noted that there should be sufficient public funding to support graduate students. The *Dearing Report*, on the other hand, focused on the entire higher education sector and hardly mentioned graduate education in particular. It did, however, endorse the recommendations of the Harris Committee. One of the recommendations in this latter report was to develop a framework of standardized degrees and qualifications, and to increase the transferability of credits between institutions. It was put forward that master's degrees should be standardized and awarded only at the graduate level. The standardization of degrees should prevent this diverging range of recognition of degrees. The committee further recommended taught program degrees.

According to Blume (1995, p. 29), "graduate training is being gradually decoupled from its traditional association with an academic career toward education and training." The U.K. research councils have developed a number of schemes, which include a variety of relationships between students, industry, and educational institutions. The production of original research, however, remains central to the purpose of graduate education. The current challenge is to ensure high-quality training in research (given political priorities and financial constraints) that emphasizes both product and process (Burgess, Band, and Pole 1998).

In general, one might say that universities have made efforts to reform graduate education. There has been a move away from the apprenticeship model toward a program of research training that includes coursework, the appointment of joint supervisors, and a careful monitoring of progress by a research committee. Most institutions now have strict limits on the length of the research thesis. To ensure and control the quality of graduate education, some institutions have looked at the American graduate school model. In the early 1990s, a few graduate schools were established in the United Kingdom; presently, there are indications that certain other institutions will also change the administration of graduate education. In 1992, the chairman of the Advisory Board of Research Councils stated that (Ince 1992, p. 18):

> The idea of British graduate schools represented a strand of thinking which is now becoming quite common. A new center of gravity has to be found which gives a greater role to the research mentality. Leading universities increasingly need to be places that think of themselves as producers of research and as centers of systematic research training instead of places that happen to do some research and research training alongside their undergraduate training.

Changes in this direction are being made, but are still in progress.

Patterns of Support

Public funding for graduate education comes mainly from two sources: the funding councils and the research councils. The funding councils do not provide financial support for graduate students but provide the capital and some of the equipment for both research and teaching. The research councils make grants available for research and studentships for graduate education. Sources of support for postgraduate students in 1996-97 are shown in table 1.

Table 1. Sources of support in 1996-97

Source	Full-time	Part-time
Total	7,629	13,551
No award or financial backing	3,344	6,308
UK LEA mandatory/discretionary awards	2,095	333
Institutional waiver of support costs	296	426
Local government	8	1
Research councils and British Academy	593	18
Charities and international agencies	60	39
Governmental authorities	440	1,152
EU Commission	65	103
Other overseas sources	63	13
UK industry and commerce	202	3,867
Absent/no fees	29	176
Unknown	434	1,115

SOURCE: Higher Education Statistical Agency (1998).

The research councils are public bodies funded by the government. The roles of the three principal public funding bodies before 1993 are explained below.

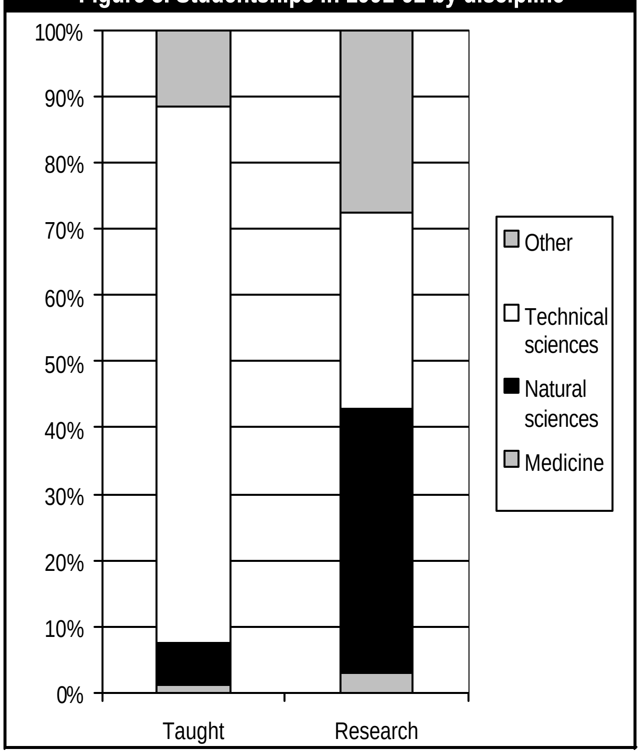
- **Economic and Social Research Council (ESRC).** The ESRC makes available approximately 300 research awards for full-time graduate research training (M.Phil. or Ph.D.) in the social sciences at recognized institutions. The council makes a distinction between so-called "Mode A" and "Mode B" departments. Mode A departments have demonstrated that they can provide formal training in research methods and techniques in the first or foundation year of the program, according to ESRC guidelines. They accept ESRC-funded students without previous graduate research training for full 3-year awards. Mode B departments can only take ESRC-funded students with a foundation in research training; usually, these students have completed a master's program that teaches research methods.

- **Science and Engineering Research Council (SERC).** The SERC awards approximately 2,355 research studentships each year. There are two types of awards: standard awards and the Cooperative Awards in Science and Engineering (CASE). Standard awards are allocated by the SERC as quotas to departments in institutions, which nominate eligible candidates. A small number are awarded to individuals on a competitive basis. The cooperative awards give students experience in research in an industrial environment.

- **British Academy.** Before 1992, the British Academy gave approximately 500 major studentships each year through its national awards competition. The majority of these provided 3 years of funding for research students in the humanities. Since 1992, the total number of awards as well as the number of 3-year awards have increased. Of the 400 3-year awards offered each year, 100 would be available to students without postgraduate experience and 300 would be restricted to students with 1 year's postgraduate research training.

Other research councils are the Medical Council and the Natural Environment Research Council. The research councils' studentships vary across disciplines. Figure 8 shows the number of studentships in 1991-92 by discipline.

Figure 8. Studentships in 1991-92 by discipline



SOURCE: Office for Science and Technology (OST). Annual Review of Postgraduate Awards 1992/1993. Unpublished.

Although the ESRC started to fund part-time students through a national competition, most part-time graduate students finance their own studies or are financed by their employers. The latter source of support is more common for taught master's degrees than for research master's or Ph.D.s because of the link between master's degrees and employment. Some universities provide their own studentships, which are mainly awarded to students who have been unsuccessful in the research councils' or British Academy's competitions. A studentship generally involves a maintenance award (equivalent to a research council or British Academy grant), together with payment of fees (Burgess et al. 1995). Furthermore, universities employ graduate students as class teachers or have developed teaching assistant programs.

Following the publication of the government white paper *Realising Our Potential* in May 1993, the research councils' system of funding has changed. There are now six research councils, five that provide funding for sciences and technology, and one funding the economic and social sciences:

- Biotechnology and Biological Sciences Research Council,
- Engineering and Physical Sciences Research Council,
- Medical Research Council,
- Natural Environment Research Council,
- Particle Physics and Astronomy Research Council, and
- Economic and Social Research Council.

In addition, the British Academy looks after the humanities.

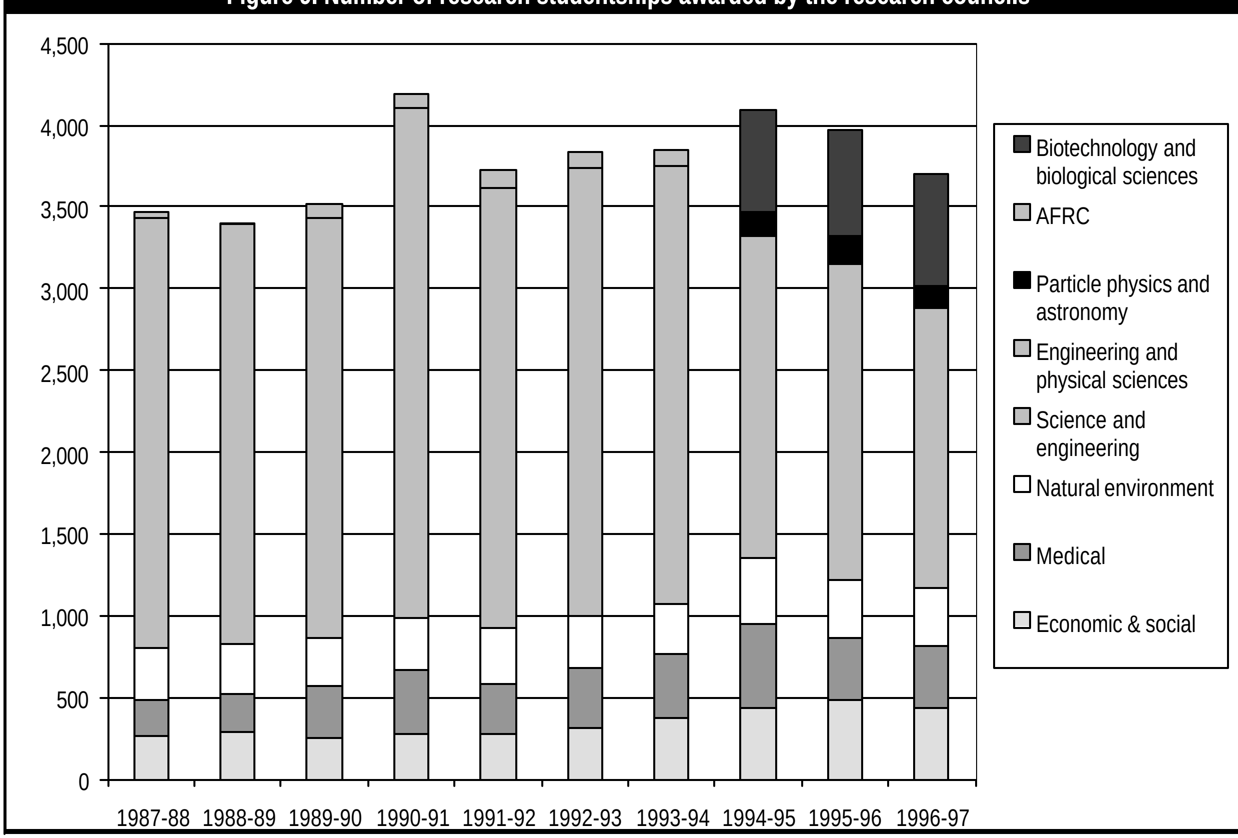
The six councils are government agencies reporting to the Office of Science and Technology; they grant funding for individual postgraduates. The competition for research funding is intense, with only a small percentage of candidates making successful applications. There are three types of funding given by the research councils (CSU 1998): advanced course studentships, which are master's level taught courses; research master's training awards; and standard research studentships, which are for Ph.D. or M.Phil. students for programs of up to 3 years full time or 5 years part time. Some of the research councils give CASEs, which are similar to standard research studentships but involve cooperation with a partner in industry. The research councils set their own level of payment, but all awards for British students include tuition fees (a payment straight to the institutions); a maintenance grant; and a contribution toward travel, fieldwork, materials, and other expenses.

To qualify for a full award, candidates should be resident in the United Kingdom and possess a first-class or an upper second-class degree (a lower second-class degree is the minimum requirement for an advanced course studentship from the Natural Environment Research Council or Engineering and Physical Sciences Research Council). Each council regularly reviews academic departments and programs, and allocates advanced course studentships through a quota system to the departments of the approved programs. The departments can select the candidates they believe to be most qualified. Figure 9 shows the number of research council studentships from 1987-88 until 1996-97.

Employment Patterns

For most of those who start a graduate program, an academic career remains the central objective (Becher, Henkel, and Kogan 1994). The strength of this aspiration, however, varies by discipline. In the humanities and social sciences, academic careers are the prime goal of those who register for doctorates. Although this goal is also strong in the natural sciences and technology, the aspiration level in these disciplines is lower when there are good employment possibilities in commercial or other nonacademic activities. Especially in many branches of chemistry and biochemistry, doctoral training is considered applicable to both theoretical and applied areas. Various studies of the employment of social science Ph.D.s show that employers generally do not consider a doctorate to be a significant advantage (Pearson et al. 1991). Employment trends for people with a Ph.D. degree in the social sciences indicate that higher education is the major employer. A larger proportion of those holding a taught master's than of Ph.D. recipients go into industry and commerce or the public sector; a smaller proportion enters academic life (table 2).

Figure 9. Number of research studentships awarded by the research councils



SOURCE: Office for Science and Technology (OST). Annual Review of Postgraduate Awards. Unpublished.

Table 2. First employment destinations of Ph.D. and Master's degree recipients, 1989 and 1992 (percentages)				
Destination	Ph.D.		Master's	
	1989	1992	1989	1992
Permanent academic appointment	4.2	3.6	2.0	2.0
Fixed term academic appointment	23.1	22.5	5.0	4.0
Further training	1.6	2.6	9.5	9.0
(School) - teacher training	1.0	1.1	0.8	1.0
Private sector (industry or commerce)	22.7	17.7	35.7	29.0
Government or other public sector	5.5	6.1	9.5	9.0
Other employment	1.8	1.8	1.0	2.0
Not employed	7.0	8.6	3.0	3.0
Unknown	22.6	25.4	28.5	38.0
Overseas	10.6	10.6	4.0	3.0

SOURCE: Office for Science and Technology (OST). Annual Review of Postgraduate Awards. Unpublished.

The first destinations of U.K. resident postgraduates in 1996-97 are shown in table 3.

One of the primary purposes of the Ph.D. is still considered to be the preparation of the future generation of academics. The limited number of vacancies available, however, largely frustrates this aim. At the same time, outside the research context, the Ph.D. does not appear to enhance job prospects. Employers are likely to be more impressed with the promise of all-around capability of a master's degree-holder than with the more narrowly focused competency associated with doctoral qualifications.

For the most part, research education is a risky investment. On the one hand, the advantage of a Ph.D. compared to undergraduate degrees is absent in a whole range of nonacademic occupations. On the other hand, only a minority of Ph.D.s are given the opportunity to secure their most preferred employment. The policies proposed in the 1993 white paper could reduce some of these uncertainties. The taught master's program can function as a selection mechanism through which all potential doctoral students should pass. The resulting fewer entrants will in this way find less competition for academic posts. In fact, their employment possibilities will be even better, since more academic posts will become available due to a large outflow of retired academics. By increasing the number of master's degrees and reducing the number of Ph.D.s in areas where there is a surplus of Ph.D.s as compared with academic labor market requirements, the connection with the labor market should be recovered.

Table 3. First employment destinations of U.K. resident postgraduates, 1996-97		
Destination	Doctorate degree	Other postgraduates
Entered work	3,356	8,258
Returned to/remained with previous employer	573	1,802
Self-employed	83	450
Entered study or training	163	2,022
Seeking employment or training	97	687
Not available for employment/studies/training	83	350
Percentage with known destinations	77.5	73.2

SOURCE: Higher Education Statistical Agency (1998a).

Patterns of International Mobility

In 1991, over 46 percent of the graduate students in British institutions were from overseas. The large increase in overseas full-time graduate students, both in absolute numbers and in comparison with U.K. students, is shown in table 4.

In the 1990s, the relative number of all overseas full-time postgraduate students decreased. British postgraduate education, however, remained an attractive destination for European Union (EU) students. In 1994, 9 percent of full-time postgraduate students were from non-British EU countries (figure 10). This was mainly because students from EU countries were eligible for tuition fees

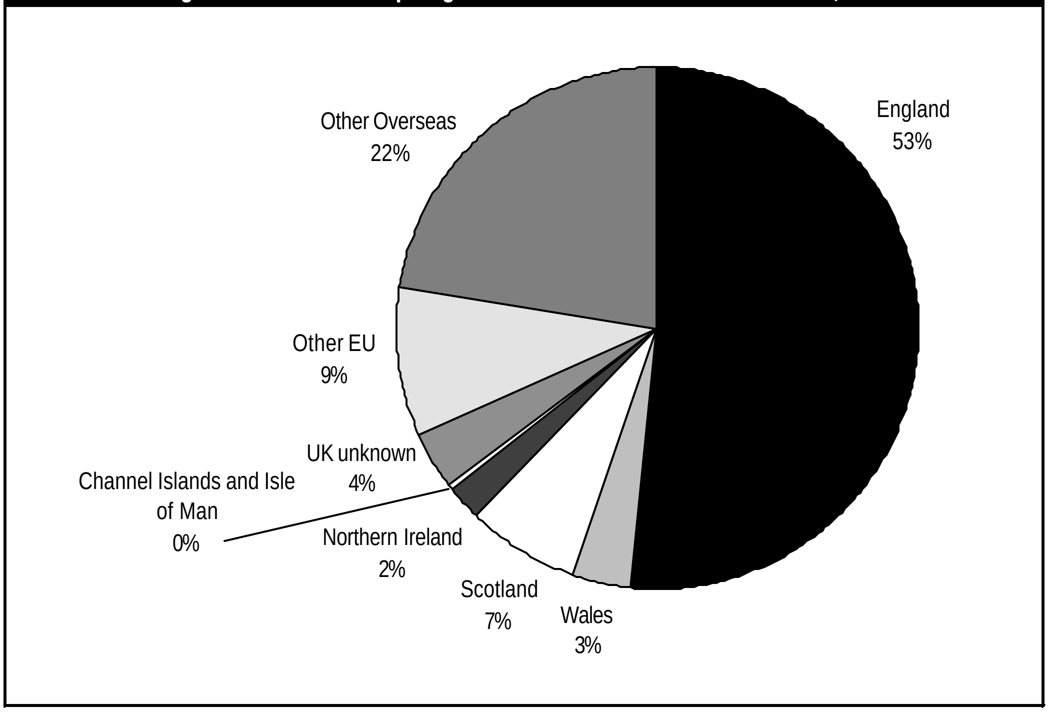
Table 4. Numbers of U.K. and overseas students from 1981-82 to 1990-91				
Year	Total students in postgraduate program	Number of U.K. students	Number of overseas students	Overseas students as percentage of total
1981-82	34,276	20,941	13,335	38.9
1982-83	33,903	20,610	13,293	39.2
1983-84	35,928	21,582	14,346	39.9
1984-85	37,563	22,377	15,186	40.4
1985-86	40,498	23,384	17,114	42.3
1986-87	42,824	24,144	18,680	43.6
1987-88	43,733	23,465	19,268	44.1
1988-89	44,175	23,899	20,276	45.9
1989-90	45,644	24,247	21,397	46.9
1990-91	49,950	26,537	23,413	46.9

SOURCE: Office for Science and Technology (OST). Annual Review of Postgraduate Awards. Unpublished.

at U.K. rates. In four subject areas, overseas students even outnumbered British students: veterinary science, agriculture and related studies, business and financial studies, and engineering and technology.

The internationalization of graduate education in the United Kingdom has raised several policy questions. Some programs are fashioned deliberately to meet the needs of overseas students. In some cases, it is expected that programs would not even be viable without overseas students. Because departments gain no financial advantage from overseas students—and, in some cases, might even lose money offering these programs—a ceiling may be placed on EU admissions.

Figure 10. Domicile of postgraduate students in U.K. institutions, 1994



SOURCE: Higher Education Statistical Agency (1998c).

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THE AMERICAS

Postgraduate Degrees and Researcher Training in Argentina

Mario Albornoz, Ernesto Fernández Polcuch, and Ingrid Sverdlick

Recent Transformations of Argentina's Higher Education System

The expansion of higher education systems that began after World War II is a phenomenon shared by practically every country, regardless of its unique modes and traditions. There are other features in common besides expansion: among others, the separation into various levels (including the rapid growth of higher nonuniversity education), the fostering of research, and the development of postgraduate education. Osvaldo Barsky (1997) states that three of the factors that contributed to this process were the following: (1) a certain causal relationship between higher education becoming *massified and segmented*; (2) the scientific and technological explosion, and the subsequent broadening of the *knowledge-based economy*; and (3) the political determination of national states to contribute to the expansion of higher education systems, emphasizing advanced studies.

Barsky cites another series of factors that specifically have a bearing on the development of postgraduate studies. These factors allow us to depict the differences in the models and specific characteristics that postgraduate training acquires in each country, regardless of the general trend. Some of these factors are exogenous and others endogenous as regards university institutions; Barsky specifies them as the following:

- the *centralized or decentralized nature* of the higher education system;
- the *size* of university institutions;
- the *unity of teaching and research* as derived from the Humboldtian conception of higher education;
- the *organizational logic* of research activities in the realm of the university; and
- the *concern for reducing costs* (as a result of the massification of higher education), added to research and development (R&D) policies that tend to concentrate research and the training of a critical mass of scientists working in certain key subjects.

Besides the above-listed factors, one should also take into account the scientific and academic tradition of a country, and, as a general context, its degree of economic development and industrialization.

Analysis of the development processes of postgraduate training using the criteria outlined above helps explain the different directions they have taken in countries that—to an untrained eye—have similar structural characteristics, such as Brazil and Argentina. Although both countries share many features and at present belong to a common market (the MERCOSUR), their degree of industrialization is different, as are the historical processes through which both societies acquired the features that may be termed "modernization"; among these the diversification of the social structure and the level of education of the population. In the 1960s, when Brazil reformed and expanded its system of higher education and postgraduate training, the prevailing feature was that of an accelerated and successful industrialization process, which exerted pressure on the social structure of incipient modernization.

Argentina carried out a reform of higher education during the first years of this century; its society was "modern"—in line with the most advanced in Europe—although its economy was based on revenues from farming and agriculture. Some of these reform features lingered until the 1960s, and the Argentine scientific system achieved a certain splendor. This infrastructure enabled some researchers to be awarded the Nobel Prize in the sciences. In those years, however, the delay in industrialization was beginning to be felt, and the economic crisis that was to come later was starting to take shape.[1] This had an influence on the higher education expansion process, which

[1] Development of a thesis on the asymmetries between modernization and industrialization can be found in Suárez (1972).

was basically geared toward traditional professional training rather than to the training of the high-level human resources industry demanded. In that context, postgraduate training in Argentina remained significantly backward vis-à-vis that in other countries, such as Brazil.

It is worth pointing out that the expression "new trends in higher education" is, to a large extent, a euphemism for "the spread of the U.S. model of higher education." In fact, many features of the new model are customary in that country: the segmented structure, the role of research, the training of scientists and engineers, and the fact that higher education is not free, combined with the availability of a variety of private sources for donations and fellowships. Also—unlike in other countries—private universities are a major feature of the system.

This model is in keeping with the basic U.S. political philosophy, in which education and science are not responsibilities delegated to the federal government; this implies that the government does not act directly upon the fields of education and science. During World War II and after, American society carried out very complex debates aimed at establishing the extent to which the federal government should play a role in fostering fields of science and technology. The spread on a worldwide scale of the U.S. model has to do with its success in the context of the American economy, and with the importance that the United States itself has ascribed to this issue, which has been expressed in periodical reports alerting Americans to the strategic value of knowledge ranging from the historical *Science, the Endless Frontier* (Bush 1945) to the most recent *Unlocking Our Future* (U.S. House of Representatives 1998).

The relevance of the process of reform in higher education, and the training that scientists and engineers are undergoing in almost every country in the world, is also in keeping with Daniel Bell's theory of the post-industrial society, according to which knowledge is the central characteristic of the transformations of a social structure (Bell 1974). Therefore, institutions concerned with knowledge (particularly universities) become all-important institutions in society, and, at the same time, they themselves go through great transformations. Bell warned, however, that his statements applied to a handful of countries and could not be applied to developing countries.

The development of competitive conditions and their ideological unfolding accelerated the process of reform in higher education during the 1980s and forced changes in countries that had originally resisted adopting this model. It is natural, however, that the model's spread turned out to be wider and swifter in countries that put active policies of industrial development into practice, such as Brazil; and that it should be faced with greater difficulties in countries with more traditional social structures, such as Argentina.

Higher Education in Argentina

The Argentine Tradition

Postgraduate studies have a short tradition in Argentina, as a result of the university model that was strongly established in the country since the beginning of this century and which has remained without structural changes for decades in a context of economic crisis and scarce industrialization. It was only in this last decade that a great expansion in postgraduate training has been taking place and that certain symptoms of reform and updating of the higher education system as a whole can be perceived.

The Argentine university system is very old and dates back to the early colonial period. The first university founded in present-day Argentine territory was what is today the Universidad Nacional de Córdoba, created in 1610. The Universidad de Buenos Aires was established in 1821 after Argentina became independent from Spain. In the last years of the last century, as of Sarmiento's presidency, successive governments put into practice policies supporting education and science as part of a project to build a modern state that would break away from the colonial tradition and unify the country after decades of civil war. During his term, President Sarmiento invited, in 1870, the American astronomer Benjamin Gould and a group of collaborators to live in Argentina; they created the Córdoba Astronomic Observatory. President Sarmiento's speech at the inauguration of the astronomic center is regarded as one of the founding documents of science policy in Argentina.

Development of the contemporary Argentine university system has been influenced by two strong traditions: the Napoleonic model, whereby the state takes on the responsibility of higher education and the regulation of professions with a rigid, compartmentalized bureaucratic structure; and the model of the German scientific university created by Wilhelm von Humboldt, which gives precedence to research. In 1891, the Universidad Nacional de La Plata was created; it was expressly informed by the Humboldtian model. In fact, it was not a mere adoption of the model, but rather involved cooperation with German scientists. This university was very active in some domains and paved the way for the first development of a modern school of physics in our country.

With varying force, both influences converged to underscore the responsibility of the state in matters of higher education. This became a lasting feature in the Argentine educational model, which has a strong public preeminence. In 1918, the University Reform movement established the autonomy of universities and the concept of “shared government”—i.e., participation of students and graduates in the government of the university. That tradition is ensconced in the present Law of Higher Education (Law #24.521, Ley de Educación Superior—LES), which legalizes autonomy and shared government as basic principles of the university system.

In spite of the fact that the Humboldtian tradition lies at the very foundation of the Argentine university model, the weight of the “professionalist” trend became dominant. It should be emphasized that in this area, the Argentine university was successful. It trained professionals at an internationally renowned level and responded to a growing demand for higher education. Nevertheless, the hegemony of the professionalist trend meant that teaching became a part-time dedication and a supplement to professional work outside the university, among other consequences.

Since the beginning of the century, one of the main conditions the Argentine scientists have laid claim to has been that of having full-time employment status for some university posts, with a salary that allowed them to devote themselves entirely to teaching and research. The resolution of this conflict was rather peculiar. Not many full-time posts were created, but in 1958, the Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET) was established. The CONICET was conceived of as a structure with paid staff, organized hierarchically and serving as “career researchers.” Originally, this “career” was supposed to be supplementary to teaching at the universities; the CONICET was intended as the means by which university researchers would be given full-time posts.

In the 1960s, the University of Buenos Aires, which is the biggest and most important institution in the Argentine university system, was able to organize several high-level research teams in almost all scientific fields, mainly in the biological and health sciences. The University of La Plata was also able to build a strong synergy with the CONICET and thus reinforced its Humboldtian roots. Other public universities achieved similar good results in the consolidation of their research capacities.

That golden age turned into a crisis in 1966 when military forces interrupted the democratic process. Police forces invaded university campuses, striking teachers, scientists, and students alike. As a result, several of the most renowned scientists and engineers left the country and went into political exile. A very long process of scientific migration for political reasons thus began; this process would be repeated time and again over subsequent years. Argentina’s resulting “brain drain” was far more serious than that of other Latin American countries.

From this point on—and especially during the dictatorial government inaugurated in 1976—the CONICET became detached from the university system. It created its own institutes, and the “career” gradually became an endogenous instrument of the scientific community, rather than a stimulus to university research. Thus the training of researchers became, for more than 30 years, a question that strictly pertained to the CONICET, alienated from the universities. Only in recent years has this trend begun to be reversed, with universities again having high-level researchers. The relationship between the CONICET and the universities has improved, and most CONICET researchers work at university centers. However, the structural malformation remains. Even today, only one-eighth of university teachers have full-time employment status. Low university budgets, resulting in low university salaries, make it difficult to reverse this process—and make full-time employment in academic work unattractive.

During the last 10 years, the Argentine university system has undergone a new process of reform; this is taking place in a rather disorderly fashion, and mainly under the auspices of the federal government, which tends to deprive it of legitimacy in the academic world. Resorting to several legal instruments (the LES and decrees issued according to regulations), specific university programs, and new funding mechanisms in the Argentine university system (FOMEC, for example, which is dealt with below), the government—via the Ministry of Culture and Education—intends to regulate and organize a transition toward a model that is closer to international contemporary tendencies.

The Argentine curricular model has continental European roots and is drawn more from the old French and German models than from Anglo-Saxon tradition. Undergraduate courses are long: theoretically, they take 5, 6, or even 7 years to be completed, depending on the university degree (the real duration of the entire course of study is often even longer). Given such length, curricular content is often equivalent to a 4-year university course plus a master's degree in the Anglo-Saxon model. This explains why development of postgraduate training is very recent; such development is related to the need for an internationally homologous structure rather than to demand for new forms of knowledge.

Until very recently, Ph.D. degrees were restricted to the physical and natural sciences, and only those who wished to take up a scientific career applied for a Ph.D. In the health sciences field, postgraduate studies took on the form of specialization courses. In all other fields, especially those related to professions, postgraduate studies were quite uncommon.

THE SYSTEM OF HIGHER EDUCATION

Higher education in Argentina consists of a university system and a nonuniversity system (colleges for teacher training, or for humanities, social work, technical, professional, or artistic training). The university system includes the universities and university institutes; these are different from nonuniversity institutes because they are dedicated to a single field. Both types of institutions can be either public or private; in the latter case, however, certification by a public institution is required.

Within the higher education system, it is the exclusive prerogative of university institutions to grant undergraduate degrees (*licenciado* and other professional equivalents) as well as postgraduate master's or Ph.D. degrees. In keeping with the LES, an undergraduate degree is required in order to be admitted to postgraduate training.

As of May 1998, there were 88 university institutions: 36 national public universities, 22 private universities with permanent authorization, 20 private universities with provisional authorization, and 6 private university institutes. As shown in table 1, although most public universities had already been created at the beginning of this decade, there has been a strong growth in private universities and university institutes; this is a result of the government's 1989 higher education policy to encourage development of the private higher education system.

In 1996, the Argentine university system had 953,801 students. Eighty-five percent studied at public universities, and the rest attended private ones. The number of students in public universities increased by 3.6 percent in the 1993-96 period. The rate of annual growth of private university students is the highest, amounting to 6.5 percent in the 1985-94 period. Over the last decade, the private sector has grown enormously, especially in terms of number of institutions. The student population is still only 15 percent of the total, however. Private universities have a very low impact on the training of scientists and engineers, and are mostly devoted to training for professional careers in the social sciences.

THE POSTGRADUATE SYSTEM TODAY

GENERAL FEATURES

Academic postgraduate training is beginning to emerge in Argentina. However, it is highly regulated by laws, government decrees, and university resolutions. According to this series of regulations, there are three

Table 1. Growth of universities in Argentina, 1990-97

Institutions	1990	1991	1992	1993	1994	1995	1996	1997
Total	60	66	67	69	76	82	87	89
National universities	29	29	31	31	33	36	36	36
Private universities with permanent authorization	21	22	22	22	22	22	22	22
Private universities with provisional authorization	5	9	10	12	17	18	18	20
National university institutes	3	4	-	-	-	-	5[a]	5[a]
Private university institutes with permanent authorization	2	2	2	2	2	2	2	2
Private university institutes with provisional authorization	-	-	2	2	2	4	4	4

[a] The National University Institute of Art, created by Decree # 140 (Dec. 3, 1996) is not open at present.

KEY: (-) = not applicable

SOURCE: National Commission for University Evaluation and Certification (CONEAU).

types of postgraduate courses: specializations, master's, and doctorates. Each of these has its own profile and degree; institutional conditions for teaching the postgraduate courses; syllabus characteristics (including number of hours); academic body requirements; and prerequisites concerning equipment, library, document centers, and other related matters.

The LES put into force in 1995 requires that postgraduate degrees be certified. This task has been delegated to an organization created by the LES, the National Commission for University Evaluation and Certification (CONEAU). The LES states that the processes for certifying postgraduate courses must be carried out according to the Ministry of Culture and Education in consultation with the University Council.

In order to certify postgraduate courses, the CONEAU must make a public summons, via the university institutions themselves, and then report to the National Inter-University Council, which comprises the presidents of public universities, and the Council of Private University Presidents. The CONEAU certifies specializations, master's, and doctorates upon the recommendations of expert peer committees.

During the last months of 1997, the CONEAU made the first summons to certify specializations in the health sciences, which mainly comprise postgraduate courses and projects in the fields of medicine and dentistry. Two hundred and ninety-two recommendations have been presented and submitted for approval. In 1998, the rest of the university specialization courses were summoned (251 presentations were received) along with master's and doctorates (which are still open, although it is estimated that there will be 600 to 700 applications).

In law, medicine, dentistry, architecture, engineering, and—to a lesser degree—pharmacy and biochemistry, there are specializations; in agronomy as well as in economics and the administrative sciences, there are master's degrees. In the exact sciences, natural sciences, and humanities—and partly in pharmacy and biochemistry—there are doctorates.

As far as funding is concerned, only 18.8 percent of postgraduate activities receive funding from sources outside the university. This setup is not so different in private universities: few institutes receive funds from large corporations. In general, the financing of postgraduate courses comes from the student's registration fee.

Expansion of Postgraduate Courses: Means of Regulation

The supply of postgraduate degrees in Argentina increased to 1,071 in 1996. This is equivalent to a 35 percent growth in only 2 years. The main growth was in the postgraduate courses offered by public institutions, which amounted to 40 percent. By type of postgraduate course, the segment of greatest growth was the master's degree at almost 70 percent.

If we consider the last 15 years, the total supply of postgraduate courses grew by 234 percent. Besides the quantitative increase, the structure of the supply changed, since specialization and master's courses have multiplied, and the rate of expansion was much greater than that for doctorates. In 1982, there were 205 doctorate courses, master's courses hardly existed, and specialization courses amounted to 97. The present state of affairs is represented in table 2.

Table 2. Supply of postgraduate courses, 1994 and 1996

Level	1994			1996		
	Total	Public sector	Private sector	Total	Public sector	Private sector
Total	792	518	274	1,071	725	346
Specialization	303	216	87	420	290	130
Master's	245	151	94	415	290	125
Doctorate	244	151	93	236	145	91

SOURCE: Barshy, Osvaldo, *Los posgrados universitarios en la República Argentina* (University Postgraduate Courses in Argentina). Buenos Aires: Troquel, 1997 and National Commission for University Evaluation and Certification (CONEAU).

In comparing the years under consideration (1994 and 1996), the postgraduate system expanded by 38.6 percent in terms of specialization courses and by just under 70 percent for master's; the supply of doctorate courses, on the other hand, fell by 3.27 percent. Table 3 shows the breakdown by field in specialization courses; note the strong prevalence of the health sciences and, to a lesser extent, the law as courses of study.

Out of 681 doctorate and master's courses offered in 1998, only 26 percent (176) were certified by the CONEAU. Of those certified, 93 percent were offered by public institutions, 57 percent are master's courses, and the rest are doctorate courses. It is worth noting that of 145 doctorate courses offered by public institutions, 50 percent have been certified. In the private sector, this proportion amounts to only 3 percent (see table 4).

Table 3. Specialization courses by field, 1998		
Field	Number of courses	Percent
Total	434	100.0
Health sciences	249	57.4
Law sciences	46	10.6
Administration	37	8.5
Pharmacy and biochemistry	20	4.6
Engineering	14	3.2
Social sciences	14	3.2
Education sciences	13	3.0
Dentistry	11	2.5
Psychology	10	2.3
Architecture	8	1.8
Farming and agriculture	6	1.4
Basic sciences	3	0.7
Humanities	3	0.7
Total	434	100.0
Public institutions	377	86.9
Private institutions	57	13.1

SOURCE: National Commission for University Evaluation and Certification (CONEAU).

Of the certified postgraduate courses, 41 percent are in the basic sciences; 36 percent are in the technological sciences; and 23 percent are in the social, human, and health sciences (table 5). In both the basic and technological sciences, the largest proportion of certified postgraduate courses are categorized as "A," which means they are at the highest level; in the social, human, and health sciences, the largest proportions are rated as "B" and "C," which means their level is intermediate or incipient.

Table 4. Certified postgraduate courses - 1998			
Level	Total	Public institutions	Private institutions
Total	176	164	12
Master's	100	91	9
Doctorate	76	73	3

SOURCE: National Commission for University Evaluation and Certification (CONEAU).

Of the total number of postgraduate courses supplied, about a quarter are in the health sciences, another quarter is in the applied sciences and engineering, and a third quarter is accounted for by the social sciences. The rest of the supply is in the basic sciences and humanities, each of which accounts for about the same proportion (table 6). In the applied, social, and human sciences, there is a predominant supply of master's courses; in the basic sciences, doctorates; and in the health sciences, specialization courses of study.

Table 5. Certified postgraduate courses in the public system by field, 1998				
Field	Total	A	B	C
Total	164	63	64	37
Basic sciences	67	30	24	13
Technological sciences	59	28	23	8
Social, human, and health sciences	38	5	17	16

KEY: A= Postgraduate course categorized as highest level.
B= Postgraduate course categorized as intermediate level.
C= Postgraduate course categorized as incipient level.

SOURCE: National Commission for University Evaluation and Certification (CONEAU).

Registration and Graduation

Barsky has estimated the number of students registering for postgraduate courses to be 20,180 in 1994, of which 57 percent were master's and doctorate students and 43 percent were students attending specialization courses (table 7). The recent expansion in the supply of courses seems to have had a direct effect on demand, since the available figures now show a more than 50 percent increase. Note, however, that these data are from different sources, and that the 1994 data presented by Barsky come from the certification of postgraduate programs, while the 1997 data are from a census taken by the Ministry of Culture and Education. This would suggest that 1994 data are underestimated and that growth has been slower than that shown in table 7.

Table 6. A breakdown of the postgraduate course supply by field (percent)				
Field	Total	Specialization	Master's	Doctorate
Total	100	100	100	100
Basic sciences	13.1	1.9	13.3	29.8
Applied sciences and engineering	25	15.6	31.1	30.4
Health sciences	26.3	52.7	11	8.8
Social sciences	24.3	24.8	30.6	14
Human sciences	11.3	5	14.1	17

SOURCE: National Commission for University Evaluation and Certification (CONEAU).

During the 1950s and 1960s, Argentina turned out more than 5,000 Ph.D.s per decade; in the 1970s and 1980s, this figure dropped to 3,000. In the current decade, changes in field breakdown have made it difficult to ascertain changes in the number of Ph.D.s by area of study. However, as table 8 shows, the total remains practically constant.

Table 7. Postgraduate student registration

	1987	1994	1997
Total	-	20,180	31,914
Specialization	-	8,750	13,165
Master's and doctorates	9,006	11,430	18,749

KEY: (-) = not applicable

SOURCES: 1987 and 1994 data are from Barshy, Osvaldo, *Los posgrados universitarios en la República Argentina* (University Postgraduate Courses in Argentina). Buenos Aires: Troquel, 1997 and 1997 data are from the Ministry of Culture and Education.

The Universidad de Buenos Aires is the institution responsible for awarding the largest proportion of postgraduate degrees—41.2 percent.

By field of study, of the 1,129 Ph.D.s. trained in the 1989-93 period in the basic and technological sciences, 72 percent received their degrees in the exact and natural sciences, 4 percent in engineering, and 0.2 percent in farming and agricultural sciences (table 9).

By fine field within the basic and technological sciences, most (53 percent) Ph.D.s received their degrees in interdisciplinary areas, 14 percent in pharmacy, and less than 10 percent in chemistry and biology. There were between 4 and 5 graduates per year (2 to 4 percent) in geology, physics, civil engineering, math and computing, astronomy, and chemical engineering. There were also some Ph.D.s in the areas of electrical engineering, geophysics, agronomy, and veterinarian medicine; there were no Ph.D.s in architecture, communication engineering, industrial engineering, and mechanical and mining engineering during this period (table 10).

Fellowships for Postgraduate Studies and Researcher Training

The organization that has usually granted fellowships for training researchers and for postgraduate studies at home and abroad is the CONICET. When new programs, such as the Fund for the Improvement of University Quality (Fondo para el Mejoramiento de la Calidad Universitaria—FOMEC), were put into effect, CONICET participation decreased; it has, however, managed to keep up a high percentage of fellowships, especially for all postgraduate studies carried out in the country. Recently, the Ministry of Culture and Education created a program for postgraduate training (PROFOR), which also grants fellowships for postgraduate studies abroad and administers programs together with the Fulbright Foundation and the Ministry of Education/Coordination for the Improvement of Higher Education Personnel from Brazil. Other organizations have their own postgraduate training policy in their area of competence, such as the National Institute for Public Administration, the National Institute of Farming and Agricultural Technology, and the Universidad de Buenos Aires itself, among others.

The CONICET

The CONICET was created February 5, 1958, with the aim of orienting, fostering, and subsidizing scientific and technological research, as well as supporting activities in both the public and private sectors. It also aims to foster scientific cooperation and exchange at home and abroad.

Table 8. Graduates from doctorate courses

Field	1950-54	1955-59	1960-64	1965-69	1970-74	1975-79	1980-84	1985-88[a]	1989-93[b]	1996[c]
Total	2,578	2,603	2,462	2,745	1,983	1,391	1,534	1,146	1,402	347
Basic sciences and technology	764	583	542	504	750	650	684	676	1,129	228
Social sciences	471	449	279	508	341	181	145	79	111	61
Human sciences	44	26	32	33	66	46	77	41	101	27
Medical sciences	1,299	1,545	1,609	1,700	826	514	628	350	61	31

[a] Note that this is a 4-year period, rather than 5 as elsewhere.

[b] In this period, changes were made in the disciplinary breakdown.

[c] These are the last available data

SOURCES: Data for 1950-93 are from Barsky, Osvaldo, *Los posgrados universitarios en la República Argentina* (University Postgraduate Courses in Argentina). Buenos Aires: Troquel, 1997; 1996 data are from the Ministry of Culture and Education.

Table 9. Graduate degree recipients by field of study and type of degree, 1989-93

Field of study	Total	Specialization	Master's	Doctorate
Total	6,500	3,847	1,251	1,402
Basic sciences and technology	2,594	1,202	263	1,129
Agricultural and farming sciences	197	0	195	2
Architecture	52	52	0	0
Engineering	1,233	1,147	37	49
Exact and natural sciences	835	-	19	816
Biochemistry, pharmacy, chemistry	277	3	12	262
Social sciences	2,456	1,404	941	111
Administration and economics	1,727	950	764	13
Law and political science	688	415	177	96
Other	41	39	0	2
Humanities	107	4	2	101
Philosophy and literature	65	-	1	64
Education	3	0	0	3
Other	39	4	1	34
Medical sciences	1,343	1,237	45	61
Medicine	1,237	1,163	45	29
Dentistry	82	50	0	32
Health sciences	24	24	0	0

SOURCE: Barsky, Osvaldo, *Los posgrados universitarios en la República Argentina* (University Postgraduate Courses in Argentina). Buenos Aires: Troquel, 1997.

Table 10. Ph.D.s in basic and technological sciences, by fine field, 1989-93

Fine Field	Ph.D. graduates	Percent
Total	1,129	100
Astronomy	22	1.9
Biology	88	7.8
Physics	37	3.3
Geophysics	1	0.1
Geology	47	4.2
Math and computing	24	2.1
Chemistry	102	9.0
Agronomy	1	0.1
Veterinarian medicine	1	0.1
Civil engineering	26	2.3
Communication engineering	0	0.0
Electrical engineering	3	0.3
Industrial engineering	0	0.0
Mechanical engineering	0	0.0
Mining engineering	0	0.0
Chemical engineering	20	1.8
Architecture	0	0.0
Pharmacy	160	14.2
Interdisciplinary	597	52.9

SOURCE: Barsky, Osvaldo, *Los posgrados universitarios en la República Argentina* (University Postgraduate Courses in Argentina). Buenos Aires: Troquel, 1997.

To meet these objectives, the CONICET, like its counterpart science-promoting agencies around the world:

- sponsors Scientific and Technological Researcher Career and a Staff Support Career (R&D);

- provides assistantships and fellowships for the training of university graduates or for doing specific research work at home or abroad;

- subsidizes and fosters scientific technological research aimed at achieving scientific and technological progress, and supports activities for this kind of research, in both the public and private sectors;

- fosters scientific and technological exchange and cooperation at home and abroad; and

- provides organization and subsidies for institutes, laboratories, and research centers, which usually operate in universities and other private or public institutions, or even within the CONICET itself.

For a long time, the CONICET was the only entity that gave fellowships for the training of researchers and highly qualified human resources both at home and abroad.

However, the training of researchers did not necessarily involve acquiring a postgraduate degree. The reason for this was that there was a very limited tradition of doctorate studies in Argentine universities; and—on the other hand—a certain "patriarchal" or magisterial culture in Argentine science, according to which the training of new researchers was conceived of as the practice of researchers working with a master or being included in a research team. This process included a "beginner" level and an "updating" level. The fellowships granted by the CONICET were either of these two types. They did not necessarily require obtaining a Ph.D. degree, not even when they were granted to train researchers abroad.

The fellowships offered by the CONICET for the training of researchers were considered a practically indispensable prerequisite for entry into a "researcher career"; thus, the CONICET tried to regulate the number of fellowships to be given every year according to the vacancies available in the course of studies. In those years when entering this course was highly restricted, conflicts arose with the fellows whose aspirations were frustrated. The negative consequences of this situation ultimately have affected the researcher career itself, bringing about an overall aging of the researcher staff roster. This situation changed in 1997, when entry to the course was expanded; the course has since been enlarged by almost 20 percent.

The fact that the CONICET did not require a doctorate of its fellows complied with the policy of regulating the number of fellows according to registration, and limited the number of fellowships the organization offered. Since, in practice, the fellowships stretched out much farther than the previously established 4 years, it was quite usual for a CONICET fellow to remain for up to 7 years (and sometimes even longer) in the status of a researcher-trainee. Obviously, this reduced the organization's capacity to give other fellowships due to budget limitations.

The reordering of the higher education system and of the fellowship system are solutions that have been tried during the past years to put an end to this problem. At present, fellows must have a postgraduate degree, and a Ph.D. is now necessary to enter the researcher career. The CONICET has finally created fellowships for postgraduate studies that do not necessarily involve the training of a researcher, with a wider criterion of what is known as high-level human resources.

Among the innovations in the CONICET fellowship system are postdoctorate fellowships in corporations as a way of including trained researchers in the productive sector. Also, the CONICET has created a system of fellowships to strengthen the technological development of skills and the transfer of technology.

THE FOMEC

The Fund for the Improvement of University Quality, created in 1995, was designed to provide financial support for reform processes and to improve the quality of national universities. Improving the level of postgraduate courses offered by Argentine universities is one of the central aspects of the FOMEC program; with this program, both the supply (through the support of certified courses) and the demand (through fellows for young teachers) are funded. Funding to strengthen supply only applies to state universities, since Argentina does not subsidize the private sector university system except in the research area.

Before the LES was given legal force, rules were established and practices developed to evaluate postgraduate courses, since the FOMEC needed a mechanism to assess and certify the supply of postgraduate courses in order to fund their development according to their level of certification. In 1995, the Commission for the Certification of Postgraduate Courses (Comisión de Acreditación de Posgrados) was created, which carried out the first process of certification. In this first experience, 27 percent of master's and doctorate courses offered in the country were certified, qualified, and classified into three ranks: A, B, and C. Postgraduate courses certified as A—and, exceptionally, those ranked as B—were authorized to admit fellows funded by the FOMEC program.

Table 11. Fellowships given by the FOMEC, 1995-97

Level of study	Total	At home	Abroad	Mixed
Total	1,780	1,007	705	68
Master's	805	501	304	
Doctorate	675	368	239	68
Postdoctorate	207	45	162	

SOURCE: Fondo para el Mejoramiento de la Calidad Universitaria (FOMEC).

FELLOWSHIPS FOR POSTGRADUATE COURSES

In 1997, there were 3,824 fellows in Argentina attending postgraduate courses with fellowships provided by national organizations (table 12). One-third of the fellowships awarded (32 percent) were for studies abroad; the remaining 68 percent were for postgraduate studies pursued in the country.

Fifty-one percent of the fellowships (1,940) were given or administered by the Ministry of Culture and Education; 47 percent (1,783) were granted by science and technology organizations; and 2 percent were from other offices of the national administration, mainly for the training of the staff itself or for a diplomatic course of studies.

Contrary to the trend of increasing enrollment for postgraduate courses in Argentina, the CONICET fellowships, traditionally a major institution in this matter, decreased between 1993 and 1998 from 1,926 to 1,210—a 37 percent drop (table 13). The reasons for this decline

Table 12. Total active fellows, 1997

Total	3,824*
Ministry of Culture and Education	
FOMEC	1,687
International Co-operation	170
PROFOR	52
PROFOR/FULLBRIGHT	11
CAPES, Brazil	20
Science and Technology Organizations	
CONICET	1,210
INTA	120
CNEA	47
INTI	6
UBA CyT	400
Others, Public Administration	
ISEN	40
AFIP	40
ISEG	15
INAP	6

NOTE: *This figure must be interpreted as stock, since it stands for the number of postgraduate students whose fellowship was in force, regardless of the year it started.

SOURCE: National Council of Science and Technology Studies (CONICET).

are outlined above. The 1995 creation of the FOMEC as an entity that also provides grants greatly increased the supply of fellowships and seems to have compensated for this drop.

Fellowships to Study Abroad

Most of the 1,210 fellows studying abroad in 1997 were funded by the FOMEC (64 percent); the next largest sources of fellowships were those provided as part of the international cooperation mechanisms sponsored by the Ministry of Culture and Education, and CONICET fellowships to study abroad.

Table 13. CONICET: number of fellows, as of last month of each year

Level	1993	1994	1995	1996	1997	1998
Total	1,926	1,970	1,764	1,705	1,503	1,210
Beginner	622	523	548	571	523	529
Updating	1,013	1,251	664	544	569	537
Postdoctoral	2	2	540	578	411	144
Others	289	194	12	12	0	0

SOURCE: National Council of Science and Technology Studies (CONICET).

Table 14. FOMEC: fellowships to study abroad and mixed fellowships, 1995-98

Level	Basic sciences and engineering	Social, human, and health sciences	Total
Total	508	265	773
Master's	145	159	304
Doctorate	213	94	307
Postdoctorate	150	12	162

SOURCE: Fondo para el Mejoramiento de la Calidad Universitaria (FOMEC).

FOMEC Fellowships

Out of the 773 FOMEC fellowships provided for study abroad, 40 percent are for doctorates, 39 percent for master's, and 21 percent for postdoctorates (table 14).

Two-thirds of the fellowships are for basic science and engineering courses (primarily in doctorate programs). One-third is allotted to the social, human, and health sciences (primarily in master's programs). Most postdoctorate fellowships are in the basic sciences and engineering.

CONICET Fellowships

Of the 94 CONICET fellowships to study abroad still in force, 38 percent are for fellows pursuing doctorates in the United States, 18 percent in Great Britain, and 15 percent in France; the remaining fellowships are for doctoral study in Spain, Holland, Germany, Australia, Canada, and Italy (table 15).

These figures can be correlated to a great extent to the proportion of publications coauthored by Argentine and foreign scientists. Of the publications produced in collaboration with other countries between 1991 and 1995 and recorded in the Science Citation Index, 38 percent had U.S. coauthors; 15 percent had Spanish coauthors; 13 percent each had French and Brazilian coauthors; and 12 percent were collaborations with German authors.

Table 15. CONICET: fellows studying abroad by country (as of August 31, 1998)

Country	Fellows	Percent
Total	94	100
Australia	2	2
Canada	2	2
France	14	15
Germany	4	4
Great Britain	17	18
Holland	8	9
Italy	2	2
Spain	9	10
United States	36	38

SOURCE: National Council of Science and Technology Studies (CONICET).

Fifty-nine percent of the CONICET fellowships abroad correspond to stipends for postdoctoral courses and 40 percent for doctorate courses. The postdoctoral courses are mostly in the natural and exact sciences. In the social sciences and humanities, there is a prevalence of doctorates.

Thirty-nine percent of the fellowships abroad are for the natural and exact sciences, followed by the technological sciences (19 percent), social sciences (15 percent), farming and agriculture (13 percent), humanities (10 percent), and medical sciences (4 percent).

Fellowships in the Country

There are a total of 2,614 fellows doing postgraduate work in Argentina with grants provided by public institutions; of these, 1,116 (43 percent) were granted by the CONICET and 914 (35 percent) by the FOMEC. A significant amount of fellowships was awarded by the Universidad de Buenos Aires, which contributes toward postgraduate studies; these awards do not necessarily imply course attendance (i.e., the recipients might be doing research only).

Table 16. CONICET fellowships abroad in force as of August 31, 1998

Field	Total	Master's	Doctorate	Post-doctorate
Total	94	1	38	55
Agricultural sciences	11	1	6	4
Biological sciences	11	-	-	11
Engineering and technology	10	-	6	4
Physical sciences	8	-	-	8
Chemical sciences	7	-	-	7
Chemical engineering	6	-	1	5
Earth sciences	6	-	-	6
Economics	5	-	5	-
Math and computing	5	-	2	3
Medical sciences	4	-	1	3
Sociology	4	-	4	-
Law	3	-	3	-
Philosophy	3	-	3	-
History	3	-	2	1
Architecture	2	-	2	-
Political sciences	2	-	1	1
Anthropology	1	-	-	1
Philology	1	-	1	-
Linguistics	1	-	1	-
Veterinarian sciences	1	-	-	1

KEY: (-) = not applicable

SOURCE: National Council of Science and Technology Studies (CONICET).

CONICET Fellowships

Of the CONICET's 1,210 active fellowships, 92 percent are local fellowships. Of these, 47 percent are beginner fellowships, which are mainly for master's courses; 45 percent are fellowships for advanced courses through doctorates; and 8 percent are fellowships to take postdoctorates (table 17).

By field, 49 percent of the CONICET fellowships (547) are in the exact and natural sciences, where updating fellowships prevail; 16 percent (175 fellowships) are in the technology area, where both beginner and updating fellowships prevail; 15 percent (171 fellowships) are in medical sciences, with an equal amount for beginner and updating courses; 9 percent are in the humanities with a net prevalence of beginner fellowships; 6 percent are in the social sciences, which are mostly for beginner fellow-

Table 17. CONICET, total fellowships as of May 1998				
Field	Total	Beginner	Updating	Post-doctorate
Total	1,210	529	537	144
Medicine	175	75	72	28
Biology	160	63	72	25
Chemistry	156	61	77	18
Physics	116	42	62	12
Earth	112	45	49	18
Chemical Engineering	100	33	54	13
Agronomy	66	33	30	3
History	60	36	21	3
Engineering	58	33	23	2
Sociology	45	27	16	2
Math	40	15	19	6
Architecture	35	18	12	5
Literature	24	13	10	1
Philosophy	23	12	5	6
Law	22	14	7	1
Economics	14	6	7	1
Others	4	3	1	0

SOURCE: National Council of Science and Technology Studies (CONICET).

ships; and 5 percent (55 fellowships) go to the agricultural sciences, with a slight predominance of beginner fellowships.

FOMEC Fellowships

Out of the FOMEC's total 1,687 fellowships, 914 (54 percent) are for local fellowships. Of these, 377 are open grants directly allocated to the postgraduate courses (table 18). Fifty-five percent of the local fellowships are for master's degrees, 40 percent for doctorates, and 5 percent for postdoctoral degrees. This same scheme, with some slight differences, applies to the basic sciences and engineering, and to the social, human, and health sciences.

Table 18. FOMEC local fellowships, 1995-98			
Level	Total	Basic sciences and engineering	Social, human, and health sciences
Total	914	695	219
Master's	501	358	143
Doctorate	368	298	70
Postdoctorate	45	39	6

SOURCE: Fondo para el Mejoramiento de la Calidad Universitaria (FOMEC).

Table 19. FOMEC fellowships granted by field, 1995-98	
Total	1,687
Subtotal, Basic Sciences and Engineering	1,140
Biology	83
Physics	113
Computing	89
Math	93
Chemistry	97
Engineering courses	251
Farming and agriculture sciences	301
Other basic sciences	113
Social, Human and Health Sciences	547

SOURCE: Fondo para el Mejoramiento de la Calidad Universitaria (FOMEC).

The exact and natural sciences account for 28 percent of the total FOMEC fellowships; farming and agricultural sciences, 18 percent; engineering, 15 percent; and the social, health, and human sciences, the remaining 32 percent (table 19).

Final Remarks

Postgraduate studies and the training of researchers in Argentina have traditionally been shaped on a peculiar model that is hard to compare with that of countries that have adjusted their higher education systems to the Anglo-Saxon tradition—more specifically, to the American model.

Having a curricular model that is long and grants degrees called *Licenciaturas* (similar to a bachelor's degree in Britain), postgraduate careers have not become widespread or properly rooted in the Argentine universities, except in the exact sciences and specializations in the field of medicine. The scientific system has been geared toward training researchers through apprentice-master relationships rather than via formal doctorate studies. Added to this is the country's relatively low level of industrialization, which is manifested in a low demand for highly trained engineers.

Recently, the situation has begun to change, more due to government pressure than to societal demands. The prevailing criterion in these recent changes is to adjust Argentina's educational and scientific systems to new international trends. This process is just beginning and has little legitimacy inside the academic world; moreover, under the present circumstances, it is very disorderly. However, it is possible to consider the expansion of graduate education as a trend to be strengthened in the future.

There are not enough data available to assess the international mobility of scientists and engineers in Argentina. Nevertheless, in examining co-publications, it can be noticed that only 23 percent of the articles by Argentine authors in the Science Citation Index in the period between 1991 and 1995 are done in collaboration with other countries (Fernández, Gómez, and Sebastián 1998). This figure is by far the lowest in Latin America. There are two main reasons for this fact. The first is that the Argentine scientific community is isolated from the rest of the world, mostly due to a lack of policy instruments facilitating international mobility. The second derives from the greater degree of autonomy and maturity of the Argentine scientific community, mainly because of its longer tradition as compared to other Latin American countries.

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Graduate Education in Brazil

Beatriz Santana, Marcos Palatnik, Jacqueline Leta, and Leopoldo de Meis

Introduction

The development of scientific and technological infrastructure and the formation and expansion of the academic community in Brazil has been focused on three different strategies over three periods (Marcuschi 1996).

1. During the 1950s and 1960s, research activities began to be formally organized and received great incentives from the Federal Government. In this period, the most important scientific and technological funding institutions were established in the country, among them the National Council for Scientific and Technological Development (CNPq, linked to the Ministry of Science and Technology) and the Coordination for the Improvement of Higher Education Personnel (CAPES, linked to the Ministry of Education). In other words, during these 2 decades, Brazil invested in building up an infrastructure for science and technology.

2. In the 1970s and 1980s, public policies focused on the expansion of graduate programs. During this period, CNPq and CAPES gave significant financial support to master's and Ph.D. programs and offered fellowships for graduate students. The focus was on the training of human resources for science and technology.

3. At the beginning of the 1990s, Brazil recognized the importance of addressing the scientific education of undergraduate students in order to improve their later performance in graduate schools. In this context, CNPq moved to reinforce the Initiation in Science (IC)[1] Fellowship Program, which consists of stimulating the involvement of university students in research being carried out by faculty members.

In this report, we analyze national policies for science and technology and their effects on graduate programs in Brazil. The discussion examines the accomplishments and failures of the federal government as it has attempted to train capable human resources for science and technology. It points out some of the difficulties Brazil still faces regarding the return on investments in personnel for scientific and technological activities. In addition, we discuss the sources and scope of investments in research and development (R&D), which present a great challenge for the country.

Brazilian Graduate Programs: Origin and Main Features

In the period between 1950 and 1980, Brazil experienced great changes, shifting from an agrarian to an industrial economy. A large part of the population migrated from small towns to urban centers, generating serious local and regional imbalances.

Since 1951, CAPES and CNPq have assumed the responsibility for training both scientists and technologists for R&D activities and academic personnel to teach in institutions of higher education. The importance of both agencies in the support of graduate studies was discussed in a recent report by Guimarães and Humann (1995). According to the authors, in 1992-93, these two agencies granted 96.6 percent of all national fellowships;[2] the remaining 3.4 percent was granted by the state agency of São Paulo (FAPESP).

During the 1960s, the industrial complex expanded under the protection of policies that favored domestic, multinational, and state-owned companies resident in Brazil, insulating them from foreign competition (Schwartzman 1995). The policy of protecting internal industry was accompanied by an important public commitment to the development of an infrastructure for scientific and technological activities. Brazil, at this point ruled by a military government, invested in science and technology and created the Second National Development Plan, which protected nascent industries, invested significantly in research, and established the National Program for Graduate Studies (PNPG). According to Guimarães and Humann (1995), "the PNPG was designed as a route for accelerating the training of human resources suitable to supply the urgent need for qualified personnel capable of improving the quality

[1] "IC" from the Portuguese Iniciação Científica.

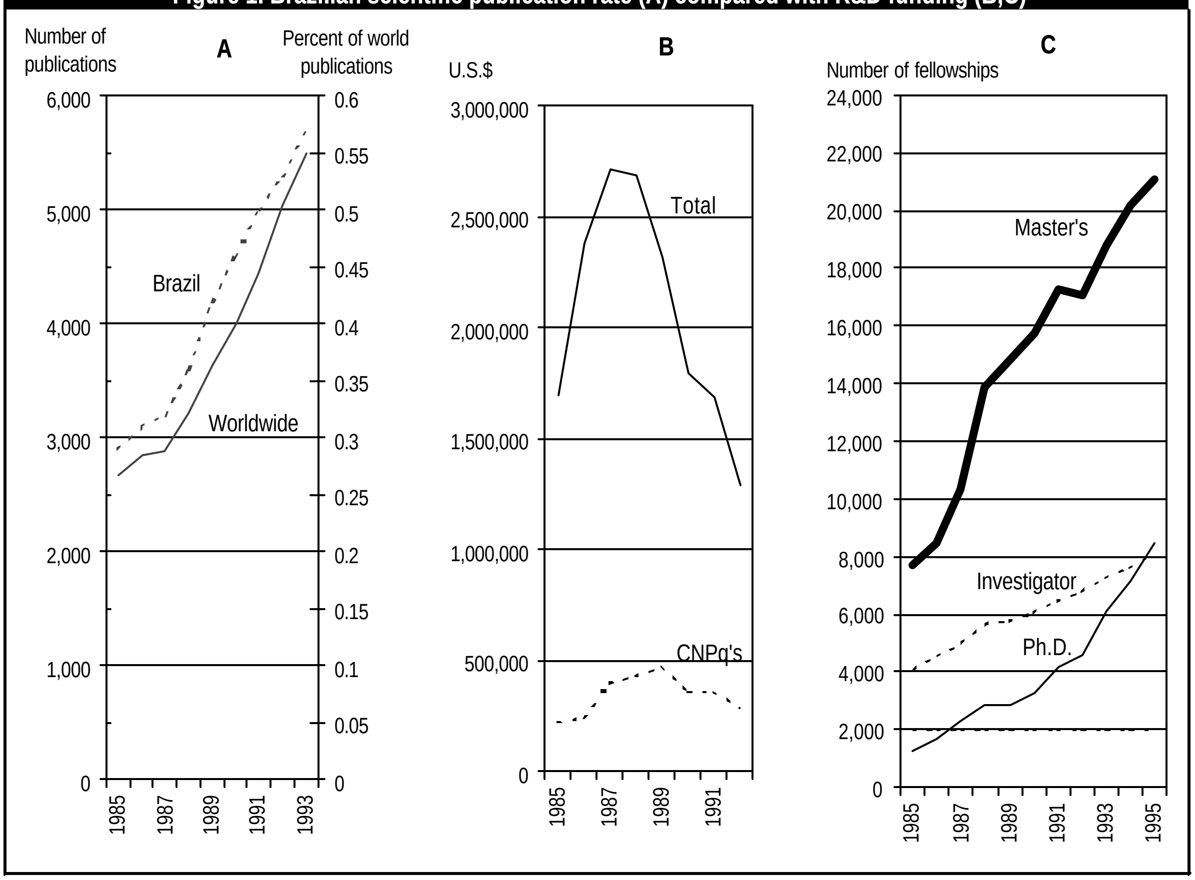
[2] This includes fellowships for specialization and master's, Ph.D., and postdoctoral programs abroad and within Brazil.

of teaching and strengthening the research activity at universities and other institutions." As a result, graduate programs were launched in public universities, and a dynamic fellowship program was established by CNPq and CAPES. Unlike in other countries, to be enrolled in a Brazilian graduate program, students must hold a degree from any of the 922 institutions of higher education established in the country. These students may require first a 2.5-year fellowship to attain a master's degree; after graduating, a 4.5-year fellowship may be required by the student to attain the Ph.D. degree. These are the maximum durations of the fellowships granted by CAPES and CNPq for graduate students.

Having received strong support from the military governments during the 1970s and 1980s, R&D faced a significant drop in federal funds in the early 1990s (figure 1B). Government policy concern is now directed toward developing and strengthening the links between academic research (at universities and research institutions) and private companies.[3]

In spite of problems with funding and the lack of investments from the productive sector, Brazil has succeeded in setting up a significant infrastructure for scientific and technological development. Today, the country has the largest R&D system in Latin America, with 4,402

Figure 1. Brazilian scientific publication rate (A) compared with R&D funding (B,C)



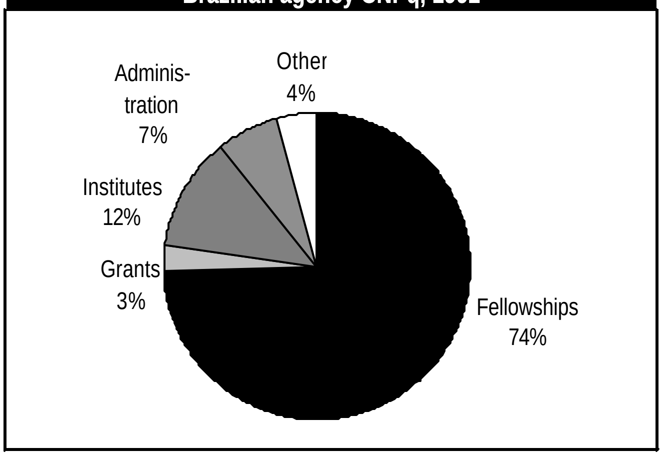
KEY: (A) Annual rate of Brazilian scientific publications from 1985 to1993, either worldwide or by Brazilian share of world's publications.
(B) Total Brazilian resources allocated to R&D and National Council for Scientific and Technological Development (CNPq)'s.
(C) Fellowships granted annually by CNPq and Coordination for the Improvement of Higher Education Personnel (CAPES) for master's students Ph.D. students, and investigators.

SOURCES: Institute for Scientific Information (1993); (CNPq), Relatório Estatístico 1993 Brasilia, 1994; *CNPq O CNPq e a ormação de recursos humanos de C&T para o Brasil, estatísticas de bolsas no pais e no exterior, 1980-95.* Brasília:MCT/CNPq, 1995, and Leta, J., D. lLannes, and L. de Meis. A formação de recursos humanos e a produção científica no Brasil. In M. Palatnik, et al., *A Pos-Graduação no Brasil.* ISBN 85-900550-2-7. Rio de Janeiro, 1998.

[3]Jose I. Vargas, in a speech given during the meeting with state ministers on the announcement of a new economic plan coordinated by Fernando Henrique Cardoso, minister of Finance, June 14, 1993; cited in Schwartzman (1995).

research groups and about 15,000 active scientists and researchers (Schwartzman 1995). The number of publications appearing annually in international journals has increased steadily (figure 1A). In the last few years, the bulk of CNPq's expenditures, which represent approximately 10 percent of total federal investments (compare table 5 with appendix table 1), has been allocated to fellowship programs rather than to grants in aid (which pay for infrastructure and equipment) (figure 2 and appendix table 1). Leta, Lannes, and de Meis (1998b) point out a correlation between support for training human resources (figure 1C) and the annual increase in the number of Brazilian publications (figure 1A). They conclude that investment in the education of qualified personnel is a key variable in determining level of scientific production.

Figure 2. Budget distribution (percent) for the Brazilian agency CNPq, 1992



NOTE: For details, see appendix table 1.

SOURCE: National Council for Scientific and Technological Development (CNPq), Brazil, 1993.

Reforms in Graduate Education

Current reforms in Brazilian education are mostly focused on the elementary and secondary levels. With respect to higher education, some important reforms are (1) the creation of shorter courses in which a student attains a degree in only 2 years, (2) annual evaluation of all institutions of higher education, and (3) a more accurate evaluation of graduate programs every 2 years.

The present system of graduate programs in Brazil dates back to the 1960s when the PNPG was established. Although Brazil has been able to expand its scientific and technological activities, the sector still faces significant problems. One of the difficulties concerns the efficiency of graduate programs, which have been evaluated by CAPES every 2 years. The evaluation process takes into account a series of indicators, among them the curriculum vitae of each faculty member and the average time students enrolled in the program take to graduate. Until 1997, CAPES rated graduate programs in five categories from A to E, with A being the best. In the 1998 evaluation, this scale changed from 1 to 7—the higher the number, the better the program. With this new evaluation, programs rated 2 or below are not allowed to register new enrollments until they achieve a better performance. Among the almost 1,800 programs established in the country, only 23 achieved a rating of 7; of these, 21 were in public universities, 1 was in a federal research institution, and the remaining 1 was in a private university. A national average time required for students to graduate is not available, either using the old or the new qualification scales.

We here present data on the best-rated graduate programs, according to the 1994-95 national evaluation, at the Federal University of Rio de Janeiro (UFRJ), the largest Brazilian federal university in the country. Tables 1A and 1B show how long it took students graduating in 1995, 1996, and 1997 to conclude their master's or Ph.D. coursework. In 1995, none of the "A"-rated master's courses had reached an average of 30 months (2.5 years); in contrast, in 1996 and 1997, the number of master's programs that attained this average increased to 4 and 6, respectively (table 1A).

The performance of the Ph.D. programs was similar. In 1995, only two of the best-rated Ph.D. programs had an average of 54 months for completion (i.e., students in these concluded their studies in 54 months or less—4.5 years). In 1996 and 1997, a larger number of Ph.D. programs achieved this average (table 1B). (For more details about UFRJ's A-rated graduate programs, see appendix tables 2 and 3.) In spite of the improvement in time students spend in UFRJ's A-rated graduate programs, one additional point has to be considered: these courses represent only 33 percent and 23 percent of the total number of master's and Ph.D. programs, respectively.[4]

To improve student performance in graduate programs, during the 1990s, CNPq greatly expanded its IC Fellowship Program. This program allocates to each investigator a number of scholarships to be awarded to un-

[4]At present, UFRJ offers 86 master's programs and 67 Ph.D. programs.

Table 1. Months to obtain a degree in the "A"-rated graduate programs at the Federal University of Rio de Janeiro

A. Master's programs

Months (average)	Number of programs 1995	1996	1997
up to 30	0	4	6
31 to 40	8	13	12
41 to 50	17	8	10
more than 50	4	4	1

SOURCE: Sub-Reitoria de Ensino para Graduados e Pesquisa (SR-2), Universidade Federal do Rio de Janeiro, Rio de Janeiro.

B. Ph.D. programs

Months (average)	Number of programs 1995	1996	1997
up to 54	2	5	7
55 to 65	6	8	5
66 to 75	4	2	3
more than 75	4	0	1

SOURCE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES) indicators for 1995, 1996, and 1996 for "A"-rated master's programs, which were the best qualified programs in the 1994-1995 evaluation.

dergraduate students who are engaged in research projects for 20 hours a week. The main goals of the IC program are to:

- attract a greater number of talented students to academic careers,
- prepare students for graduate work in order to decrease the time they will spend in master's and Ph.D. programs,
- reduce the average age of Ph.D. candidates, and
- improve the quality of future researchers.

The number of IC fellowships increased greatly after 1992, rising from 7,548 in 1990 to 11,440 in 1992 and 18,789 in 1995 (CNPq 1995). This significant expansion in the number of IC fellowships made this program one of the most important initiatives undertaken by the Brazilian government in an attempt to improve the training of scientists. During the last 2 years, CNPq has granted more fellowships to Ph.D. students than to master's. As a result, CAPES is now the main federal agency to grant master's programs.

Trends in Graduate Education

Enrollment and Degrees

Research and technological development in Brazil is carried out at 136 universities (of which 72 are public and 64 private) (INEP 1997); federal research institutions;[5] research institutes linked to state-owned companies; research institutes linked to state governments; and a few private enterprises (mainly in the fields of paper and pulp, computers, automobile suppliers, and steel).

In spite of this apparently diverse group of research establishments, most research in Brazil is concentrated in the public universities. Out of the total 922 institutions of higher education, only 10 public universities (0.01 percent) were responsible for 52.5 percent of all Brazilian publications indexed in the Institute for Scientific Information database during the 1981-93 period (Leta and de Meis 1996). Further evidence of the predominant role of the public universities is the distribution of graduate programs. In 1996, 91.3 percent of graduate programs were offered by public universities; the great majority of graduate students were later hired by these institutions. The growth in the number of graduate courses from 1987 to 1996 is shown in table 2. In this period, the number of master's and Ph.D. programs in the country increased by 37 percent and 63 percent, respectively. As a result of this increase, the total enrollment and the number of graduate degrees awarded annually have also grown (figures 3A and 3B), as has the number of scholarships allocated by CNPq and CAPES within the country (figure 1C).

Although the number of students enrolled in and graduated from master's programs is higher than for the Ph.D., there is a trend toward a decrease. This is suggested by the decreasing ratio of enrollment in master's versus Ph.D. programs (inset, figure 3A). The same is true for degrees awarded (inset, figure 3B). It is important to note that Ph.D. enrollment increased over the 10-year period by 176 percent (from 7,960 to 22,004), while Ph.D. degrees rose by 240 percent (from 872 to 2,972);

[5]Institutions linked to the Ministry of Science and Technology are: the National Institute for Space Research, the National Institute for Research on the Amazon, and the National Institute of Technology; those linked to CNPq: the Brazilian Center for Physics Research, the Center for Mineral Technology, the Institute of Applied and Pure Mathematics, the National Observatory, the National Laboratory of Synchrotron Light; those linked to the Ministry of Agriculture: the Brazilian Corporation for Agricultural Research; and those linked to the Ministry of Health: the Oswaldo Cruz Foundation.

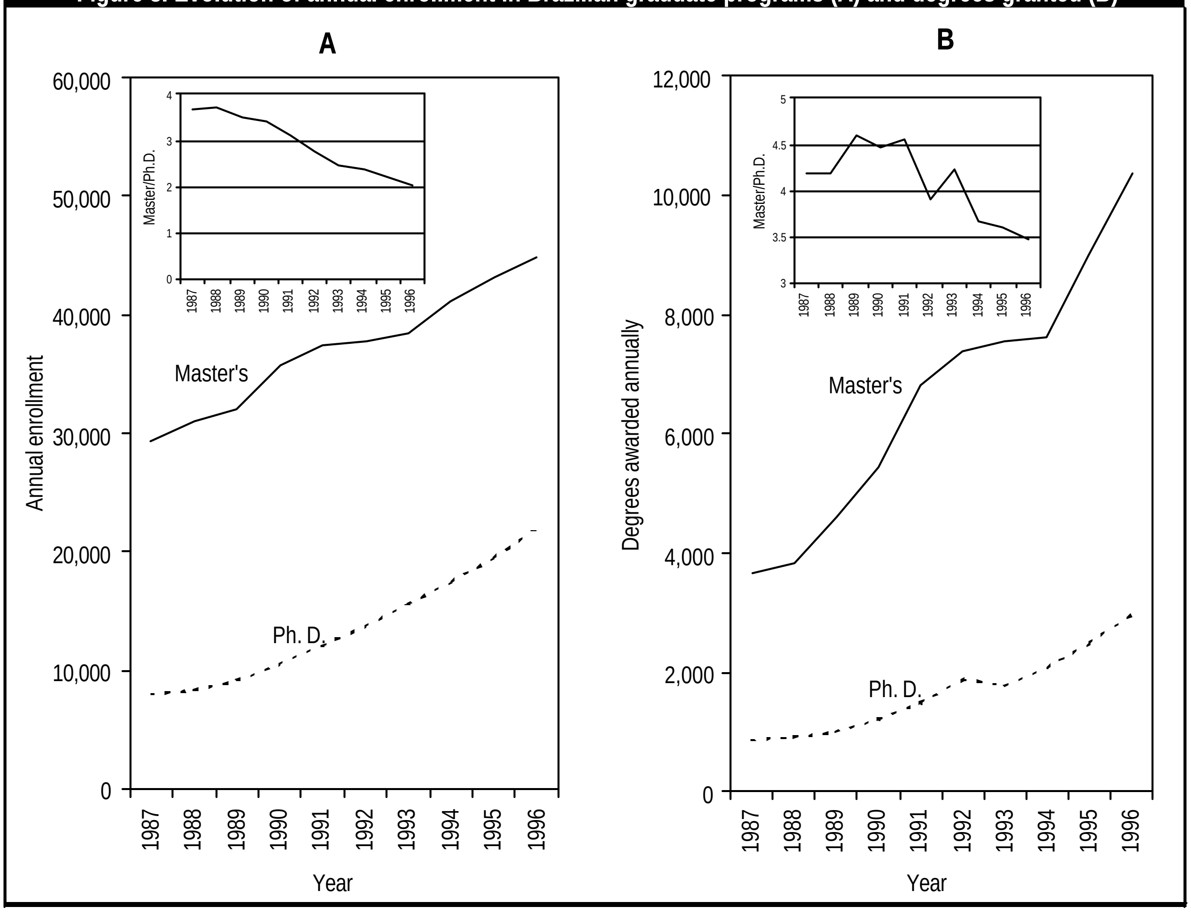
Table 2. Growth in the number of graduate programs in Brazil		
Year	Master's	Ph.D.
1987	861	385
1988	899	402
1989	936	430
1990	964	450
1991	982	468
1992	1,018	502
1993	1,039	524
1994	1,139	594
1995	1,159	616
1996	1,181	627

SOURCE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998.

this indicates an improvement in national capacity for training new Ph.D.s. This tendency is seen across various fields, as shown in appendix tables 5 and 7.

Despite efforts on the part of the Brazilian government to develop a diversified R&D system, the percentage of the population that receives a graduate degree is still very low compared to some other developed countries. In 1996, Brazil's population was 157,070,163 (IBGE 1996)—larger than that of either Germany or the United Kingdom. However, the total numbers of Ph.D. degrees awarded in these latter countries were, respectively, 7.5 and 2.7 times higher than the number awarded in Brazil. Compared with the United States, the difference is even higher: 7.8 times (figure 4A). If we compare the ratio of

Figure 3. Evolution of annual enrollment in Brazilian graduate programs (A) and degrees granted (B)



KEY: (A) Number of students enrolled annually in Master's and Ph.D. courses from 1987-99. Insert: ratio between Master's and Ph.D. enrollments.
(B) Number of degrees conferred annually to master's and Ph.D. students in the same period. Insert: ratio between master's and Ph.D. degrees.

SOURCE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998.

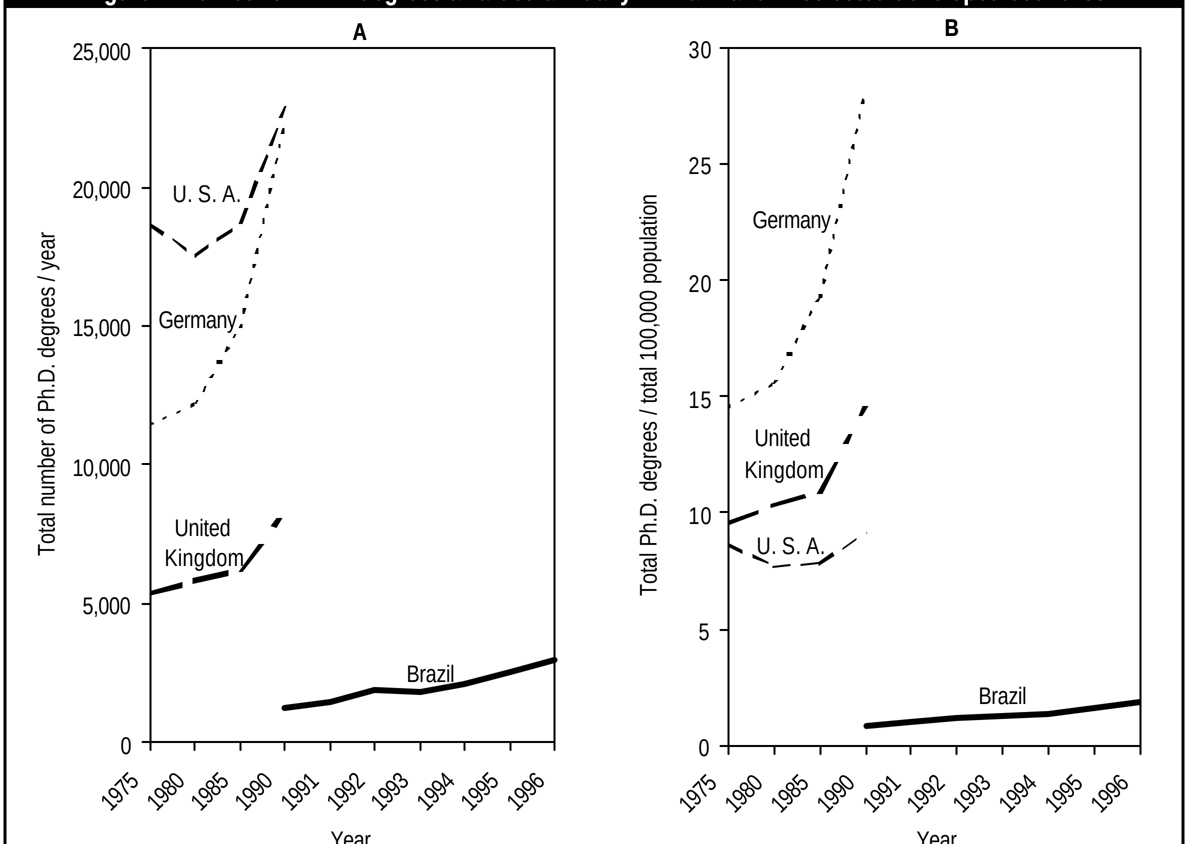
Ph.D.s awarded annually to the total population, Germany stands out among the other countries, with almost 30 Ph.D. degrees per 100,000 inhabitants in 1992 (figure 4B). Although this ratio is increasing in Brazil, it is still far below the ideal for a competitive R&D system. It is worth mentioning that, unlike in most developed countries, 41.4 percent of the Brazilian population consists of young people aged 5 to 24 (IBGE 1996). This fact reveals a great challenge for the country's modern education: a small scientific community is responsible for promoting science education to a very large young population (de Meis and Leta 1997). This challenge is a common feature among most developing countries. An effective science education would provide youngsters with the sophisticated scientific and technological skills required to enter the workforce today.

The Overseas Fellowship Graduate Program

Throughout the last decades, CNPq and CAPES have allocated scholarships for students to pursue their studies outside the country as well as within it. Table 3 shows the growth in both types of fellowships awarded by these agencies in 1990-95. It is worth noting that, while the number of fellowships for study within Brazil increased over that time, the number of fellowships for study abroad remained constant.

The master's and Ph.D. students awarded scholarships to study within Brazil receive monthly stipends of about US$600 and US$900, respectively. Students enrolled in public institutions are not charged tuition or labo-

Figure 4. Number of Ph.D. degrees awarded annually in Brazil and in selected developed countries



KEY: (A) Total Ph.D. degrees per year in Brazil, Germay, United Kingdom and United States.
(B) Ratio of number of Ph. D. degrees and total 100,000 population for each country.

SOURCES: For Brazilian data: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998, and IBGE, *Anuário Estatístico do Brasil.* Rio de Janeiro: Fundação Instituto Braileiro de Geografia e Estatística, 1996; for foreign data: National Science Foundation, Division of Science Resources Studies (NSF). *Human Resources for Science & Technology: The Asian Region.* NFS 93-303. Arlington, VA, 1993, and *Human Resources for Science & Technology: The European Region.* NSF 96-316. Arlington, VA, 1996.

Table 3. Scholarships for study at home and abroad awarded by CNPq and CAPES						
Agency and destination	1990	1991	1992	1993	1994	1995
CNPq total	28,696	33,041	37,834	40,955	44,420	52,041
Home	26,542	30,586	34,991	38,218	42,002	49,909
Abroad	2,154	2,455	2,843	2,737	2,418	2,132
CAPES total	14,518	15,611	15,377	21,511	23,124	25,523
Home	12,319	13,557	13,406	19,309	20,922	23,578
Abroad	2,199	2,054	1,971	2,202	2,202	1,945
Total	43,214	48,652	53,211	62,466	67,544	77,564
Home	38,861	44,143	48,397	57,527	62,924	73,487
Abroad	4,353	4,509	4,814	4,939	4,620	4,077

NOTE: Home scholarships include science technician, specialization, master's, Ph.D., postdoctorate, investigator, technician, and industrial science technician. Scholarships abroad include specialization, master's, Ph.D., postdoctorate, "sandwich," and sabbatical leave.

SOURCES: National Council for Scientific and Technological Development. (CNPq), *Indicadores Nacionais de Ciência e Tecnologica 1990-1995.* Brasília: MCT/CNPq, 1995 and Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998.

ratory fees. However, in recent years (1993-97), CNPq and CAPES allocated an additional sum—equivalent to a third of the value of each student's stipend—to the graduate program. These resources are called "bench fees." Considering both stipends and bench fees, the total expenditure for a Ph.D. student enrolled in a graduate program within the country in that period amounted to approximately US$58,000 for a 4-year course.

A Brazilian graduate student who pursues a degree in a foreign institution receives a monthly stipend of US$1,100 and has his or her tuition and other fees paid by one of the two Brazilian agencies (an average of US$10,000 per year). The scholarship can be renewed for a maximum of 4 years. Therefore, at the end of the course, the total cost of educating these students amounts to approximately US$93,000. In addition to the higher costs of studying abroad, the Brazilian government is concerned about the risk of a "brain drain." As noted before, Brazil is still struggling to increase the number of investigators within the country; hence the importance of having the young Ph.D.s return to Brazil after they graduate. Moreover, de Meis and Longo (1990) observed that Ph.D. students studying abroad or within Brazil present similar profiles in terms of number of publications and citations during their thesis work and in their professional life after degree award. This suggests that training in Brazil is not very different from that received abroad.

To minimize the emigration of talent and, at the same time, offer Brazilian graduate students the opportunity to work in important research centers abroad, CAPES and CNPq have developed a special program called the "sandwich" Ph.D. Graduate students engaged in this program begin their training in a Brazilian institution and then spend 1 to 2 years doing research abroad. After this period, they return to the Brazilian university in which they are enrolled to conclude their work. The degree is conferred by the Brazilian institution. In this program, the chances of losing the student to a foreign research center are diminished. From 1992-95, enrollment in CNPq's sandwich program doubled, rising from 158 to 305 (table 4). In spite of this new program, however, almost 70 percent of CNPq

Table 4. Number of scholarships granted for study abroad in different programs: CNPq, 1988-95								
Graduate students	1988	1989	1990	1991	1992	1993	1994	1995
Total	1,611	1,979	2,154	2,455	2,843	2,737	2,418	2,132
Master's	172	234	225	192	148	69	17	5
Full Ph.D	956	1,243	1,508	1,821	1,977	1,912	1,726	1,475
Sandwich	-	-	-	-	158	255	302	305
Postdoctorate	330	335	285	306	346	301	248	293
Specialization	153	167	136	136	196	172	91	33
Sabbatical leave	-	-	-	-	18	28	34	21

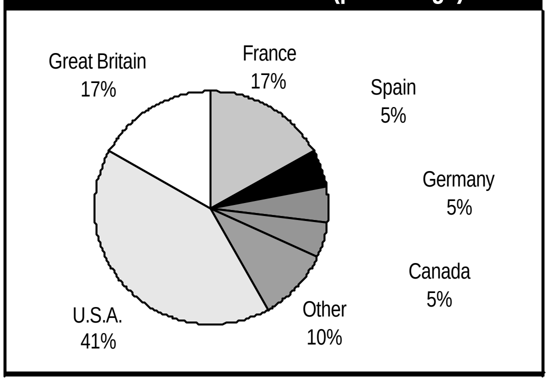
KEY: (-) = not applicable

SOURCE: National Council for Scientific and Technological Development. (CNPq), Indicadores Nacionais de Ciência e Tecnologica 1990-1995. Brasília: MCT/CNPq, 1995.

scholarships abroad are still allocated to Brazilian Ph.D. students enrolled for a full 4-year program in a foreign university.

The majority of students abroad are pursuing their degrees in American institutions (figure 5). This share is almost the same as that observed by Meneghini (1996) for international collaboration in Brazilian scientific publications. In this study, the author reports that the United States, France, the United Kingdom, Germany, and Canada were the countries that tended to collaborate with Brazil on international publications, with shares of 37.9 percent, 13.3 percent, 10.9 percent, 8.9 percent, and 6.6 percent, respectively. The data suggest that the choice of students for the foreign institution reflects the collaboration established by the Brazilian research group in which the students are engaged.

Figure 5. Countries in which Brazilian recipients of scholarships from the National Council for Scientific and Technological Development (CNPq) studied abroad in 1995 (percentage)



NOTE: "Other" includes 23 countries.

SOURCES: National Council for Scientific and Technological Development. (CNPq), Indicadores Nacionais de Ciência e Tecnologica 1990-1995. Brasília: MCT/CNPq, 1995.

There are no official data available regarding foreign graduate students enrolled in Brazilian programs. Most probably, however, the majority of these students come from other Latin American countries.

The Role of Government, Industry, and Academic Institutions in Supporting Science and Technology and in Employing Graduates

Despite the fiscal incentives established to encourage the private sector to invest in R&D during the 1960s, most of the resources for this activity come from the public sector (state and federal governments). There is, however, some evidence that industry's contribution to total R&D costs may be increasing. In 1959, only two Brazilian companies invested in R&D. By 1988, this number had risen to 81 (de Meis et al. 1991). According to Schwartzman (1995), only 6 percent of the investment in science and technology came from private sources during the period 1981-89. More recently, however, data compiled by the Ministry of Science and Technology indicate that Brazilian firms increased their participation to 22 percent of the total amount allocated to this activity (table 5).

From 1990 until 1996, the number of Ph.D. degrees conferred annually in Brazil grew from 1,222 to 2,972 (appendix table 4). Subsequently, there has been an increasing demand for academic positions in research institutions for these recent graduates. In this context, CNPq and CAPES created and have been supporting a Program for Recent Graduates. In 1995, the program awarded 561 recent Ph.D.s a 3-year assistantship to work on a research project under the aegis of some established group in a high-quality research center. These 3 years are meant to help the postdoctoral fellows maintain their academic research activity, keeping them in an academic environment while at the same time allowing them time to look for a permanent position.

As noted before, the bulk of Brazilian scientific activity takes place in public universities. As a result, they are the primary source of jobs for new graduates. In a preliminary study, it was found that, out of a group of 519

Table 5. Annual investments in science and technology by source (percent)						
Source	1990	1991	1992	1993	1994	1995
Total (US$ million)............................	3,081.5	3,034.4	2,442.5	4,703.0	4,995.0	5,957.0
Federal government [a]....................	83.9	79	74.8	54.9	51.8	47.1
State government [b].......................	16.1	21	25.2	18.4	15.2	21.8
Public enterprises [c]......................	NA	NA	NA	8.3	9.1	9.3
Private enterprises [c].....................	NA	NA	NA	18.2	23.9	21.8

[a] 1995 value includes an estimate of US$350,000 for wages of investigators who are faculty members at federal university. The current data collection procedure apparently fails to capture most of these payments. Preceding years do not include this estimate.

[b] The number of states included from 1990 to 1994 was 23, 21, 20, 23, and 27, respectively. Value for 1995 was estimated by the Ministry of Science and Technology.

[c] Estimate based on preliminary results from the first 500 firms responding to ANPEI's latest survey.

KEY: NA = not available

NOTES: Values were updated based on the gross domestic product implicit price deflator and translated to dollars using the average exchange rate for 1995 provided by the Brazilian Central Bank (US$1,00 = R$0,918). Totals for 1990-92 totals show only federal and state government expenditures.

SOURCES: Public sector data: Ministério da Ciência e Tecnologia/Coordenação de Estatísticas e Indicadores de C&T, Brasília, 1996; private sector data: Associação Nacional de Pesquisas e Desenvolvimento das Empresas Industriais (ANPEI), 1996.

alumni in the life sciences (Ph.D. students graduated from UFRJ whose employment could be identified), 64.4 percent have an academic position at UFRJ and another 16 percent are teaching at other public universities (table 6). In contrast, only four alumni from this group are employed in private universities and only one in industry.

Table 6. Employment of Ph.D.s graduated in the life sciences: an example from the UFRJ		
Position	Number	Percent
Total..	519	100.0
Faculty at UFRJ...	334	64.4
Faculty at other public universities.........................	83	16.0
Faculty public universty retired or deceaser..........	36	6.9
Postdoctorate or Program for Recent Graduate....	29	5.6
Investigator at a public research institute..............	27	5.2
Other[a]...	10	1.9

[a] Includes five highschool teachers, four private university professors, and one industrial researcher.

SOURCE: Sub-Reitoria de Ensino para Graduados e Pesquisa (SR-2), Universidade Federal do Rio de Janeiro, Rio de Janeiro, March 1998

The contrast in distribution between public and private schools is also observed among professors employed at institutions of higher education. In 1996, a total of 148,320 faculty members were almost equally distributed among public and private institutions (table 7). However, teachers employed at public institutions are better qualified than those at private universities: the percentage of faculty members holding a master's or Ph.D. degree is two times higher at public institutions. The discrepancy is still greater if we take into account only faculty with a Ph.D. degree: they comprise 24.8 percent of the total at public institutions, as opposed to 7.4 percent at private institutions. From these data, it appears likely that a majority of new Ph.D.s begin their careers in public universities.

Table 7. Faculty members in Brazilian institutions of higher education by their credentials, 1996				
	Public		Private	
Credentials	Number	Percent	Number	Percent
Total......................................	74,666		73,654	
Undergraduate degree......	14,905	20.0	18,465	25.1
Specialization....................	19,261	25.8	34,729	47.2
Master...............................	21,974	29.4	14,980	20.3
Ph.D..................................	18,526	24.8	5,480	7.4

NOTE: Data include faculty members of the 136 universities (public plus private) and 786 colleges and upperlevel technical schools (139 public and 647 private).

SOURCE: INEP, Censo Educacional: Evolução das Estatísticas do Ensino Superior no Brasil 1980/1996. Brasília: MEC/INEP/SEEC, 1997.

The growth in the number of graduate degrees among university faculty is also an indicator of employment trends for new graduates. From 1990 to 1996, this number rose by 33.2 percent for master's degrees and 41.7 percent for Ph.D.s (table 8). This increment is in accordance with a strong governmental policy of stimulating university faculty to obtain a Ph.D. degree. Faculty academic credentials are a major component in the current evaluation of Brazilian universities and graduate courses.

Table 8. Shifts in faculty credentials in Brazilian universities, 1990-96

Credentials	1990 Number	1990 Percent	1996 Number	1996 Percent	Percentage change 1990-96
Total	131,641	100	148,320	100	
Undergraduate degree	45,352	34.5	33,370	22.5	-26.4
Specialization	41,597	31.6	53,990	36.4	29.8
Master's	27,753	21.1	36,954	24.9	33.2
Ph.D	16,939	12.9	24,006	16.2	41.7

SOURCE: INEP, Censo Educacional: Evolução das Estatísticas do Ensino Superior no Brasil 1980/1996. Brasília: MEC/INEP/SEEC, 1997.

CONCLUSION

During the last 3 decades, the Brazilian scientific and technological system has experienced significant changes. In the 1960s, the National Program for Graduate Studies was established, representing an important step toward structuring a national academic community. In the 1970s and 1980s, graduate programs were established throughout the country. A significant increase in the quality and quantity of human resources engaged in scientific and technological activities has facilitated the consolidation of a national infrastructure for research. However, there are still many challenges to be faced. These include:

- improving the efficiency of graduate programs (decreasing the time taken to train a Ph.D.),
- increasing the proportion of the population with graduate degrees,
- increasing the participation of private universities in R&D activities,
- decreasing the risk of brain drain, and
- expanding the job market for scientific and technological activities.

Policies that respond adequately to these challenges will depend on the engagement not only of the federal government, but also of the state and municipal governments as well as the private sector. Improvements in quality and expansion of graduate programs will require an increase in the number of academic positions offered by research centers throughout the country. The performance of graduate students may be improved if more undergraduates are given the opportunity of working under the IC Fellowship Program. By working on research projects at an early stage of their education, more talented students will be attracted to pursue careers in science and will also enroll in graduate programs with skills already acquired, allowing them to conclude their studies more rapidly. Another important issue to be considered is the role of master's programs. Today, students are required to complete a master's degree in order to enroll in most of the Brazilian Ph.D. programs. This requirement extends the amount of time and money spent on their education.

Recent advances in science and technology, together with a trend toward a globalized market, have reinforced the relationship between knowledge and economic gains. Knowledge and creativity are highly valued by different sectors, and science is increasingly significant to industrial production. As a result, scientists in developed and developing countries are positioned as central actors in the struggle for economic growth (Schwartzman 1995, Perez 1983, and Fransman and King 1984). In this context, widespread public debate has reinforced the importance of training scientists for the challenges presented by the new "information age." Brazil has engaged in this debate, focusing on the implementation of effective policies for educating scientists capable of responding to the dynamic challenge of the global market.

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Appendix

Appendix table 1. CNPq: allocation of resources, 1980-92 (US$000)

Year	Fellowships	Grants [a]	Institutes	Administration	Other [b]	Total
1980....................	42,252.3	23,166.3	26,233.9	40,598.9	4,243.2	136,494.6
1981....................	46,567.7	21,815.5	29,557.7	41,837.5	2,420.1	142,198.5
1982....................	72,396.3	37,793.5	34,489.4	35,032.4	2,265.8	181,977.4
1983....................	68,137.6	28,106.6	26,949.6	28,769.8	3,194.6	155,158.2
1984....................	61,400.8	21,521.1	23,092.8	37,682.4	5,034.5	148,731.6
1985....................	88,153.1	41,517.0	33,141.5	33,631.7	5,212.8	201,656.1
1986....................	94,630.1	50,996.2	35,497.9	27,931.3	7,552.3	216,607.8
1987....................	184,069.4	48,886.4	57,739.4	63,729.7	4,416.3	358,841.2
1988....................	238,004.4	46,552.1	49,322.2	47,281.9	4,415.3	385,575.9
1989....................	236,143.1	33,570.1	85,569.2	48,693.0	22,732.4	426,707.8
1990....................	178,339.5	41,672.8	50,529.1	36,513.3	14,684.5	321,739.2
1991....................	232,440.4	19,884.0	30,838.3	26,361.2	14,907.9	324,431.8
1992....................	193,820.4	7,635.8	30,655.5	17,362.2	10,603.2	260,077.1

[a] Includes special projects.

[b] Includes debt service payments; fringe benefits to employees (for food, child care and, transportation); and salaries of personnel temporarily allocated to other government agencies.

NOTE: Figures were adjusted for inflation according to the General Price Index of Fundação Getúlio Vargas, and converted to dollars according to the mean exchange rate for 1992.

SOURCE: Schwartzman, S. 1995. Science and Technology in Brazil: A New Policy for a Global World. IN S. Schwartzman er al., *Science and Technology in Brazil: A New Policy for a Global World.* Rio de Janeiro: Fundação Getúlio Vargas.

Appendix table 2. Months to obtain a degree in UFRJ "A"-rated master's programs

Program	1995	1996	1997
Administration	48	46	49
Biological chemistry	32	30	28
Biomedical engineering	40	39	38
Biophysics	42	41	35
Chemical engineering	40	33	31
Civil engineering	37	40	32
Computer science	40	36	41
Dentistry - Orthodontics	33	32	30
Dermatology	37	45	44
Electrical engineering	42	30	29
Engineering (Production management)	46	42	33
Geography	46	43	43
History	59	51	42
Information studies	47	35	40
Linguistic	50	54	50
Literature	47	43	49
Mathematics	45	37	30
Mechanical engineering	44	35	35
Metallurgy and material engineering	45	36	35
Microbiology	41	37	35
Nuclear engineering	45	33	33
Nursing	32	25	21
Organic chemistry	45	39	39
Parasitology and infectious diseases	65	29	54
Philosophy	44	51	43
Physics	53	35	34
Regional and urban planning	49	58	50
Social anthropology	43	45	28
Social welfare	54	49	41

NOTE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES) indicators for 1995, 1996, and 1996 for "A"-rated master's programs, which were the best qualified programs in the 1994-1995 evaluation.

SOURCE: Sub-Reitoria de Ensino para Graduados e Pesquisa (SR-2), Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Appendix table 3. Months to obtain a degree in UFRJ "A"-rated Ph.D. programs

Program	1995	1996	1997
Biological chemistry	43	44	43
Biophysics	71	61	63
Chemical engineering	80	66	58
Civil engineering	78	57	67
Dermatology	63	49	54
Electrical engineering	63	64	90
Linguistic	66	58	53
Literature	70	59	73
Metallurgy and material engineering	72	73	64
Microbiology	55	37	66
Nuclear engineering	118	58	58
Nursing	38	37	33
Orthodontics	83	-	40
Parasitology and infectious diseases	65	62	43
Philosophy	65	52	45
Social anthropology	64	65	43

KEY: (-) = not applicable

NOTE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES) indicators for 1995, 1996, and 1997 for "A"-rated master's programs, which were the best qualified programs in the 1994-1995 evaluation.

SOURCE: Sub-Reitoria de Ensino para Graduados e Pesquisa (SR-2), Universidade Federal do Rio de Janeiro, Rio de Janeiro.

Appendix table 4. Annual enrollment in master's programs in Brazil by field

Field	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total......................................	29,273	30,990	31,992	35,727	37,428	37,813	38,414	41,084	43,121	44,925
Natural sciences...............	3,432	3,577	3,634	3,956	4,175	3,847	4,015	4,223	4,487	4,492
Biological sciences...........	2,078	2,255	2,103	2,426	2,516	2,772	2,780	3,153	3,286	3,445
Engineering.......................	3,921	5,005	5,109	5,657	5,998	6,618	6,278	6,779	7,197	7,335
Health sciences................	3,684	3,913	3,715	4,501	4,797	4,963	5,195	5,417	6,155	6,248
Agricultural sciences.........	2,475	2,893	3,107	3,302	3,437	3,532	3,685	4,102	3,936	4,099
Applied social sciences....	5,720	4,778	5,562	6,054	6,044	5,895	6,086	6,255	6,451	7,033
Humanities........................	6,070	6,704	6,597	7,497	7,651	7,557	7,651	7,974	8,146	8,500
Language & linguistic........	1,616	1,708	1,823	1,921	2,103	2,022	2,150	2,467	2,607	2,655
Arts...................................	270	141	318	358	657	449	403	485	464	459
Multidisciplinary................	7	16	24	55	50	158	171	229	392	659

NOTE: Natural sciences include mathematics, statistics and probability, computer sciences, astronomy, physics, chemistry, earth sciences, and oceanography; biological sciences include genetics, botany, zoology, ecology, morphology, physiology, biochemistry, biophysics, pharmacology, immunology, microbiology, and parasitology; engineering include all fields of engineering; health sciences include medicine, dentistry, pharmacy, nursing, nutrition, public health, phonoaudiology, physiotherapy, and physical education; agricultural sciences include agronomy, forestry, agricultural engineering, zootechnology, veterinary medicine, fisheries, and food science and technology; applied social sciences include law, economy, architecture and urban studies, urban and regional management, demography, information science, museum, communications, social services, home economics, industrial design, and tourism; humanities include philosophy, sociology, anthropology, archeology, history, geography, psychology, education, political science, and theology; and language & linguistics include linguistics, language, and arts.

SOURCE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998.

Appendix table 5. Annual enrollment in Ph.D. programs in Brazil by field

Field	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total......................................	7,960	8,345	9,148	10,496	12,095	13,764	15,556	17,464	19,492	22,004
Natural sciences...............	1,452	1,309	1,562	1,804	2,053	2,249	2,632	2,828	3,162	3,290
Biological sciences...........	1,094	1,215	1,108	1,346	1,504	1,755	1,891	2,161	2,371	2,721
Engineering.......................	1,074	1,159	1,242	1,435	1,758	2,400	2,512	2,739	3,278	3,550
Health sciences................	1,236	1,370	1,287	1,689	1,846	2,097	2,455	2,977	3,042	3,338
Agricultural sciences.........	577	545	730	858	820	1,211	1,307	1,730	1,829	2,012
Applied social sciences....	984	797	1,048	1,170	1,285	1,174	1,330	1,285	1,519	1,857
Humanities........................	955	1,356	1,404	1,468	1,915	2,038	2,445	2,672	3,136	3,819
Language & linguistic........	516	594	659	648	727	796	957	928	964	1,175
Arts...................................	72	0	108	78	187	44	15	46	20	59
Multidisciplinary................	0	0	0	0	0	0	12	98	171	183

NOTE: Fields are defined as in appendix table 4.

SOURCE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998.

Appendix table 6. Master's degrees awarded annually in Brazil, by field

Field	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total	3,653	3,845	4,597	5,452	6,799	7,380	7,554	7,627	8,982	10,356
Natural sciences	655	557	669	829	1,022	950	972	1,007	1,122	1,233
Biological sciences	346	372	432	440	607	644	673	678	808	947
Engineering	527	554	739	934	1,205	1,153	1,231	1,209	1,383	1,541
Health sciences	491	562	547	696	803	991	1,013	1,081	1,233	1,417
Agricultural sciences	492	526	674	707	937	882	953	922	1,154	1,300
Applied social sciences	427	389	494	586	698	890	874	823	934	1,090
Humanities	547	679	799	957	1,180	1,448	1,353	1,469	1,792	2,048
Language and linguistic	146	196	200	250	304	341	387	338	440	582
Arts	22	10	43	51	40	65	75	70	89	106
Multidisciplinary	0	0	0	2	3	16	23	30	27	92

NOTE: Fields are defined as in appendix table 4.
SOURCE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998.

Appendix table 7. Ph.D. degrees awarded annually in Brazil, by field

Field	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total	1,005	990	1,139	1,410	1,750	1,759	1,875	2,081	2,497	2,972
Natural sciences	151	149	179	209	307	303	322	328	420	455
Biological sciences	168	180	183	193	262	322	252	271	365	407
Engineering	111	81	116	138	205	171	244	254	304	417
Health sciences	166	239	220	335	385	324	352	380	489	612
Agricultural sciences	81	102	113	131	127	145	169	197	244	311
Applied social sciences	71	55	92	111	152	129	145	188	192	185
Humanities	124	118	154	186	233	266	279	262	341	435
Language and linguistic	55	66	69	74	74	84	95	138	128	143
Arts	5	0	13	11	5	15	16	7	9	4
Multidisciplinary	0	0	0	0	0	0	1	2	5	3

NOTE: Fields are defined as in appendix table 4.
SOURCE: Ministry of Education, Coordination for the Improvement of Higher Education Personnel (CAPES), July 1998.

Graduate Education in Traditional Chilean Universities: A Historical Analysis

Sergio H. Marshall

Summary

Important changes have occurred in higher education in Chile during the past 20 years. During this period, a variety of newly formed private universities have become strong competitors of state-funded traditional universities for undergraduate students. These newer institutions are quite different in quality, focus, and history from the traditional universities. In the early eighties, traditional universities were forced to look for self-financing, and therefore had to compete with private universities for incoming secondary education graduates. As a result, graduate education in the traditional universities has not been able to evolve as expected by taking advantage of the country's growing scientific research potential. Nevertheless, the integrity of traditional universities, and their unquestionable historical strength in basic and applied research, has allowed them to rapidly recover their place and use key strategies to slowly reposition graduate education as one of the main activities distinguishing the highly intellectual Chilean society.

Preliminary Remarks

In Chile, there are two educational options following completion of a university degree: *postgrado*, equivalent to graduate education in the United States, with a minimum requirement of a bachelor's-type degree (*licenciado*); and *postítulo*, which refers to professional education for jobs such as engineer, teacher, or lawyer. Only the former qualifies a student for research activities.

Introduction

Since the beginning of this century, due to its homogeneous population, a long-term sustained economic stability, a solid European-based cultural background, and a strong democratic upbringing, Chile has turned out to be a natural leader in Latin America. Among other institutions, its universities have had a crucial role in the structuring, shaping, and strengthening of a highly efficient society, maintained by qualified and competitive professionals. Many of these professionals are world-renowned for their accomplishments. Natural evolution and the need to internationalize academic activities in the early 1950s and 1960s led seven of the most traditional Chilean universities to establish graduate programs in selected competitive areas. These programs were mostly generated as a means of optimizing internal potential as well as to better serve an always-demanding society. Globalization strategies and international quality assessments also led universities to participate in ongoing mobility programs as well as to establish their own programs.

The abrupt disruption of democracy in Chile in 1973 severely fractured the academic community. Exile, combined with central and imposed government control, disrupted the freedom to speak openly and to organize academic activities within the universities. As a result, the previous harmony in academic activities was threatened, seriously hampering the dynamics of day-to-day academic life. Another consequence was that most academic leaders who remained in the country and in their universities ended up sheltered in their own intellectual environments, suffocated by stringent rules and nonparticipative policies. This situation led universities to become partially isolated from their social and natural environment, resulting in a diminished perception of the real needs of a fast-changing society. For 17 years, the country was forced to function under a defined set of general rules and principles wherein intellectual pursuits were not a priority. In the meantime, a well-organized economy created a new generation of youth who cared more for material things and were unmotivated by the more transcendental aspects of life. These historical developments had a clear impact on university life in Chile and especially on the evolution of graduate education.

From Traditional to Private Universities in Chile

Up to 1980, higher education in Chile was represented by eight traditional universities (table 1 and figure 1) with 118,000 students (for comparison, note that, in 1955, this number was 11,000). These students were mostly undergraduates, and a significant percentage of the university budgets were provided by the state. Under the military regime, a new law was established that restricted state funding for traditional universities. The new scenario created an almost immediate imbalance in the

Chilean higher education system, with an emphasis on undergraduate, rather than graduate, education. The logic behind this strategy was that universities should become self-sustaining from an economic point of view and therefore mainly focused on highly qualified undergraduate formation. As a result, an overwhelming number of new private institutions were created; these developed academic programs primarily oriented to the most attractive and competitive professional careers, and had a "blackboard and chalk" basis—i.e., oriented toward careers that did not require laboratories, special facilities, or any type of previous scientific research.

At present, there are around 250 institutions of higher education in Chile distributed as follows: 67 universities (25 traditional, 42 new private); 70 professional institutes; and over 118 technological centers. In all, these have a total of 370,000 officially registered students, of whom 266,000 are university undergraduates (Frei 1998). Almost all of the faculty members associated with these newborn organizations were, and still are, distinguished professors from classical traditional universities hired on a part-time basis for teaching purposes.

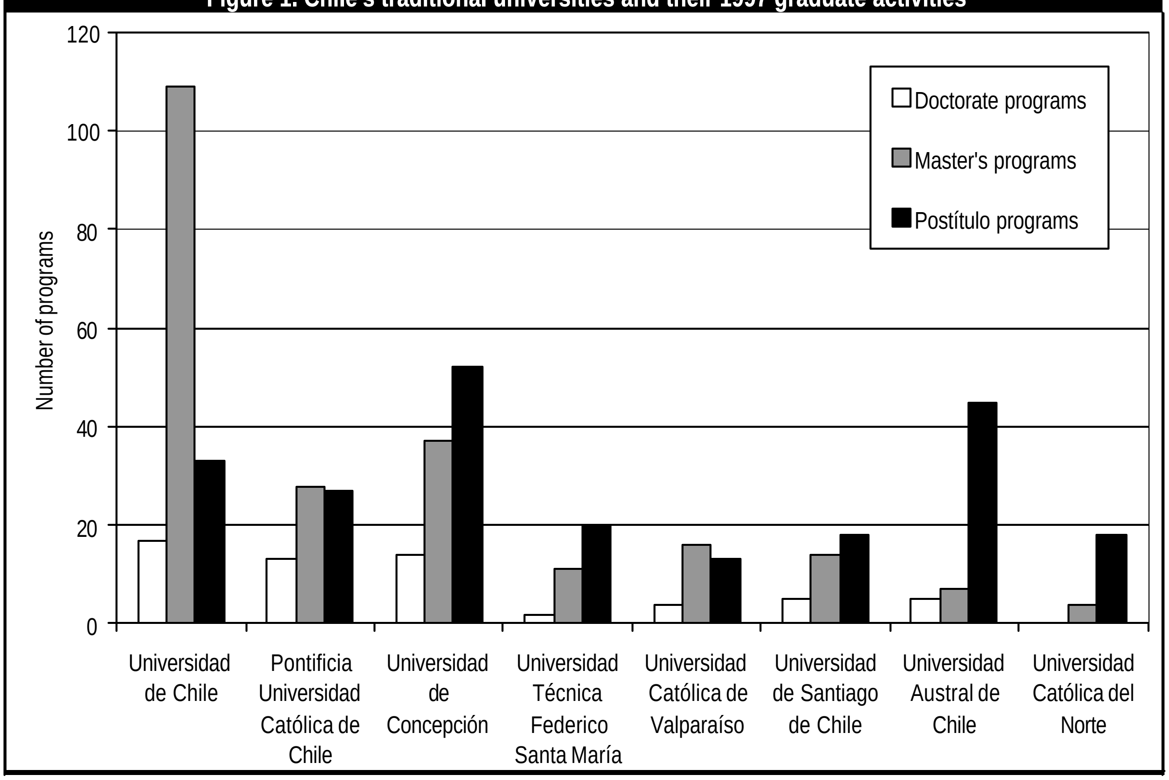
When democracy was reinstated in Chile in March 1990, traditional state-funded universities still maintained

Table 1. Chile's traditional universities and their 1997 graduate activities

University	Year of foundation	Doctorate programs	Master's programs	Postítulo programs
Total		60	226	226
Universidad de Chile	1622	17	109	33
Pontificia Universidad Católica de Chile	1888	13	28	27
Universidad de Concepción	1919	14	37	52
Universidad Técnica Federico Santa María	1926	2	11	20
Universidad Católica de Valparaíso	1928	4	16	13
Universidad de Santiago de Chile	1947	5	14	18
Universidad Austral de Chile	1954	5	7	45
Universidad Católica del Norte	1956	0	4	18

SOURCE: Information from individual university Internet (web sites).

Figure 1. Chile's traditional universities and their 1997 graduate activities



SOURCE: Information from individual university Internet (web sites).

their dignity and their standards although their structure was notoriously weakened. The latter was reflected in a less committed, over-middle-aged faculty, and the absolute absence of new faculty positions. Moreover, the new 1980 law stated that the best-ranked 27,500 students applying for university enrollment each year would receive a significant subsidy from the state. This situation occurred under a tight budget, and led traditional universities—besides competing among themselves—to design yearly changing, aggressive strategies for survival as a means of overcoming the uneven competition from private universities for incoming undergraduate students. Thus, the country was not prepared for significant development of graduate training since this simply could not be a priority for traditional universities outnumbered by their private counterparts.

Actual Structure and Organization of Traditional Universities in Chile

At present, there are 25 traditional universities in Chile, out of 68 universities in all; these are scattered over the 12 administrative regions of the country plus the metropolitan region that comprises the country's capital. Most of these universities are concentrated in Santiago, the capital city, and in Regions V and VIII (table 2). All traditional universities have in common—to a certain extent—some kind of state support; in contrast, private universities do not. The original eight traditional universities still exist, and all of them have active graduate programs (table 1). Due to the complexity of branch distributions across regions of some of the original universities and the new economic scenario faced by universities in the middle to late 1980s, most regional branches have become autonomous and have acquired new names; nonetheless, they continue to be state-funded just like their progenitors. Something similar happened in the early 1990s to regional branches of Universidad Catolica de Chile, the second most important university in the country. This university, although dependent on the Catholic Church (like Universidad Catolica de Valparaiso), still receives marginal funding from the state.

The 25 traditional universities are affiliated with the Consejo de Rectores (C.R.), or Council of Rectors, which comprises the rectors of these universities, which are officially recognized by the state; the council is headed by the minister of Education. Besides the rectors, the council has a general secretary who is nominated by the minister of Education and who administers the council's activities. The head of the Department of Higher Education of the Ministry of Education also attends the council sessions as a permanent guest. In the minister's absence, the council is headed by the rector of Universidad de Chile, the first established and strongest university in the country. Foreseeing the need to strengthen graduate activities, the council has, since 1991, had an advisory committee on graduate affairs comprised of all graduate program directors from the 25 member universities. Its objective is to keep this activity alive within these universities and to set quality standards for all programs so they might be recognized internationally. Within this committee, there is an executive commission, composed of all seven university members offering doctorate programs, most of which are accredited by international standards (table 3 and figure 2). At present, this commission is headed by the author of this paper.

Graduate Activities in Traditional Universities

Most C.R. university members offer some kind of graduate programs, although the great majority promote master's over doctorate degree programs. Nonetheless, as a way to promote and maintain regular graduate activities—by themselves expensive—most universities have developed *postítulos*, in which a certificate is granted after 1 to 2 years of advanced specialization courses. In a *postítulo*, no research or thesis work is required for graduation, and the program is mainly oriented to competitive professionals who need to be updated in specific areas of knowledge. Because of their orientation, these programs have a high tuition fee and have become an efficient way to relate to the national productive sector. They have also become an efficient alternative for traditional universities to provide financial support for other academic activities, among them graduate programs. Tables 4, 5, and 6 show the official registration for doctorate, master's, and *postítulo* programs, respectively.

It is clear that the seven leading universities in terms of granting doctorates are also the ones with solid master's and *postítulo* programs. With the exception of Universidad Catolica del Norte—one of the eight originals—and its *postítulo* programs (table 6), most activity is concentrated in Santiago and two or three other regions. No doctorate programs are available at any of the private universities, and only a few private universities have MBA-type master's programs—these number fewer than 10 at any one university.

Table 2. Total undergraduate and graduate enrollment in traditional universities, 1997

University/Region	Total	I	II	III	IV	V	VII	VIII	IX	X	XI	XII	RM
Total	184,282	7,418	12,553	3,432	6,974	23,181	7,338	27,703	9,475	13,057	0	2,343	70,808
Univ. de Chile	21,910	0	0	0	0	0	0	0	0	0	0	0	21,910
P.Univ. Católica de Chile	15,821	0	0	0	0	0	0	0	184	0	0	0	15,637
Univ. de Concepción	15,124	0	0	0	0	0	0	15,124	0	0	0	0	0
Univ.Católica Valparaíso	8,689	0	0	0	0	8,689	0	0	0	0	0	0	0
Univ. T.F. Santa María	8,218	0	0	0	0	6,028	0	1,708	0	0	0	0	482
Univ. Santiago de Chile	18,295	0	0	0	0	0	0	0	0	0	0	0	18,295
Univ. Austral de Chile	9,698	0	0	0	0	0	0	0	0	9,698	0	0	0
Univ. Católica del Norte	8,592	0	7,203	0	1,389	0	0	0	0	0	0	0	0
Univ. de Valparaíso	4,920	0	0	0	0	4,920	0	0	0	0	0	0	0
Univ. de Antofagasta	5,350	0	5,350	0	0	0	0	0	0	0	0	0	0
Univ. de la Serena	5,585	0	0	0	5,585	0	0	0	0	0	0	0	0
Univ. del Bio Bio	7,779	0	0	0	0	0	0	7,779	0	0	0	0	0
Univ. de la Frontera	6,892	0	0	0	0	0	0	0	6,892	0	0	0	0
Univ. de Magallanes	2,343	0	0	0	0	0	0	0	0	0	0	2,343	0
Univ. de Talca	0	0	0	0	0	0	0	0	0	0	0	0	0
Univ. de Atacama	7,204	0	0	3,432	0	0	3,772	0	0	0	0	0	0
Univ. de Tarapacá	5,098	5,098	0	0	0	0	0	0	0	0	0	0	0
Univ. Arturo Prat	2,350	2,320	0	0	0	0	0	0	30	0	0	0	0
Univ.Metrop.Cs.de la Ed	6,549	0	0	0	0	0	0	0	0	0	0	0	6,549
U.P.Ancha Cs. de la Ed	3,544	0	0	0	0	3,544	0	0	0	0	0	0	0
U. Tecnol. Metropolitana	7,935	0	0	0	0	0	0	0	0	0	0	0	7,935
Univ. de Los Lagos	3,359	0	0	0	0	0	0	0	0	3,359	0	0	0
Univ. Católica del Maule	3,566	0	0	0	0	0	3,566	0	0	0	0	0	0
Univ. Católica de Temuco	2,369	0	0	0	0	0	0	0	2,369	0	0	0	0
Univ. Catolica S.Concepc	3,092	0	0	0	0	0	0	3,092	0	0	0	0	0
Percentage distribution	100.0	4.03	6.81	1.86	3.78	12.58	3.98	15.03	5.14	7.09	0.00	1.27	38.42

KEY: RM = metropolitan region (Santiago)

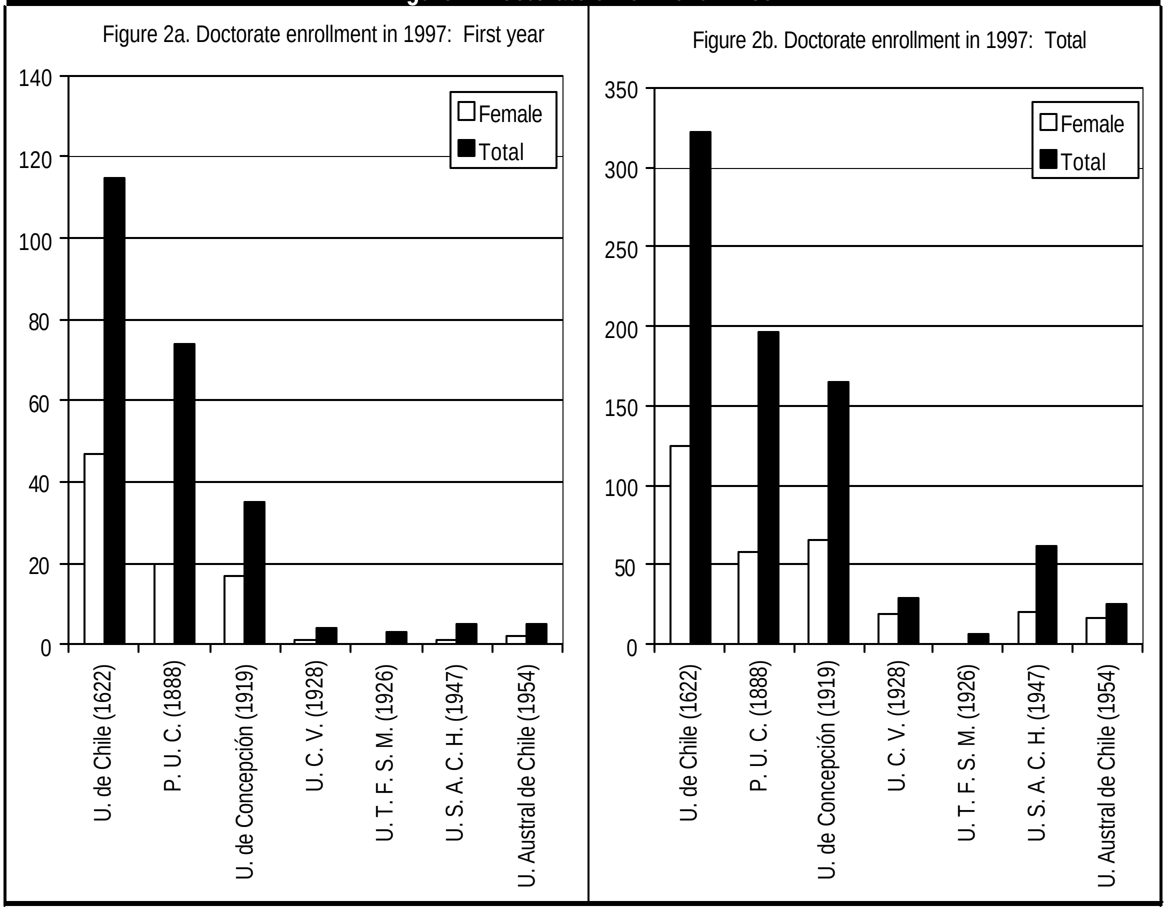
SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

Table 3. Doctorate enrollment in 1997

University	First year registration		Total registration	
	Total	Female	Total	Female
Total	241	88	807	305
Universidad de Chile	115	47	322	125
P. Universidad Católica de Chile	74	20	197	58
Universidad de Concepción	35	17	165	66
Universidad Católica de Valparaíso	4	1	29	19
Universidad T. F. Santa María	3	0	6	0
Universidad de Santiago de Chile	5	1	62	21
Universidad Austral de Chile	5	2	26	16

SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

Figure 2. Doctorate enrollment in 1997



SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

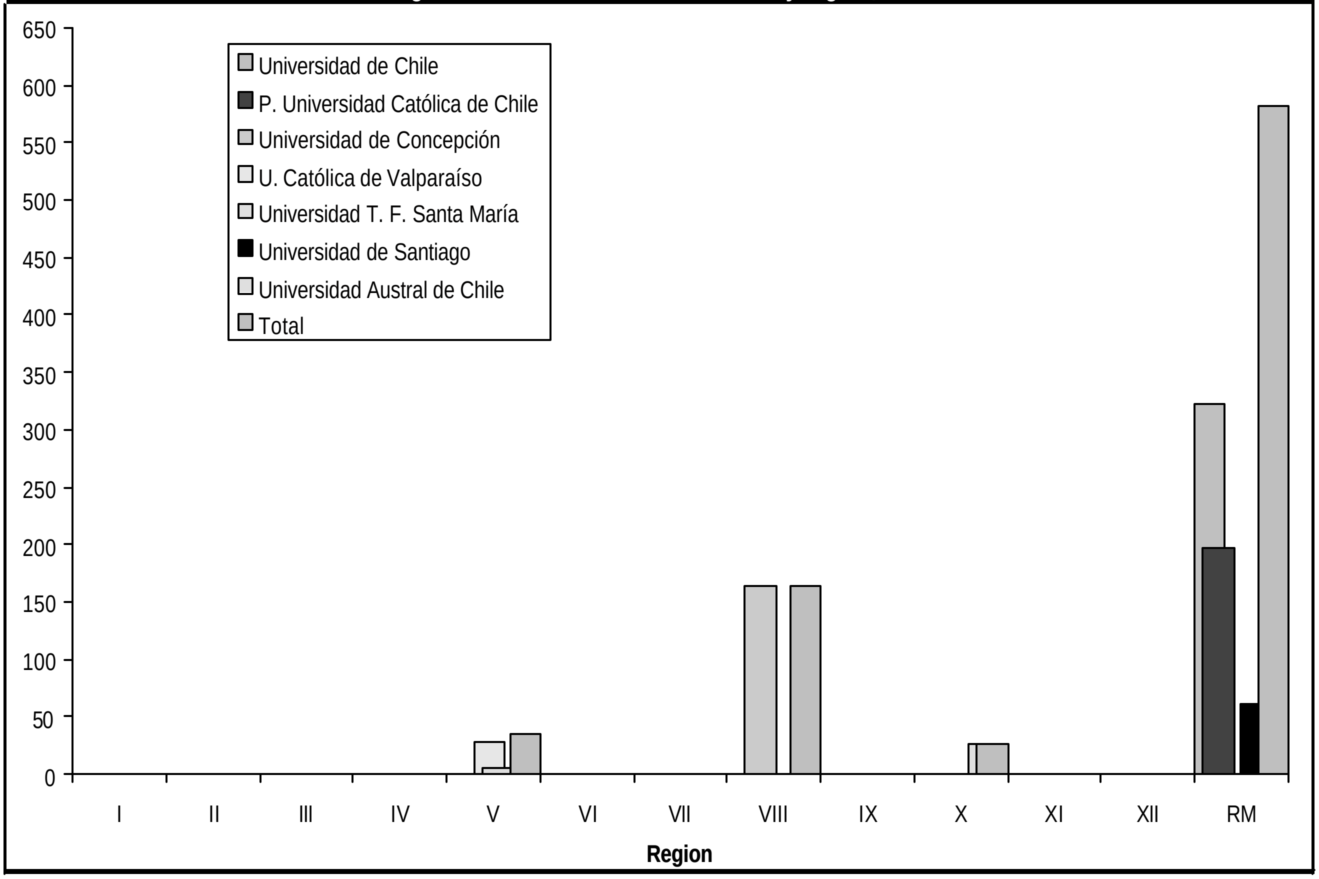
Table 4. Total doctorate enrollment by region, 1997

University/ Region	Total	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	RM
Total	807	0	0	0	0	35	0	0	165	0	26	0	0	581
Univ. de Chile	322	0	0	0	0	0	0	0	0	0	0	0	0	322
P.Univ. Católica de Chile	197	0	0	0	0	0	0	0	0	0	0	0	0	197
Univ. de Concepción	165	0	0	0	0	0	0	0	165	0	0	0	0	0
Univ.Católica Valparaíso	29	0	0	0	0	29	0	0	0	0	0	0	0	0
Univ. T.F. Santa María	6	0	0	0	0	6	0	0	0	0	0	0	0	0
Univ. Santiago de Chile	62	0	0	0	0	0	0	0	0	0	0	0	0	62
Univ. Austral de Chile	26	0	0	0	0	0	0	0	0	0	26	0	0	0
Percentage distribution	100.0	0.0	0.0	0.0	0.0	4.3	0.0	0.0	20.4	0.0	3.2	0.0	0.0	72.0

KEY: RM = metropolitan region (Santiago)

SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

Figure 3. Total doctorate enrollment by region, 1997



KEY: RM = metropolitan region (Santiago)

NOTE: No doctoral enrollment in regions I-IV,VI-VII, IX-X, and XI-XII.

SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

Table 5. Total master's enrollment by region, 1997

University/Region	Total	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	RM
Total..	5,442	133	57	47	236	510	0	0	547	245	322	0	22	3,323
Universidad de Chile..................................	1,578	0	0	0	0	0	0	0	0	0	0	0	0	1,578
P. Universidad Católica de Chile................	841	0	0	0	0	0	0	0	0	0	0	0	0	841
Universidad de Concepción........................	547	0	0	0	0	0	0	0	547	0	0	0	0	0
Universidad Católica de Valparaíso............	147	0	0	0	0	147	0	0	0	0	0	0	0	0
Universidad T. F. Santa María....................	91	0	0	0	0	91	0	0	0	0	0	0	0	0
Universidad de Santiago de Chile...............	312	0	0	0	0	0	0	0	0	0	0	0	0	312
Universidad Austral de Chile......................	316	0	0	0	0	0	0	0	0	0	316	0	0	0
Universidad Católica del Norte..................	75	0	57	0	18	0	0	0	0	0	0	0	0	0
Universidad de Valparaíso..........................	73	0	0	0	0	73	0	0	0	0	0	0	0	0
Universidad de la Serena...........................	218	0	0	0	218	0	0	0	0	0	0	0	0	0
Universidad de la Frontera..........................	245	0	0	0	0	0	0	0	0	245	0	0	0	0
Universidad de Magallanes.........................	22	0	0	0	0	0	0	0	0	0	0	0	22	0
Universidad de Atacama.............................	47	0	0	47	0	0	0	0	0	0	0	0	0	0
Universidad de Tarapacá............................	133	133	0	0	0	0	0	0	0	0	0	0	0	0
U. Metropolitana de Cs. De la Ed................	592	0	0	0	0	0	0	0	0	0	0	0	0	592
U. De Playa Ancha Cs. De la Ed.................	199	0	0	0	0	199	0	0	0	0	0	0	0	0
Universidad de los Lagos...........................	6	0	0	0	0	0	0	0	0	0	6	0	0	0
Percentage distribution..................................	100.0	2.4	1.0	0.9	4.3	9.4	0.0	0.0	10.1	4.5	5.9	0.0	0.4	61.1

KEY: RM = metropolitan region (Santiago)

SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

Table 6. Total *postítulo* enrollment by region, 1997

University/Region	Total	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	RM
Total	10,091	175	2,644	97	117	1,084	50	572	1,188	280	936	0	0	2,948
Universidad de Chile	1,019	0	0	0	0	0	0	0	0	0	0	0	0	1,019
P. Universidad Católica de Chile	871	0	0	0	0	0	0	0	0	70	0	0	0	801
Universidad de Concepción	511	0	0	0	0	0	0	0	511	0	0	0	0	0
Universidad Católica de Valparaíso	415	0	0	0	0	415	0	0	0	0	0	0	0	0
Universidad T. F. Santa María	1,127	0	0	0	0	459	50	0	159	0	0	0	0	459
Universidad de Santiago de Chile	365	0	0	0	0	0	0	0	0	0	0	0	0	365
Universidad Austral de Chile	745	0	0	0	0	0	0	0	0	0	745	0	0	0
Universidad Católica del Norte	2,687	0	2,644	0	43	0	0	0	0	0	0	0	0	0
Universidad de Valparaíso	136	0	0	0	0	136	0	0	0	0	0	0	0	0
Universidad de la Serena	74	0	0	0	74	0	0	0	0	0	0	0	0	0
Universidad de la Frontera	210	0	0	0	0	0	0	0	0	210	0	0	0	0
Universidad de Atacama	97	0	0	97	0	0	0	0	0	0	0	0	0	0
Universidad de Tarapacá	175	175	0	0	0	0	0	0	0	0	0	0	0	0
U. Metropolitana de Cs. De la Ed.	304	0	0	0	0	0	0	0	0	0	0	0	0	304
U. De Playa Ancha Cs. De la Ed.	74	0	0	0	0	74	0	0	0	0	0	0	0	0
Universidad de los Lagos	191	0	0	0	0	0	0	0	0	0	191	0	0	0
Universidad Católica del Maule	572	0	0	0	0	0	0	572	0	0	0	0	0	0
Universidad Católica S. Concepción	518	0	0	0	0	0	0	0	518	0	0	0	0	0
Percentage distribution	100.0	1.7	26.2	1.0	1.2	10.7	0.5	5.7	11.8	2.8	9.3	0.0	0.0	29.2

KEY: RM = metropolitan region (Santiago)

SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

There are significant differences among the 25 C.R. member universities in their experience in graduate education activities. Graduate activity in Chile constitutes a natural heritage of traditional universities. Out of the 25, 7 universities offer doctorate programs, 17 offer master's programs, and 18 offer *postítulo* programs (tables 1, 3, 4, 5, and 6). Most programs show a reasonable degree of efficiency, as measured by the number of graduates in each type of program. Table 7 shows the 1997 official data for graduation in doctorate programs. Table 8 does the same for master's programs. When comparing the number of candidates in doctorate programs (table 3) against the number of graduates (table 7), the yearly average graduation is 5 to 10 percent of all enrolled students. As expected, the average graduation frequency for master's programs (tables 5 and 8) is much higher, reaching levels up to 20 percent per year.

The core of qualified graduate programs lies in traditional universities, which are outnumbered by their private counterparts. Internationally competitive graduate programs occur almost exclusively at the doctorate level. Only 7 of Chile's 68 universities participate at this level, offering 60 different programs, most of which are fully accredited either nationally or—in a few cases—internationally. College-level activity in all traditional universities

Table 7. Total doctorate degrees granted, 1997

University/Area	Total	Agronomy	Art	Sciences/ mathematics	Social sciences	Law	Humanities	Education	Technology	Health
Total	57	0	0	45	0	0	1	3	0	8
Universidad de Chile	26	0	0	18	0	0	0	0	0	8
P. Universidad Católica de Chile	12	0	0	8	0	0	1	3	0	0
Universidad de Concepción	7	0	0	7	0	0	0	0	0	0
Universidad Católica de Valparaíso	4	0	0	4	0	0	0	0	0	0
Universidad de Santiago de Chile	2	0	0	2	0	0	0	0	0	0
Universidad Austral de Chile	6	0	0	6	0	0	0	0	0	0
Percentage distribution	100.0	0.0	0.0	78.9	0.0	0.0	1.8	5.3	0.0	14.0

SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

Table 8. Total master's degrees granted, 1997										
University/Area	Total	Agronomy	Art	Sciences/ mathematics	Social sciences	Law	Humanities	Education	Technology	Health
Total	648	35	5	95	197	4	59	134	76	43
Universidad de Chile	201	14	3	29	67	0	20	4	24	40
P. Universidad Católica de Chile	173	14	2	9	98	4	10	8	28	0
Universidad de Concepción	53	1	0	19	6	0	8	8	8	3
Universidad Católica de Valparaíso	18	0	0	7	0	0	5	4	2	0
Universidad T. F. Santa María	13	0	0	2	0	0	0	0	11	0
Universidad de Santiago de Chile	31	0	0	2	14	0	11	1	3	0
Universidad Austral de Chile	36	5	0	22	7	0	2	0	0	0
Universidad Católica del Norte	5	0	0	5	0	0	0	0	0	0
Universidad de la Serena	51	1	0	0	0	0	0	50	0	0
Universidad de la Frontera	5	0	0	0	5	0	0	0	0	0
Universidad de Magallanes	2	0	0	0	0	0	0	2	0	0
Universidad de Tarapacá	22	0	0	0	0	0	0	22	0	0
U. Metropolitana de Cs. De la Ed	29	0	0	0	0	0	2	27	0	0
U. De Playa Ancha Cs. De la Ed	6	0	0	0	0	0	1	5	0	0
Universidad de Antofagasta	3	0	0	0	0		0	3	0	0
Percentage distribution	100.0	5.4	0.8	14.7	30.4	0.6	9.1	20.7	11.7	6.6

SOURCE: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1997).

has had to increase heavily in the last 10 years and has been forced to perform at a level of high efficiency in terms of graduates. This has not been the case for graduate education, which annually graduates 2 doctorate students per million inhabitants, not counting those graduating abroad. This is quite a low figure when compared to 10 in Brazil and 150 in the United States (Zumelzu 1997).

After this rather somber evaluation, one might question why such an evolution has occurred—and even wonder how graduate activity has survived. The main answer to both questions is that traditional universities in Chile know, and have known for a long time, that without graduate activity, a strong, complex university cannot survive. In addition, Chile is very much aware that a reduced scientific mass necessarily undermines the future of science and, to a lesser degree, technology; therefore, it is the responsibility of its universities to generate, maintain, and renew the scientific and technically trained personnel sustaining the country. Certainly, graduate education is one of the pivotal instruments required to achieve these objectives.

The Research Mission Supporting Graduate Education

Today, the organized body of knowledge that makes it possible to understand the causes of verifiable phenomena (science) and the application of knowledge to the production of goods and services (technology) permeates all sectors and activities of society (Mayorga 1997). There are many areas in which the spheres of science and technology and the socioeconomic development of any country overlap. Universities should act as interfaces to harmonize the process, providing not only knowledge, but also—and most importantly—the actors. In recent years, as discussed previously, significant changes in the university environment have affected the research-related missions of these institutions and, as a consequence, their approach to graduate education. In particular, universities are becoming more diverse in structure and more oriented toward economic and industrial needs, while coping with year-to-year higher college-level student enrollment. On the other hand, government budgets to support traditional universities, as well as those related to research and development (R&D), are increasing very slowly and at a percentage not comparable to those of developed countries. Table 9 shows the percentage of the gross domestic product (GDP) invested in R&D in Chile starting in 1965 and the estimated rate expected at the year 2000.

Table 9. Percentage of Chile's GDP invested in R&D, 1965-2000

Year	R&D expenditures (Mil. US Dollars)	Percent
1965	0.02	0.32
1966	0.02	0.35
1967	0.03	0.41
1968	0.03	0.42
1969	0.03	0.39
1970	0.03	0.39
1971	0.05	0.49
1972	0.06	0.51
1973	0.04	0.41
1974	0.04	0.33
1975	27.00	0.37
1976	39.29	0.40
1977	57.61	0.43
1978	76.21	0.49
1979	82.56	0.40
1980	107.59	0.39
1981	123.86	0.38
1982	108.91	0.45
1983	96.20	0.49
1984	99.30	0.52
1985	80.16	0.50
1986	81.02	0.48
1987	104.76	0.55
1988	108.35	0.45
1989	131.01	0.47
1990	161.95	0.53
1991	183.34	0.53
1992	248.58	0.58
1993	286.82	0.63
1994	340.49	0.65
1995	430.37	0.64
1996	454.98	0.66
1997	528.34	0.69
1998	678.28	0.84
1999	850.93	0.98
2000	1,005.04	1.09

SOURCE: Comisión Nacional de Investigación Científica y Tecnológica (CONICYT), Santiago, Chile.

These data suggest that, in the near future, sustainability of traditional universities will become more and more dependent upon the annual fees paid by undergraduate students and, to a lesser extent, upon any lateral activities they could perform in the areas of applied research, technical assistance, training courses or programs, and knowledge and technology transfer to the productive sectors of the economy. These trends undoubtedly raise serious questions about how to ensure that universities can continue to make their unique contribution to long-term basic research—a pivotal and unavoidable key component supporting graduate activities inside established universities. Unfortunately, these are considered unprofitable activities with high unit cost to achieve graduation for a small number of students, where external support is limited and scholarships scarce. Therefore, traditional Chilean universities, as elsewhere, must adapt to this reality in largely positive ways, evolving toward new roles and configurations to properly face the needs of the 21st century. One example of this trend is the fact that, with declining government support, there is an obvious need not only to seek new sources of funds but also to establish a new basis for that support. One appealing strategy applied in Europe (OECD 1998), and which could be applicable in Chile, would be to change the nature of government funding to make it mission-oriented, contract-based, and more dependent on output and performance criteria. If applied, this would lead universities to perform more short-term and market-oriented research.

Financing R&D Activities: Competitive Funds for Research

It has been already stated that research is essential in supporting qualified graduate programs, and vice versa. It is also well known that, in order to do that, external funding is a must. Therefore, an indirect way to examine the efficiency of graduate activity in a country is to analyze the economic resources invested in R&D as a percentage of GDP (UNESCO 1993) and identify where the research activity occurs. The low level of R&D funding helps explain the low level of graduate formation in the country. Chile used only 0.7 percent of its GDP in 1994 in this area, compared with 0.8 percent in Argentina, 0.9 percent in Brazil, and 2.77 percent in the United States (Zumelzu 1997). The main reason for this is that most of the research performed in Chile occurs in universities. Table 10 shows that, for the last 15 years, on average, almost 70 percent of all researchers work at universities; this might be interpreted as meaning that the productive sector is not involved or not interested in developing its own research potential. Table 11 further suggests that this might be the case. Over 70 percent of R&D done in the country is performed at universities, mostly—but not exclusively—by graduates. Table 10 also shows that the industrial sector has a negligible participation; in addition to universities, most market-oriented research is done at professional institutes supported by the state where graduate training is not at all considered.

To do highly competitive and consistent research, funding is fundamental; to get this funding appears to be the sole responsibility of each researcher through state-provided competitive funds. Since graduate programs normally require an experimental thesis for graduation, it is also the responsibility of the research advisor to provide the required financial support. This is indeed the case, and can be inferred from figure 4, where the most relevant state-provided competitive funds are summarized. It can be clearly seen in the figure that the only direct support for the development of graduate education corresponds to graduate student fellowships, representing a low 4 percent of the total. This support is restricted to accredited programs. In the figure, Fondecyt is a research fund that supports single principal investigators; Fondef, an equivalent supporting institution, generally supports universities in association with industries. Thus, the only real sources of money to carry out graduate work are indirect and unstable, depending on researchers to provide them.

To understand these data in a more general context, a closer analysis of the steady-state annual national budget distribution in the field might help. As an example, in 1997 the national R&D expense reached US$480 million. From this lump sum, 70 percent (US$336 million) corresponded to state expenditure, and 23 percent (US$110 million) to enterprise expenditure. Of the state expenditure, 26 percent (US$87 million) was competitive funds,

Table 10. Total researchers at universities

Year	Total in Chile	Researchers in universities	Percent at universities
1981	3,420	2,434	71.2
1982	3,547	2,561	72.2
1983	3,727	2,677	71.8
1984	3,886	2,789	71.8
1985	4,079	2,924	71.7
1986	4,251	3,056	71.9
1987	4,588	3,169	69.1
1988	4,803	3,279	68.3
1989	5,115	3,389	66.3
1990	5,421	3,609	66.6
1991	5,628	3,710	65.9
1992	5,860	3,942	67.3
1993	6,028	4,029	66.8
1994	6,223	4,168	67.0
1995	6,388	4,356	68.2
1996	6,619	4,583	69.2

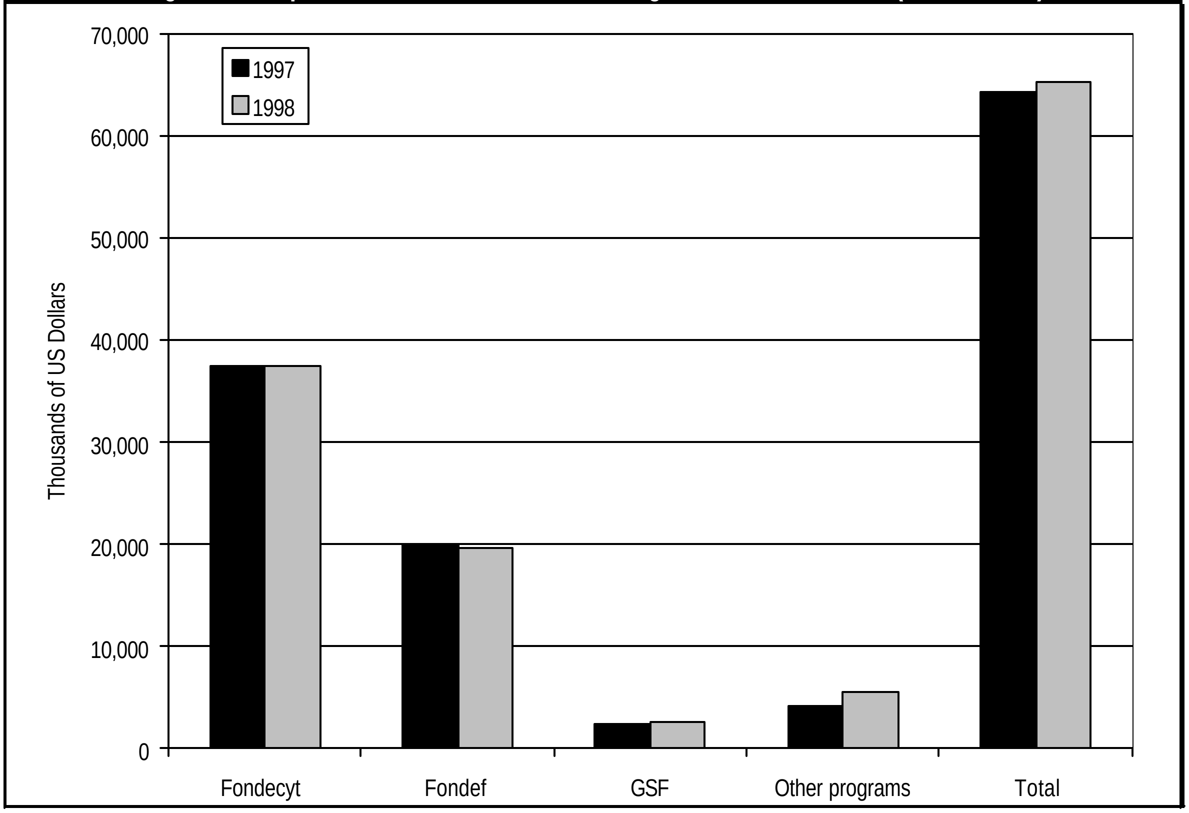
SOURCES: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1981 a 1996). Information submitted directly by universities and institutes; Department of Information, Comisión Nacconal de Investigación Centifica y Tecnológica (CONICYT).

Table 11. Graduate involvement in the national R&D system

Year	Total researchers	Total graduates	Universities	Professional institutes	Industry	Percent of graduates
1981	3,420	2,314	2,239	75	none	67.6
1982	3,547	2,408	2,325	83	none	67.8
1983	3,727	2,718	2,633	85	none	72.9
1984	3,886	2,884	2,793	91	none	74.2
1985	4,079	3,213	3,111	102	none	78.8
1986	4,251	3,551	3,440	111	none	83.5
1987	4,588	3,667	3,541	126	none	79.9
1988	4,803	3,631	3,484	131	16	75.6
1989	5,115	3,833	3,677	137	19	74.9
1990	5,421	3,775	3,628	147	none	69.6
1991	5,628	3,815	3,661	154	none	67.8
1992	5,860	3,869	3,692	177	none	66.0
1993	6,028	3,884	3,692	192	none	64.4
1994	6,223	4,455	4,259	196	none	71.6
1995	6,388	4,926	4,730	196	none	77.7
1996	6,619	5,153	4,957	196	none	77.9

SOURCE: Comisión Nacional de Investigación Científica y Tecnológica (CONICYT), Santiago, Chile.

Figure 4. Competitive state funds available for higher education in Chile (via CONICYT)



SOURCE: Comisión Nacional de Investigación Científica y Tecnológica (CONICYT), Santiago, Chile.

31 percent (US$104 million) was the state direct allowance shared by the 25 traditional universities, and 17 percent (US$57 million) was the direct subsidy the state provides for its technological institutes (Frei 1998 and Santibañez 1998). It is appropriate to say, at this point, that the direct state allowance received by traditional universities is not evenly distributed; it varies widely based on a number of factors. Therefore, and as already mentioned, a minimum amount of this fund goes to graduate students—mainly as fellowships—and not in direct support of experimental research.

The Situation in Science and Engineering

Most graduate programs in traditional universities deal with basic sciences and mathematics rather than with engineering. This may be one of the factors underlying the weak relationship existing between universities and the productive sector. Engineering is an activity that builds on sciences, techniques, and arts to improve and diversify the production of good and services, contributing in this way to societal satisfaction. The relationship of empirical engineering with basic sciences to make up what is currently known as "engineering sciences" is a rather recent phenomenon; therefore, the development of graduate activities has naturally been delayed in relation to basic sciences. This is the situation in Chile, where the universe of people and organizations devoted to research in this field is not very large nationwide. Fewer than 15 percent of all graduate programs currently in progress in Chile correspond to engineering and related areas. Table 12 shows the distribution of scientists and engineers involved in research in Chile, where engineers represent about 30 percent of the total. The difference is even higher when the analysis is limited solely to universities. Table 13 shows that, in the last 15 years, the proportion of engineers among researchers at universities has declined from over 16 percent to less than 14 percent. This is an evident sign of the already discussed tendency of graduates to prefer the private sector to universities.

Table 14 shows that the number of scientists and engineers per 1,000 population has increased modestly from 0.9 in 1981 to 1.2 in 1996.

Although the representation of engineers in research—and, as a consequence, in graduate activities—is low, their efficiency might be high. To test this hypoth-

Table 12. Scientists and engineers involved in research in Chile					
Year	Total number of researchers	Scientists		Engineers	
		Number	Percent	Number	Percent
1981....................	3,420	2,369	64.3	1,051	30.7
1982....................	3,547	2,488	70.1	1,059	28.9
1983....................	3,727	2,632	10.6	1,095	29.4
1984....................	3,886	2,739	70.5	1,147	29.5
1985....................	4,079	2,873	70.4	1,206	29.6
1986....................	4,251	3,000	70.6	1,251	29.4
1987....................	4,588	3,174	69.2	1,414	30.8
1988....................	4,803	3,222	67.1	1,581	32.9
1989....................	5,115	3,427	67.0	1,688	33.0
1990....................	5,421	3,669	67.7	1,752	32.3
1991....................	5,628	3,784	67.2	1,844	32.8
1992....................	5,860	3,979	67.9	1,881	32.1
1993....................	6,028	4,055	67.9	1,973	32.8
1994....................	6,223	4,177	67.1	2,046	32.9
1995....................	6,388	4,350	68.1	2,038	31.9
1996....................	6,619	4,552	71.3	2,067	31.2

NOTE: The engineers included here are those who perform research.

SOURCES: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1981 a 1995); and Departamento de Información y Departamento de Estudios, CONICYT, Chile.

Table 13. Percentages of scientists and engineers at universities					
Year	Total number of researchers	Scientists		Engineers	
		Number	Percent	Number	Percent
1981....................	2,434	2,035	83.6	399	16.4
1982....................	2,561	2,153	84.0	408	16.0
1983....................	2,677	2,260	84.4	417	15.6
1984....................	2,789	2,363	84.7	426	15.3
1985....................	2,924	2,489	85.1	435	14.9
1986....................	3,056	2,612	85.5	444	14.5
1987....................	3,169	2,716	85.7	453	14.3
1988....................	3,279	2,817	85.9	462	14.1
1989....................	3,389	2,918	86.1	471	13.9
1990....................	3,609	3,117	86.4	493	13.7
1991....................	3,710	3,206	86.4	504	13.6
1992....................	3,942	3,406	86.4	536	13.6
1993....................	4,029	3,472	86.2	558	13.8
1994....................	4,168	3,589	86.1	580	13.9
1995....................	4,356	3,755	86.2	601	13.8
1996....................	4,583	3,960	86.4	623	13.6

SOURCES: Consejo de Rectores de las Universidades Chilenas, *Anuario Estadístico* (Santiago, Chile, 1981 a 1995); and Departamento de Información y Departamento de Estudios, CONICYT, Chile.

Table 14. Total scientists and engineers per 1,000 population			
Year	Active population (Thousands)	Scientists and engineers	Per / 1,000
1981	3,815.1	3,420	0.90
1982	3,897.4	3,547	0.91
1983	4,127.3	3,727	0.90
1984	4,174.5	3,886	0.93
1985	4,239.3	4,079	0.96
1986	4,346.9	4,251	0.98
1987	4,392.3	4,588	1.04
1988	4,551.6	4,803	1.06
1989	4,674.6	5,115	1.09
1990	4,728.6	5,421	1.15
1991	4,794.1	5,628	1.17
1992	4,990.4	5,860	1.17
1993	5,219.3	6,028	1.16
1994	5,299.5	6,223	1.17
1995	5,538.2	6,388	1.15
1996	5,776.9	6,619	1.15

SOURCES: Instituto Nacional de Estadísticas, INE, *Anuarios Estadísticos,* años: 1984 a 1994, Santiago, Chile; Banco Central de Chile, Boletines Mensuales, años: 1984 a 1996 Santiago, Chile; Consejo de Rectores, *Anuarios Estadísticos,* años: 1982 a 1995; and Departamento de Información y Departamento de Estudios, CONICYT, Chile.

esis, one reasonable way to analyze the productivity level of engineering sciences and technology research in a developing country like Chile would be to look into indexed mainstream articles at the Institute of Scientific Information (ISI) over a defined period of time (Zumelzu 1997).

Such an analysis allows one to quantify and evaluate research activities in a given field, which indirectly may be a basic reflection of graduate activities performed in a given country. According to ISI data, the contribution of Latin American countries to indexed scientific publications accounts for only 1.3 to 1.8 percent of the world's total; of this, Brazil, Argentina, Mexico, and Chile represent a solid 85 percent of Latin America's contribution (Appenzeller 1995). When considering the number of publications per million inhabitants, Chile occupies the first place, followed by Argentina (Ayala 1995). In contrast, Latin American engineering publications, when compared to other disciplines, do not exceed 5 percent of the total, of which Chile has the lowest impact (Krauskopf et al. 1995).

Final Remarks

This presentation updates as well as summarizes the most relevant issues that have defined the state of development of graduate education in Chile. Although its standards remain high, graduate education has a low representation in university life in Chile. To increase its prominence as a key instrument for social and technical development, stronger support from the state is required, in close association with traditional universities and—hopefully—the private sector as well. A 5-year state program supported by the World Bank oriented to graduate education is in the process of being implemented in Chile, thus providing new reason for optimism.

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Mexico, Colombia, and Venezuela

Hebe Vessuri

Mexico

Recent Reforms and Trends

In 1987, the National Council for Science and Technology (CONACYT) started a support program in Mexico for graduate courses that required all graduate programs to provide data about their current state, curricula, enrollment, graduates, teaching staff, etc. In addition, members of an ad hoc evaluation committee visited each program. Although only a limited number of programs responded to this initiative at first, public universities, together with educational authorities, did make an effort to increase the number of responding graduate programs; 8 years later, CONACYT had accredited 614 graduate programs. By 1996, however, this number had dropped substantially from 614 to 478 accredited graduate programs. This drop may be explained in terms of a change in the evaluation criteria recently applied by CONACYT and to the disappearance of the "others" category. With some ups and downs, a group of 160 doctoral programs (33.5 percent of the accredited graduate programs) has been established that competes with some high-level doctorates abroad. However, only a small number of domestic doctoral programs have achieved such a level of quality. Among the doctoral programs, 18.8 percent are in the basic sciences, and 16.9 percent are in engineering.

Table 1. Mexican graduate population by field of study, 1991-96

Field	1991	1992	1993	1994	1995	1996
Total	425	453	461	574	614	478
Basic sciences	46	52	55	64	74	68
Natural sciences	32	36	31	36	36	29
Health	34	41	43	51	52	35
Earth sciences	20	19	17	18	20	18
Social sciences	52	59	70	95	107	103
Human & behavioral sciences	51	52	48	67	69	45
Applied & engineering sciences	109	103	102	131	135	97
Biological applied sciences	81	91	95	112	121	83

SOURCE: National Council for Science and Technology (CONACYT) <<http://www.main.conacyt.mx1/>>, 1998.

In the Government Program of Science and Technology (Programa de Gobierno de Ciencia y Tecnología 1995-2000), the training of human resource professionals was given priority, due to the insufficient quantity and quality of those already in the workforce. It was agreed to support more strongly high-quality doctoral programs offered by Mexican institutions through evaluation by groups of prestigious academics and better fellowships to the students enrolled in these programs, and by establishing a postdoctoral fellowship program for those graduating from such programs. As a result of continuous effort, graduate enrollment grew 129.48 percent between 1987 and 1997, to a total of 87,696 students. Adding to this figure those who were abroad (data available for 1995-96 indicate that there were 3,360 Mexican graduate students abroad) yields a total global graduate population of over 91,000. It is estimated that postgraduates represent slightly over 1 percent of those new employees who join the workforce each year.

Many a graduate program, even within the same institution, tends more to disintegration than to union, collaboration, and collective effort; moreover, they are often centered in groups that are not highly productive, as reflected in times to degree completion. Perhaps the most disturbing feature is the scant number of students with few instructors in some fields. The small number of graduates produced in the different fields therefore comes as no surprise; this in turn results in very low growth of research scientists and engineers.

A frequent complaint is the lack of connection between *licenciatura* and graduate programs, and between teaching and research programs. Often, an institution hires researchers with the aim of strengthening its teaching through lecture-giving, rather than making it a requisite part of the program that students spend a work period in a research group. The old system of laboratory practices is frequently preferred, although some universities have very well-furbished research labs, and excellent students could undoubtedly be oriented toward the graduate level and research.

Table 2. Number of graduate programs accredited by field of knowledge in Mexico, 1991-97						
Field	1991	1992	1993	1994	1995	1996-97
Total	425	453	463	574	614	NA
Doctorate	118	120	129	172	195	160
Basic sciences	25	30	30	35	41	38
Natural sciences	21	23	18	19	19	15
Health	21	26	28	33	31	21
Earth sciences	11	11	10	11	12	10
Social sciences	43	49	59	73	81	77
Human and behavioral sciences	32	37	32	45	46	29
Applied and engineering sciences	84	78	77	96	98	70
Biological applied sciences	60	69	70	82	84	58
Master's	297	323	324	394	412	318
Basic sciences	25	30	30	35	41	38
Natural sciences	21	23	18	19	19	15
Health	21	26	28	33	31	21
Earth sciences	11	11	10	11	12	10
Social sciences	43	49	59	73	81	77
Human and behavioral sciences	32	37	32	45	46	29
Applied and engineering sciences	84	78	77	96	98	70
Biological applied sciences	60	69	70	82	84	58
Others	10	10	10	8	7	NA
Basic sciences	3	3	2	2	2	NA
Natural sciences	0	1	1	1	0	NA
Health	0	0	0	0	0	NA
Earth sciences	1	0	0	0	0	NA
Social sciences	1	2	2	2	2	NA
Human and behavioral sciences	10	0	0	0	0	NA
Applied and engineering sciences	4	3	3	3	3	NA
Biological applied sciences	1	1	1	0	0	NA

SOURCE: National Council for Science and Technology (CONACYT) <<http://www.main.conacyt.mx1/>>, 1998.

The government's policy aims with regard to training high-level scientists and engineers include the following:

- to increase the number of fellowships for graduate studies in Mexico and abroad;
- to support training programs for the *licenciaturas* teaching staff;
- to foster increased offerings of good-quality *licenciaturas*;
- to accelerate improved quality in domestic graduate programs—particularly, to stimulate the establishment and accreditation of high-level doctoral degrees comparable to those available internationally in the coming years; and
- to promote improved professional training in the sciences and engineering.

Levels of Graduate Enrollment and Degrees in Mexico

Enrollment. The development of higher education in Mexico is necessary to support research and improve the training of teaching staff within higher education itself, as well as influencing the remaining levels and subsystems of education. At the present time, most higher education teachers (about 80 percent) have only a first degree (*licenciatura*), and the number of researchers in this country of 90 million is less than 10,000. If the figures of the National System of Researchers (SNI) are taken as a reliable indicator, the development of the scientific endeavor in Mexico—particularly in connection with training the future generation of scientists—rests upon a little over 5,000 people in SNI levels I, II, and III (1997).

As far as graduate education is concerned, enrollment is very low (87,696) relative to the *licenciatura* (1,310,229) and normal education[1] (188,353) programs; it represents only 5.85 percent of total higher education enrollment in Mexico—thus indicating the need to give priority to the growth of graduate education. Note, however, that graduate enrollment has more than doubled in the last 10 years, rising from about 38,200 in 1987 to about 87,700 in 1997. (See appendix table 1.)

Although the proportion of students seeking education in science and technology in Mexico is not significantly different from that of more industrialized countries, the schooling rate of the age group is lower, because the latter students have more extensive nonuniversity sectors that provide shorter training of a more practical and vocational nature—i.e., more students have a nonuniversity education adequate to meet the conditions of the employment market. Qualified observers of the Mexican educational system notice a weak enrollment in training for work and terminal secondary higher education,[2] which on the whole comprises barely 3 percent and has lost its attractiveness since the 1980s (OECD 1997, p. 38). The modalities of what in many countries is called post-obligatory secondary education and in Mexico is known as *formación media superior*, its content, and its structure help explain to a large extent the evolution of the demand for higher education. It is also at that level that many countries offer broad possibilities for technical and professional training. It is for this reason that Organisation for Economic Co-operation and Development (OECD) examiners called attention to the need for observing the extent to which these training programs coincide with those of higher education. In Mexico, this educational level has traditionally had a preparatory function: many educational institutions depend directly upon higher education institutions. It thus seems advisable, when trying to get an overview of higher education and the role of graduate education, not to disregard the complex structure and interlocking levels and subsystems.

Higher education in Mexico has a long history. It has managed to educate an internationally recognized intellectual and professional elite, but the mean level of education and professional qualification continues to be very modest. The organizational framework within which the Mexican system of higher education fulfills its function is through the following programs and levels of study: (1) the *licenciatura* level, traditionally associated with professional training; and (2) graduate studies, specifically specialization certificates and master's and doctoral degrees. To complete a *licenciatura* takes from 4 to 6 years; specializations take 1 year, except for medical options; master's programs, 2 years after *licenciatura*; and doctoral studies from 2 to 3 years after the master's degree or from 4 to 5 years after the *licenciatura*. However, the *licenciatura* or first degree often takes a considerably longer period to be completed.

As far as the public sector is concerned, these levels of study operate in a very complex political and administrative setting of institutions of higher education dependent on the federal and state governments. These, in some cases, have to deal with the Secretariat of Public Education (SEP); in others, with the Secretary of Finance and Public Credit; and in still others, with the presidency.

Enrollment in Doctoral Programs. Growth at the doctoral level has been remarkable in relative terms, with a 342.85 percent rise in the 10-year period under consideration. During that same time, the master's level grew 151.68 percent, and the specialist's degree level had an increase of 66.15 percent. But the participation of the population in doctoral programs continues to be minimal (rising only from 1,400 to 6,200 in 10 years) relative to that in master's programs, which still have the bulk of enrollment with 59,900 students, and specialist programs, with 21,600. At the doctoral level, the distribution of enrollment by field is relatively homogeneous: 26 percent corresponds to the basic and natural sciences, 7 percent to health and applied biological sciences, 26 percent to social and administrative sciences, 18 percent to education and humanities, and 16 percent to engineering and technology. But only two disciplines had more than 500 students enrolled: biology (522) and education (668) in

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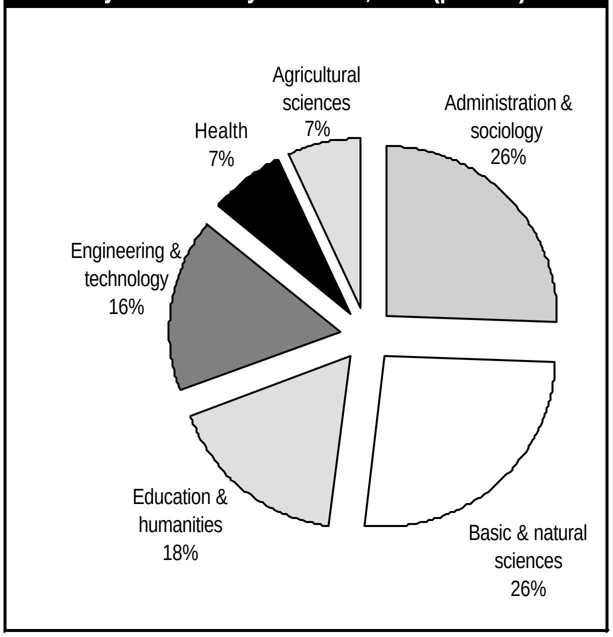
[1]Normal education, which involves the training of basic education teachers in normal schools, is included here with higher education, because the degree granted since 1984 is that of *licenciatura*. However, normal education has its own identity in terms of curriculum, organization, and ideology.

[2]Secondary education lasts 3 years and is offered to the 12- to 16-year-old population that has completed primary school. It is provided in the following modalities: (1) *general secondary*, which accounts for the largest proportion of enrollment; (2) *technical secondary*, which simultaneously provides general education and terminal training for productive activities in four fields: industry, agriculture, fishing, and forestry; (3) *secondary for workers*, which is given at special times and sometimes in the workplace; and (4) *telesecondary*, created to give opportunity to inhabitants of small and isolated communities.

1997; physics followed with 413, social science with 342, chemistry with 291, agronomy with 270, and anthropology and archaeology with 246. All other fields had meager populations of fewer than 100 students.

Figure 1. Doctorate student population by field of study in Mexico, 1997 (percent)

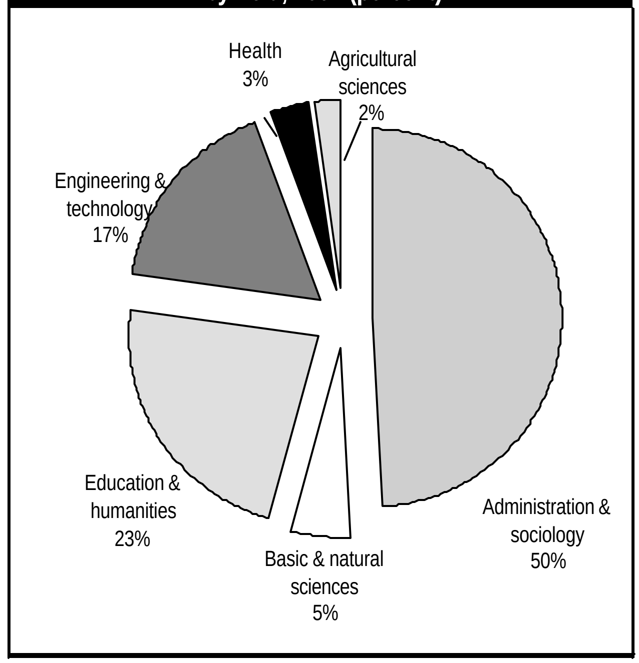


SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). Anuario Estadístico, 1997.

Accepting the premise that the doctorate is the best means to train researchers and advanced teachers, the small number of Mexican doctoral students both in the country and abroad is clearly a limiting factor for the country. When looking at potential supply and demand given the number of researchers in the SNI (5,000, excluding candidates), with good planning, a greater number of graduate students could attend than is the case at the present time; this would raise the current figure by a factor of three. Also, there are enough candidates who could enroll in doctoral programs—i.e., students newly graduated from master's programs—as well as teaching staff who do not yet have a doctoral degree.

At the master's level, enrollment is dominated by the social and administrative sciences, keeping the same proportion as at the *licenciatura* level: i.e., approximately half the total enrollment. There follow in importance education and the humanities with 23 percent, engineering and technology with 17 percent, and the basic and natural sciences with 5 percent. The remaining fields (health and agricultural sciences and technologies) have marginal enrollments of 2 or 3 percent each. By far the most impressive concentration is in anthropology and archaeology, which had 16,923 students in 1997; followed by education (10,455) and law (2,851); taxes and finances (2,425); psychology (2,248); and economy and development (2,104).

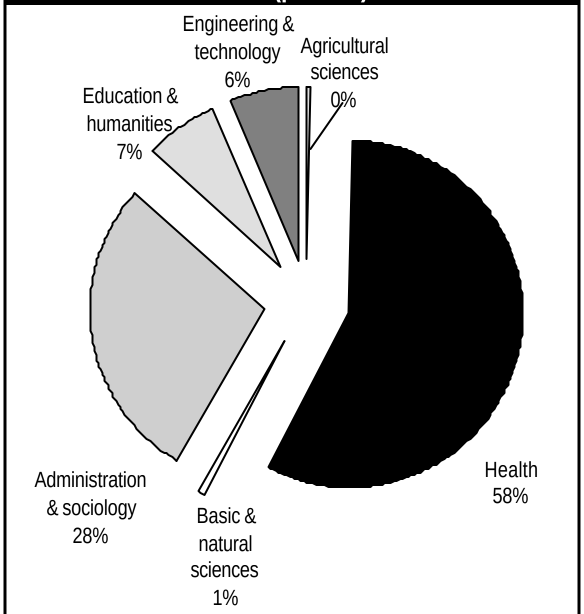
Figure 2. Master's student population in Mexico by field, 1997 (percent)



SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). Anuario Estadístico, 1997.

Specialization studies are graduate studies carried out after the *licenciatura* which prepare students for work in a specific field of professional endeavor without constituting an academic degree. In 1997, 21,600 students were enrolled in specialization programs, or 24.62 percent of total graduate enrollment. At the specialist level, most of the enrollment has historically been concentrated in the health sciences, due to the fact that medicine and dentistry professional specializations are obtained through this means. However, the proportion of enrollment captured by the health sciences and technologies at this level has been decreasing. In 1985, it represented 80 percent of total enrollment, compared to less than 70 percent in 1992; by 1997, only 57.3 percent of the total population was at this level. This phenomenon may be explained by the proliferation of specialist programs (generally diploma courses) in the social and administrative sciences, in which absolute enrollment had a threefold increase during the period of reference; and, to a lesser extent, by the growth of certificates in education and in engineering and technology. In the remaining fields, enrollment has also shown an upward trend, although with less intensity.

Figure 3. National concentration of specialties: student population by field and program in Mexico, 1997 (percent)



SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). Anuario Estadístico, 1997.

The SEP has made a real effort to decentralize higher education. Whereas in 1970, over half the enrollment in higher education was located in the Federal District (D.F.), today this zone has only a fifth of national enrollment. There continues, however, to be a significant concentration in the territorial distribution of graduate enrollment. In 1985, over half the enrollment was concentrated in the universities located in the capital city; by 1997, the D.F. continued to have over 41 percent of total graduate enrollment, although a significant effort at decentralization was also noticeable. In 1985, three states still lacked master's programs (Aguascalientes, Chiapas, and Quintana Roo); in 1992, only Quintana Roo was without programs at this level. In that year, however, more than 80 percent of doctorates were awarded to individuals in the D.F.

Along with the territorial distribution is an institutional concentration, which includes outstanding names such as UNAM, which alone has 23.7 percent of all graduate enrollment in the country, as well as the Autonomous Metropolitan University (UAM), the Iberoamerican University, and the National Polytechnic Institute (IPN). Some institutions outside the Metropolitan Zone also have large concentrations of graduate students, particularly at the master's level. Among these are the University of Guadalajara, the University of Nuevo León, and the Technology and Advanced Studies Institute of Monterrey. Finally, there is a concentration of graduate studies and research in the public sector, which accounts for over three-quarters of enrollment, and nearly 87 percent in specialist and doctoral programs.

Table 3. Main geographical concentrations of Mexican graduate student population, 1997

State	Number of enrollments	Number of graduates
Total	87,696	20,203
Specialization	21,625	8,305
Federal District	11,192	3,988
Mexico	1,438	777
Jalisco	1,873	673
Puebla	660	341
Master's	59,913	11,164
Federal District	15,669	3,050
Nuevo Leon	7,169	1,269
Puebla	4,425	815
Mexico	3,934	812
Doctorate	6,158	734
Federal District	3,665	503
Guanajuato	342	35
Mexico	338	36
Jalisco	139	46

SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). *Anuario Estadístico. Poblacic escolar de posgrado.* México, D.F.

Female participation grew very considerably between 1984 and 1996, although males still dominate in some fields. Over this period, female enrollment went up 248.8 percent in master's programs and 325.7 percent in doctoral programs; male enrollment grew 116.1 percent at the master's level and 381.9 percent at the doctoral level—a clear reflection of the great expansion of studies at this level (see appendix tables 2, 3, and 4). In 1997, females accounted for 40 percent of enrollment in master's programs and in 34.42 percent in doctoral programs.

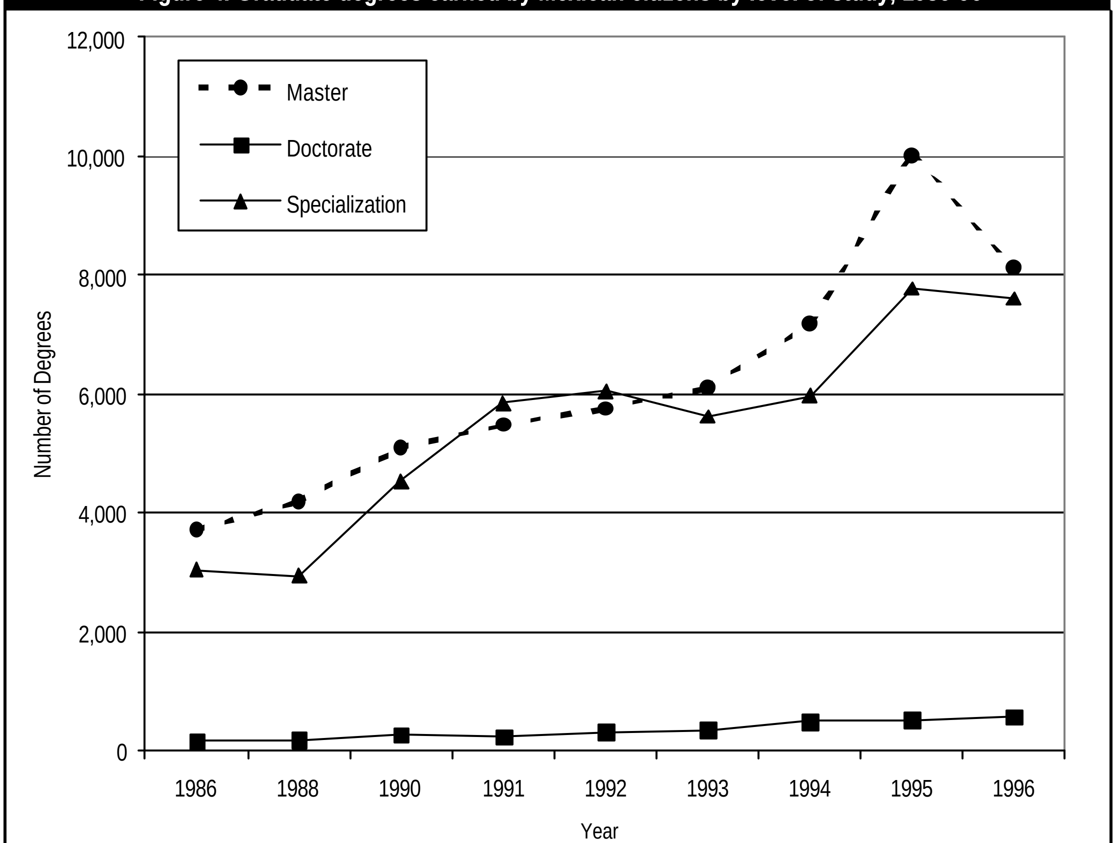
Doctoral Degrees. The number of graduates of doctoral programs has remained very low despite undeniable advances. In 1984, distribution by degree was 3.69 percent doctoral graduates (245 individuals), 54.86 percent master's graduates (3,640), and 41.43 percent graduates of specialist programs (2,749). In 1995, those proportions showed little variation: 2.83 percent doctoral graduates (519 individuals), 54.71 percent master's graduates (10,008), and 42.44 percent graduates of specialist programs (7,764). By 1996, there was a recovery in the proportion of doctorates relative to the total graduating population, increasing to 3.63 percent (734 doctorates); graduates of master's programs represented 55.25 percent (11,164 persons) and from specialist programs, 41.10 percent (8,305 individuals) (SEP-CONACYT 1997, p. 146, table II.27; and ANUIES 1995 and 1997).

The distribution of doctoral graduates by field in 1996 was as follows: over half (54 percent) corresponded to the social and human sciences combined, 17 percent to the basic and natural sciences, 14 percent to health, 8 percent to engineering and technology, and 7 percent to agricultural sciences and technologies. The most remarkable change is the increment of doctorates in the field of health, showing a 75 percent increase relative to 1995. The agricultural sciences also show a remarkable 140 percent increase in number of doctorate recipients, although the absolute figures are small (48 individuals in 1996).

As far as geographical distribution is concerned, the Federal District continues to show an increasing concentration in the number of graduates produced relative to the rest of the country. In specialist programs, the proportion rose from 19.60 percent of graduates in the D.F. in 1984 to 39.78 percent in 1995. At the doctoral level, compared to 59.59 percent of graduates in the D.F in 1984, there were 64.54 percent in 1995. A reduction is observed only at the master's level: graduates in the D.F. comprised 35.41 percent in 1984 and had decreased to 26.15 percent by 1995. At a university like UNAM, between 1989 and 1996, the granting of degrees at the doctoral level increased 69 percent (329 in 1997), with 31 percent for master's candidates (1,044) the same year. It is intriguing that the data collected for enrollment and degrees, if correct, indicate that those pursuing a doctorate degree in the D.F. are less likely to complete their degree than those pursuing a doctorate outside the D.F. We do not yet have an explanation for this.

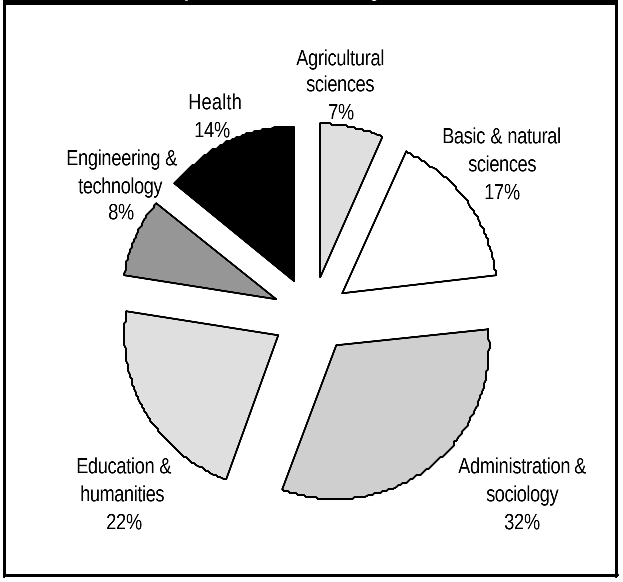
On a cursory level, the number of researchers in some disciplines—such as biology, medicine, and chemistry, with 973, 410, and 317 SNI researchers, respectively in 1997-98—does not seem so scant. Differentiating by subfield, however, reveals significant differences, with some areas showing a potential for improvement and

Figure 4. Graduate degrees earned by Mexican citizens by level of study, 1986-96



SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior ANUIES, Anuarios Estadísticos de Posgrado, 1985-96.

Figure 5. Doctoral graduates in Mexico by field of knowledge, 1996



SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior ANUIES, Anuarios Estadísticos de Posgrado, 1985-96.

growth (e.g., biochemistry and physiology); and others having only a small number of researchers in the local context and thus an apparently small potential for growth (e.g., biophysics among many others). These limitations may affect the future development of new sciences and technologies (Peña 1995, pp.15-18). The same author calls attention in another work (1994, pp. 23-27) to a lack of students, particularly at the doctoral level. He argues that science teaching is one of the weak points in the Mexican educational system, and that one of the mechanisms for attracting the young to research entails integrating them at an early stage in groups that carry out research. Peña urges increased promotion of graduate programs, although he admits that, in the biological fields, there are few places that offer adequate features conducive to fostering research.

Time to Degree. Terminal efficiency—or time to degree—has improved over time. The efficiency of the higher education system is calculated globally, correlating enrollment in a given year with graduation from the institutions 5 years later, which is the average official duration of undergraduate studies (*licenciatura*). Results obtained from the number of graduates in the 1990s give an average efficiency of slightly over 54 percent. This represents an improvement over values observed in the 1970s, when the efficiency proportion hardly reached 45 percent, and over the 1989-90 to 1993-94 period, when it was 49 percent and showed marked variations by course of study.

Improvements seem to have occurred especially at the doctoral level; this is basically attributed to the type of program and support given to graduate students during the period of thesis work. In a field like physics, which has been closely followed by analysts for the last 10 years, it is argued that the terminal efficiency of the graduate programs of the Center for Research and Advanced Studies (CINVESTAV) are the highest in the domestic context. Figures for graduates in physics doctoral programs in Mexico are given in table 4.

Among doctorate recipients from Mexico in the United States, the average time from baccalaureate to Ph.D. is 10.3 years, and the average registered time is 6.5 years; this latter varies between 5.4 years in the computer/information sciences to 6.8 years in the physical sciences and psychology/social sciences. (See appendix table 6.)

Table 4. Graduates from Mexican doctoral programs in physics, 1986-95

Institution	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Average 1992-95 (1981-95)	TE* percent
Total	12	14	21	20	21	27	25	20	30	39	34	-
UNAM	8	7	7	6	8	8	12	4	8	8	8 (8)	38
CINVESTAV	2	2	4	8	3	6	6	6	4	7	6 (5)	86
CICESE	-	2	3	1	4	3	2	3	6	6	4 (3)	
INAOE	-	1	-	-	-	1	1	1	1	4	2 (-)	40
Others	2	2	7	5	6	9	4	6	6	14		

KEY: (-) = not applicable

TE* = Terminal efficiency for the last three generations.

NOTE: Average number of graduate students per institution in 1991-95 and 1986-95 (in parentheses), as well as average terminal efficiency (percentage) for the three more recent generations.

SOURCE: Pérez, A., and V.G. Torrees. La disica mexicana en perspectiva. Interciencia 23(3): 163-75, 1998.

Fellowships. A high-level staff training policy absorbs significant amounts of money (10 percent of the Mexican science and technology domestic expenditure). The growth in recent years of the number of graduate students is largely a consequence of the support given by the federal government to several fellowship programs. In 1990-95, the fellowships granted by these programs increased 190 percent; 24,845 fellowships were awarded in 1995. Several institutions have important fellowship programs, among them the SEP, CONACYT, UNAM, and IPN.

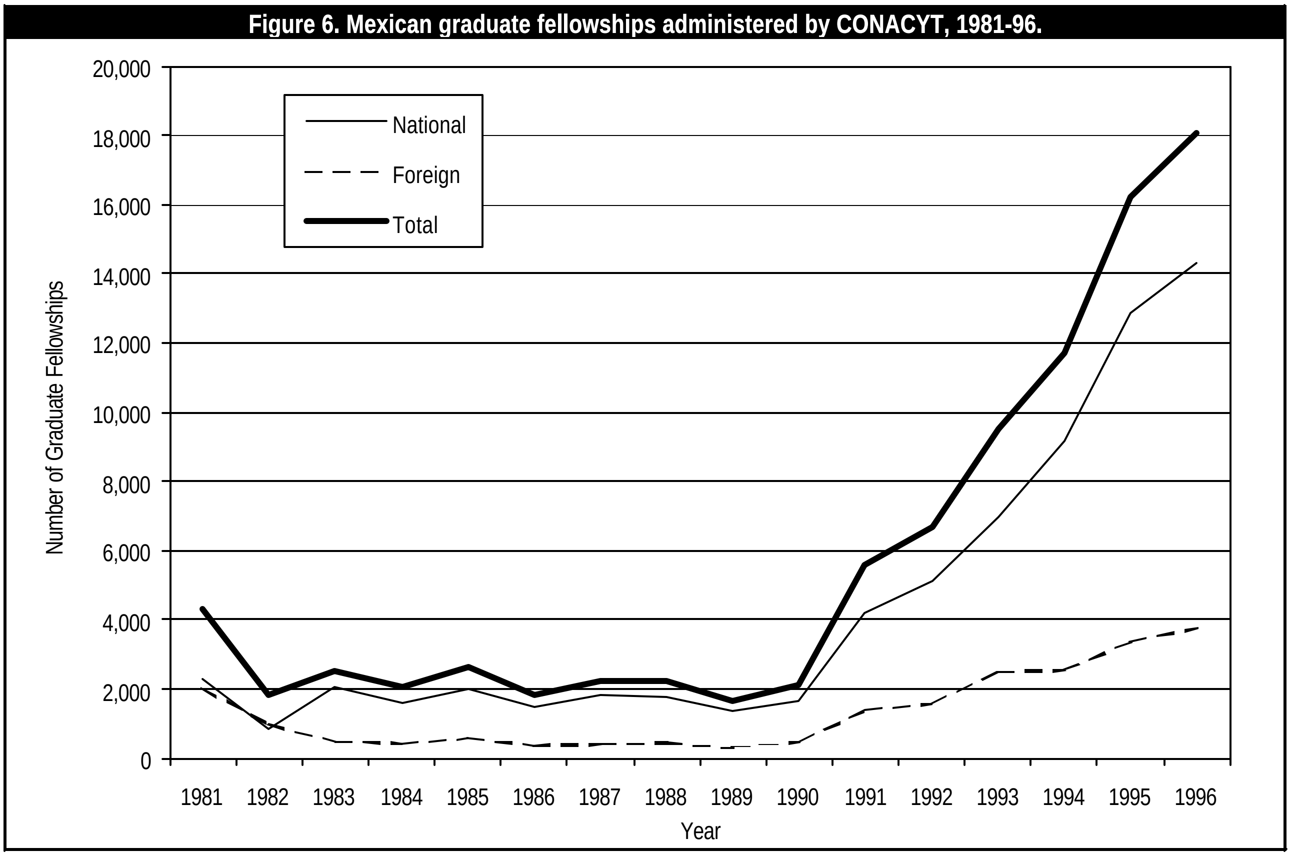
The CONACYT program is the broadest fellowship program in the country. It absorbs almost half the budget resources of the institution (46 percent in 1995) and comprises 65 percent of all fellowships supported by the federal government. In 1996, it supported 18,079 students. Of these, 21 percent were individuals who went abroad to study; the remaining 79 percent studied in Mexican institutions. Of all the fellowships, 12,479 (69 percent) were for master's courses; 5,269 (29 percent) were for doctoral degrees; and 331 (2 percent) supported other studies. This program has grown more than five times in the last 5 years. (See appendix tables 7 and 8).

Table 5. Mexican graduate fellowships granted by administrative sector, 1989-95

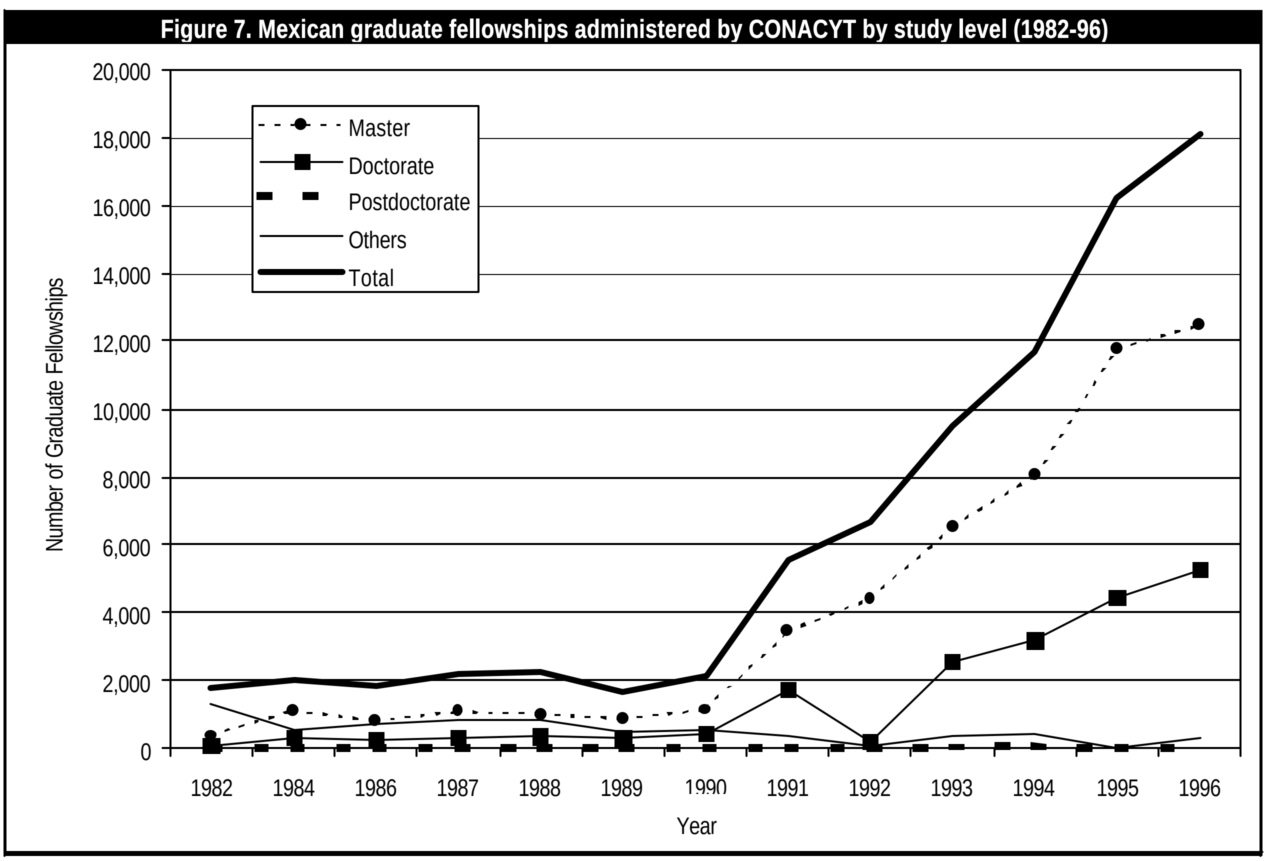
Sector	1989	1990	1991	1992	1993	1994	1995/p
Total	7,548	8,572	11,900	13,426	16,451	19,057	24,845
SAGAR	-	-	-	-	-	800	1,240
SCT	30	99	159	268	118	6	8
IMT	30	93	155	264	114	0	0
IMC	0	6	4	4	4	6	8
Secofi	-	-	-	-	-	50	61
SEP	4,125	5,401	20,935	20,935	14,351	16,214	21,554
CONACYT 1/	1,677	2,135	5,570	6,665	9,492	11,703	16,200
UNAM	778	1,277	1,417	1,549	1,714	1,494	1,197
Sistema SEP-CONACYT	86	94	147	232	260	564	751
INAH	128	206	297	248	262	n.d	n.d
UAM	90	158	92	91	270	295	350
IPN	1,170	1,344	1,552	1,717	1,860	1,735	2,593
UPN	0	3	1	11	39	NA	NA
Cinvestav	-	-	-	-	-	107	147
DCIT	196	184	422	422	454	316	316
Salud y S.S.	-	-	-	-	-	613	760
Semernap	20	24	31	19	19	138	156
Energía	3,358	2,947	2,203	1,959	1,844	402	380
IIE	369	464	466	504	394	273	239
IMP	2,840	2,405	1,588	1,295	1,321	129	141
ININ	149	78	149	160	129	0	0
PGR	15	32	124	145	37	689	538
SHCP	-	69	84	100	82	145	148
Total amount (m.N.P)	41,332	54,106	89,795	155,050	248,098	406,659	676,759

KEY:
p/= preliminary figures
(-)= not applicable
NA= not available
SAGAR= Agriculture, Livestock & Water Resources Secretary
IMT= Mexican Transport Institute
Secofi= Commerce & Industrial Promotion
CONACYT= National Council for Science & Technology
Sistema SEP-CONACYT= SEP-CONACYT Research Centers
INAH= Anthropology & History National Institute
IPN= National Polytechnic Institute
Cinvestav= Research & Directorate of Technological Institutes
m.N.P.= thousands of new pesos
SCT= Transport & Communication
IMC= Mexican Communication Institute
SEP= Secretariat of Public Education
UNAM= National Autonomous University in Mexico
UNAM= Metropolitan Autonomus Univ.
UPN= National Pedagogic University
Salud y S.S.= Health & Social Security
Energía= Energy
IIE= Institute of Electrical Research
ININ= National Institute of Nuclear Research
SHCP= Finance & Public Credit
PGR= Office of the General Attomey of the Republic

SOURCE: National Council for Science and Technology, (CONACYT) (n.d.).



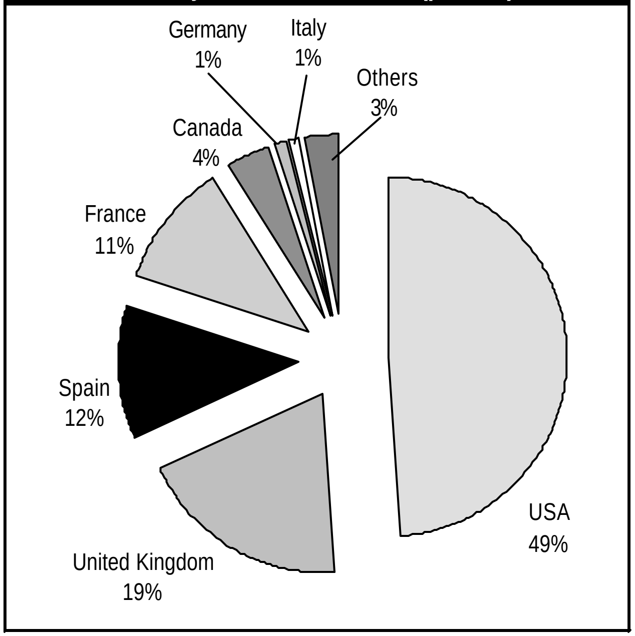
SOURCE: National Council of Science and Technology Studies (CONACYT), Mexico.



SOURCE: National Council of Science and Technology Studies (CONACYT), Mexico.

Of the fellowships abroad, there is a large concentration of students in the United States (49 percent), followed by the United Kingdom (19 percent), and Spain and France (12 and 11 percent, respectively).

Figure 8. Mexican distribution of fellowships abroad by country of destination, 1997 (percent)



SOURCE: National Council for Science and Technology (CONACYT) <<http://www.main.conacyt.mx1/>>, 1998.

When the program was established, the general intention was for CONACYT to recover a major portion of the funds. Thus, support was generally granted in the form of loans. The program was also intended to track its results. Depending on the loan amount, loans may be either all-inclusive or complementary; they also may be for master's or doctoral degrees, or for postdoctoral fellowships. For a variety of reasons, both the recovery of funds and the follow-on tracking of graduates have been deficient. Lack of loan repayments has severely restricted the growth of funds intended for this end; also, given the limited tracking, the results of the support provided are not known for certain. The program should increase its coverage, improve its operational efficiency, and obtain greater social participation in funding. Experience has shown that program expansion depends on institutional capacity to attract outside financial resources.

Data from the National Science Foundation (NSF) on Mexican recipients of doctorates in the United States provides information regarding several aspects of the collective behavior of this population. For example, it indicates that 80.7 percent of this population are males, 65.6 percent are married, and the median age at Ph.D. is 34.5 years. (See appendix table 6.) Almost half of the doctorate recipients (46.9 percent) are supported by their own families, particularly those in non-science and -engineering fields (65.7 percent). The category "personal sources of support" includes a recipient's own earnings, family support, and loans. Another 45 percent are supported by a foreign government, which may be interpreted as the Mexican government (i.e., official Mexican fellowship programs including universities, teaching or research assistantships, etc.). There is no equivalent information for groups of Mexican individuals studying in other countries, but some similarities can be presumed, except that teaching or research assistantships seem to be more common in the United States than elsewhere.

CONACYT has implemented actions to support high-quality doctoral programs in Mexico. For example, in 1996, through the Program for the Strengthening of Domestic Graduate Education, it supported 26 graduate programs in higher education institutions with the aim of enlarging their infrastructure, documenting curriculum portfolios, and/or hiring visiting professors for periods not exceeding 1 year. The main recipients were El Colegio de Mexico and CINVESTAV, which together received 35 percent of all actions approved and were geared mostly to the social and exact sciences. Nevertheless, there are still only a few high-quality graduate programs, and they receive fewer applications for enrollment than ought to be the case: many qualified students who could enroll in them fail to do so, partly because they get better fellowships to study abroad. Solving this kind of problem is important because it would serve as an incentive to improve quality in domestic graduate education.

The degree qualifications of academic staff have been improving, although they are still quite insufficient for both teachers and researchers. It is estimated that only 2.5 percent of *licenciatura* teachers have a doctoral degree, while 56 percent have only a *licenciatura*. In these figures, the considerable weight still exerted by the number of teachers-by-the-hour (the *eventuales*) becomes a heavy institutional ballast, for it is difficult to motivate staff to devote time and effort to professional development when their employment condition is so fragile. There is a trend to increase the proportion of permanent positions (full-time and part-time dedication regimes) to the detriment of those covered by *eventuales* teachers. The current understanding of the problem is that the teacher-by-the-hour is always an interesting figure to have in an institution when hoping to bring closer to the university domain people who have other employment, particularly in industry or the services. Such employees, however, should always be a small proportion of the total staff; in Mexico, though, they constitute a large proportion (over 60 percent). CONACYT has instituted a special fellowship program since 1991 to stimulate university teaching staff to carry out post-*licenciatura* studies.

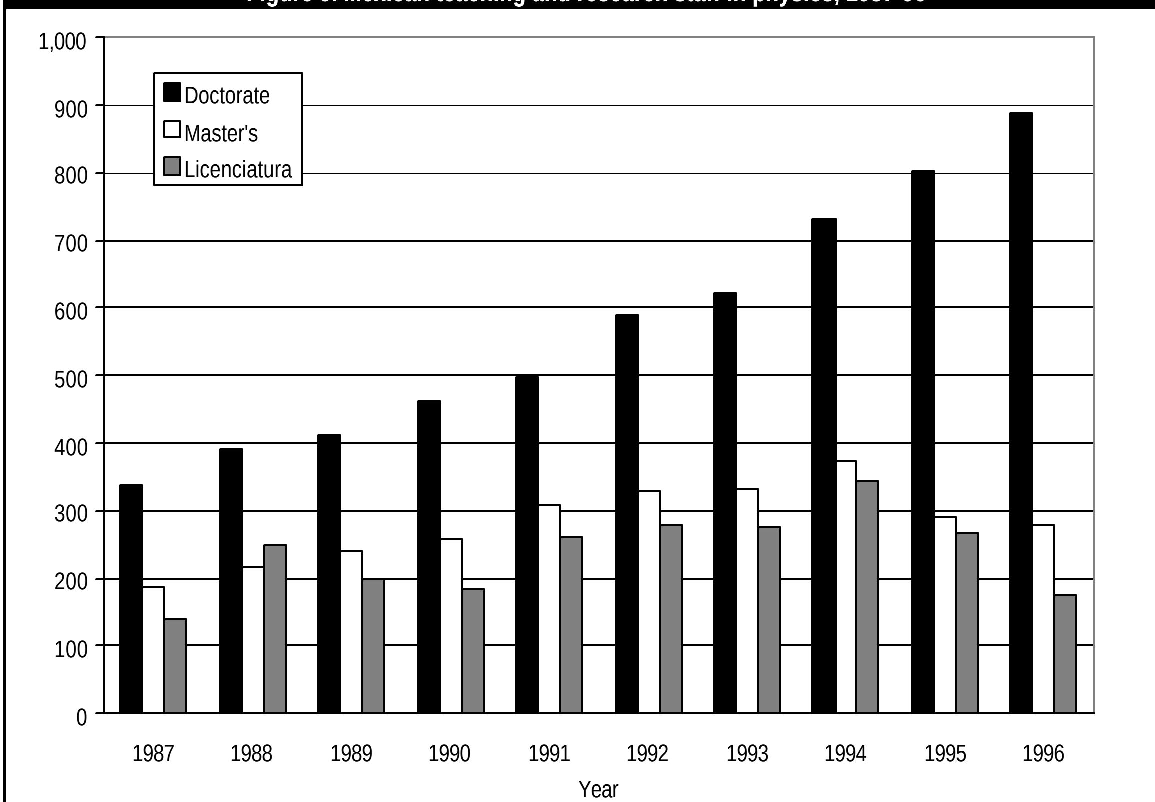
According to an influential viewpoint common in research and development (R&D) circles, new teacher positions should be reserved for persons holding a doctorate or who have a master's degree and are studying in a doctoral program. It is obvious that there is a real and potential demand for master's and doctoral programs. The evolution of teaching and research staff qualifications in the field of physics in Mexican institutions, on which detailed quantitative data are available (figure 9), may be taken to illustrate developments in some fields. But it must also be mentioned that U.S. universities have become more attractive than ever for numerous families who send their children to that country to continue or complete their studies.

International Mobility of Students and Researchers

Although the international relationships of the Mexican scientific community have broadened, especially with the United States and Europe, a good portion of the scientists and technologists are still at the margins of internationalization. Additionally, high-level foreign scientists and technologists do not come to Mexican institutions and research centers for long periods. Mexican students who go abroad to carry out undergraduate and graduate studies represent a modest proportion of total enrollment. In almost all cases, their stay is prolonged. Inversely, the flow of foreign students to Mexican university institutions and research centers is scarce; in general, it is reduced to brief periods.

According to the NSF statistical profile of Mexican doctorate recipients for the 1988-96 period, 1,115 persons were on temporary visas versus 244 on permanent visas

Figure 9. Mexican teaching and research staff in physics, 1987-96



SOURCE: Pérez, A., and V.G. Torrees. La disica mexicana en perspectiva. Interciencia 23(3): 163-75, 1998.

in the United States. Of these, 518 planned to stay longer in the United States, 28.8 percent to carry out postdoctoral studies; another 16.0 percent were seeking postdoctoral study posts, and 33.6 percent were in definite employment or seeking employment (19.5 percent) (appendix table 6).

According to another source (Noguera 1998), Mexico occupies the third place among the countries that export physicians, behind India and the Philippines; it is the first in the world in exports of young physicians less than 35 years old (31.5 percent), followed closely by India (30 percent). Mexico is also first in exporting U.S. physicians newly graduated from Mexican medical faculties who return to their country to carry out well-remunerated medical specialties, after having completed their professional medical studies in Mexico at very low cost. The same source estimates that 7 out of 10 Mexican physicians who are in the United States will stay permanently in that country. Therefore, the effort to repatriate young physicians is not an exclusive responsibility of the government's support programs for scientists.

International mobility is supported by fellowships funded by a number of bilateral and other cooperation mechanisms. They can be by agreement with foundations and governments, by open demand in agreement with universities, or in programs without subsidy. Fellowship amounts and conditions depend on the benefits that third governments, foundations, or other institutions may choose to grant. For example, for the year 1999, the number of loans offered in open demand without subsidy is 583 (this figure includes the offer of universities that have agreements with third-country institutions).

Among the fellowships that are made available by these cooperation mechanisms, the following may be mentioned in connection with CONACYT: with the United States, there is the Fulbright-García Robles program for master's and doctorate degrees, consisting of 80 fellowships for engineering and natural and exact sciences, and 40 fellowships for social sciences, including the following disciplines: economics, education, sociology, philosophy, political science, anthropology, linguistics, and psychology. With Great Britain, within the framework of the Anglo-Mexican Exchange Program (British Council), a total of 10 master's and doctoral fellowships are offered in 1999 for studies in environment, agricultural sciences and fisheries, aquaculture, biotechnology, food science, and electrical and mechanical engineering. The same exchange program (British Embassy) offers five fellowships in economics, international relations, public administration and planning, business administration, and political science and law. France offers a total of 40 doctoral fellowships in civil engineering, chemical engineering, chemistry, biotechnology, biochemistry, microbiology and food science, geological engineering and mining, water resources, electrical and electronic engineering, automation, informatics, agronomy, and ecology and environment (CONACYT 1998a). CONACYT also has exchange and collaboration programs with most Latin American science and technology councils. Among the 50 foreign universities in greatest demand by CONACYT's fellowship-holders, 19 are in the United States, 13 are in Great Britain, 7 each are in France and Spain, and 4 are in Canada (see appendix table 9).

In 1991, the Presidential Fund for Retention in Mexico and Repatriation of Mexican Researchers was established, resulting in 1,149 repatriations through 1996, with the aim of reinforcing the academic staff of higher education institutions (Bonilla-Marín and Martuscelli 1997). CONACYT provides the necessary funds for 1 year to cover salaries and other monetary incentives, depending on the decision of the collective institutional organs and the evaluation committee of the repatriation program. It also covers the travel expenses of the researcher and his or her family to settle in the selected location. The funds are granted to the recipient institution and aim to facilitate the swift hiring of the researcher, thus giving time to the institution to plan the creation of the new position required within the scope of 1 year.

The program has attracted mostly young researchers willing to start their professional lives after obtaining their doctorates or carrying out postdoctoral stays (the average age is 35), while only a few Mexican senior researchers established abroad have applied. The field of biological sciences registers the highest proportion of beneficiaries, followed by those in applied sciences (biological and engineering) and basic sciences. There are few applications from the human and behavioral sciences. The D.F. has a concentration of 42 percent of all repatriated researchers. The percentage of repatriated researchers absorbed by private institutions is low (6 percent); one institution (Instituto Tecnológico de Estudios Superiores de Monterrey) has hired 4.87 percent of these. UNAM (which has absorbed 24 percent), UAM (4 percent), IPN (2.5 percent), and the technological institutes (3 percent) together comprise 58 percent of all the beneficiaries. The majority of researchers—86 percent—come from six countries: Germany, Canada, Spain, France, the United

Kingdom, and the United States. From this latter country come 38 percent of the total. It may be noticed that 2.5 percent corresponds to retention within Mexico.

Of all repatriated researchers, 62 percent have joined the National System of Researchers. Of all those repatriated in the 1991-96 period, 0.9 percent of have gone abroad again. The number of doctors added to the national scientific community through the repatriation program, although lower than that resulting from graduates from Mexican doctoral programs, is comparable to the latter number. Adding up the two contributions affords a very close approximation to the total number of doctors who each year join the Mexican scientific and technological system.

Discussion

Some of the problems detected in the domestic graduate programs in Mexico (Bazúa y Meza 1996, pp.18-19) are:

- lack of definition and little clarity in the aims and objectives of the graduate program and its options;
- weak links between graduate education and the public and private productive sectors;
- the fact that research does not constitute a training line in some master's and doctoral programs;
- few inter-institutional programs;
- insufficient multidisciplinary or interdisciplinary graduate programs;
- absence of an effective tutorial system;
- imbalance in enrollment distribution among different fields of knowledge;
- high student attrition rate;
- low graduation rates and excessive time to degree with regard to institutional expectations;
- low research productivity of teaching staff in some of the graduate programs;
- imbalances in the offer of graduate programs;
- serious educational handicaps among candidates to the graduate programs; and
- absence of links between the graduate level and the *licenciatura* and other educational levels.

In a recent report, OECD (1997) examiners concluded that it is necessary to develop the graduate level, not in an anarchic manner wherein each institution decides for itself, but through the establishment of networks, in order to try to respond effectively to the new needs of research and higher education and to avoid an onerous prolongation of already lengthy studies.

Colombia

Recent Reforms

In the last 30 years, a scientific community in Colombia has begun to take shape, characterized by faculties that concentrate considerable numbers of full-time teachers; foreigners or Colombians trained abroad in new scientific subjects; laboratory equipment quite adequate for its time, provided by international cooperation—the Inter-American Development Bank, Rockefeller and Ford Foundations, UNESCO, etc.; incipient graduate programs; and a public institution that began to fund research. By 1996, the Colombian R&D community was said to number 7,700 persons (RICYT). At the beginning of the 1990s, science and technology were assumed to be the pillars of the current development strategy of Colombia's government, reflected in the National System of Science and Technology that was established by Law 29 of 1990 and implemented in 1991 through its organization into 11 National Programs of Science and Technology: basic sciences; social and human sciences; environmental and habitat sciences; education; health sciences and technologies; agricultural sciences and technologies; industrial technology development and quality; electronics, telecommunications, and informatics; energy and mining; biotechnology; and sea sciences and technologies. The Colombian Institute for the Development of Science and Technology "Francisco José de Caldas" (COLCIENCIAS) was transferred from the Ministry of Education and assigned to the National Department of Planning, in order to increase its capacity of strengthening research and technological development and to make it serve as the technical secretariat of the National Council of Science and Technology.

Within this institutional framework, emphasis is placed on the following aspects:

- integrating the private sector through its participation in the national councils;
- creating new forms of association between the public and private sectors, based on the Law of Science and Technology, through the establishment of mixed corporations of private law;
- decentralizing research through the creation of seven regional commissions of science and technology;
- developing human resources; and
- fostering the integration of Colombian scientists and engineers into international networks of science and technology.

Graduate Enrollment and Degrees

Among the limiting factors of science and technology development, the insufficient number of researchers and qualified human resources was recognized as possibly being the main bottleneck (Departmento Nacional de Planeamiento 1994, p. 5). At the beginning of the 1990s, graduate education in Colombia was considered to be far from fulfilling its mission as a tool for the training of researchers (COLCIENCIAS 1991). In the report of the Misión Ciencia, Educación y Desarrollo produced in 1995 for the Presidency of the Republic, the following goals for capacity building in the domain of human resources in the natural and social sciences and in engineering were set for the forthcoming 10 years:

- training 8,000 scientists with doctorate degrees;
- training 10,000 specialized professionals: individuals holding professional degrees and master's or specialist graduate diplomas; and
- training 18,000 nonspecialized professionals: technologists and technicians devoted to R&D.

These figures derived from population estimates that, according to the Colombian Institute for the Development of Higher Education (ICFES), had graduated from the university in 1990—41,000 from undergraduate education and 2,500 at the graduate level. A survey on the research potential of university students showed that 6 percent of students enrolled in the experimental sciences (medicine, physics, chemistry, and biology) had the requisite conditions to become good researchers. On this basis, assuming that 3 percent of all undergraduates had such a profile and that among graduate students the percentage is closer to 10 percent, it was considered reasonable to foresee at least 1,500 professionals per year with a tendency toward research—a figure close to the 1,800 envisaged in order to reach the proposed goals. The remainder could eventually be provided with the contribution of people from previous generations that in the past could not continue their careers for various reasons but who could be absorbed by the program through the new mechanisms and incentives set in place (Misión Ciencia, Educación y Desarrollo 1995, pp. 231-35).

Table 6. Recipients of university degrees, Colombia, 1990-95

Field	1990	1991	1992	1993	1994	1995
Total	41,431	48,897	46,103	47,016	57,114	54,188
Exact and natural sciences	802	773	528	589	859	685
Engineering and technology	8,105	9,369	8,521	9,493	11,275	11,036
Medical sciences	5,208	5,874	5,758	5,307	7,071	6,968
Agricultural sciences	1,030	1,329	806	972	761	957
Social sciences	25,812	30,817	29,653	29,627	36,136	33,636
Humanities	474	735	837	1,028	1,012	906

SOURCE: Colombian Institute for the Development of Higher Education (ICFES), *Estadísticas de la Educación Superior.*

Table 7. Recipients of masters degrees or equivalent, Colombia, 1990-95

Field	1990	1991	1992	1993	1994	1995
Total	1,226	1,716	1,703	2,359	2,444	2,396
Exact and natural sciences	68	76	78	158	124	87
Engineering and technology	161	143	86	137	168	104
Medical sciences	475	625	649	849	879	920
Agricultural sciences	7	15	0	66	31	25
Social sciences	468	816	826	1,067	1,144	1,127
Humanities	47	41	64	82	98	133

SOURCE: Colombian Institute for the Development of Higher Education (ICFES), *Estadísticas de la Educación Superior.*

The aims of Colombia's current science and technology policy in this regard are to increase the quality and size of the domestic scientific community through training—especially at the doctoral level in the various fields of the natural and social sciences, and in engineering—to stimulate research and give strong incentives to researchers, while helping solve the deficit of this level of qualification in Colombian universities and enabling the generational renewal of researchers. COLCIENCIAS's policy addresses six main lines of action: training toward a degree (doctorate or master's), training in nondegree or continuing education, strengthening of domestic doctoral programs, promotion of young researchers, incentives to researchers, and support of exchange programs and visiting researchers. The government goal in 1994 was to train 2,000 new researchers in the 1994-98 period. Of these, 550 were expected to be trained at the doctoral or master's level, through COLCIENCIAS's programs, granting fellowships in the country and abroad.

Table 8. COLCIENCIAS Human resource program, Colombia, 1995-98

Program	Number of beneficiaries	
	1995-96	1998[b]
Doctorate and master's scholarships....	297	463
Courses and *pasantías* [a]	1,233	2,329
Young researchers...............................	237	435
Support to doctoral infrastructure..........	24	24
Researcher mobility.............................	32	35
Incentives for researchers....................	283	283

[a] pasantías = visit to a foreign university.

[b] Preliminary figures.

SOURCE: The Colombian Institute for the Development of Science and Technology (COLCIENCIAS).

FELLOWSHIPS

Support for developing a fellowship program was provided by COLCIENCIAS, the Colombian Institute for Educational Loans and Technical Studies Abroad (ICETEX), and the Foundation for the Future of Colombia, as well as new programs of professional training advanced by the various ministries and international cooperation resources. To ensure adequate availability of students, it was considered necessary to support undergraduate programs as well, offering loans or donations geared to the improvement of the educational infrastructure. ICETEX and COLCIENCIAS fellowship mechanisms were reinforced, and both institutions—in a combined effort—signed a series of agreements with international organizations having wide experience in the management of fellowships in several countries. By 1997, they had signed agreements with LASPAU, the British Council, and the Ibero-American States Organization. Talks were also under way with Germany's DAAD and similar agencies in France, Switzerland, Canada, Israel, and Japan (COLCIENCIAS 1997a, p. 7). The basic sciences received 30 percent of the fellowships in the 1995-97 period, followed by the social and human sciences (16 percent) and health science and technology (14 percent).

Taking into account that each fellowship has a 4-year maintenance and fees component, in addition to travel and installation costs, thesis expenses, the acquisition of a

Table 9. Number of fellowship holders by COLCIENCIAS S&T program, Colombia, 1995-97

Program	1995		1996		1997		Total	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total..	139	100.0	141	100.0	183	100.0	463	100.0
Biotechnology..	6	4.3	6	4.3	2	1.1	14	3.0
Agricultural S&T..	5	3.6	9	6.4	14	7.7	28	6.0
Health S&T..	28	20.1	21	14.9	16	8.7	65	14.0
Sea S&T..	3	2.2	8	5.7	6	3.3	17	3.7
Basic sciences..	43	30.9	37	26.2	60	32.8	140	30.2[a]
Environment and habitat...	19	13.7	13	9.2	5	2.7	37	8.0
Social and human science..	11	7.9	27	19.1	38	20.8	76	16.4
Industrial technology development and quality.........	6	4.3	10	7.1	25	13.7	41	8.9
Electronics, information, and telecommunications....	6	4.3	7	5.0	11	6.0	24	5.2
Education..	1	0.7	2	1.4	4	2.2	7	1.5
Energy and mining..	11	7.9	1	0.7	2	1.1	14	3.0

[a] Many are doing molecular biology.

KEY: S&T = Science and technology

SOURCE: The Colombian Institute for the Development of Science and Technology (COLCIENCIAS).

computer, and books, a quick estimate indicates that domestic doctoral fellowships cost considerably less than those granted to study in foreign universities—a little more than half the cost abroad (see appendix table 10).

The nondegree training programs are oriented to the development of postdoctoral and research visits to centers of excellence in the country and abroad, with a duration of between 3 and 24 months. The purpose is to encourage an active exchange between Colombian researchers and their colleagues in other countries through participation in research projects and specialized courses aimed at updating researchers about new techniques. Between 1996 and 1998, eight postdoctoral fellowships were granted. It is expected that this number will grow in the future, since they are perceived as a useful mechanism for making the Colombian research community more dynamic and fostering its international mobility and visibility.

philosophy, 1 in theology, 1 in history, 1 in economics). ICFES is in charge of the accreditation of all graduate programs.

Actions directly related to scientific capacity building through training are complemented with other actions aimed at consolidating and improving the local environment for research. Thus the Program of Young Researchers aims at linking young researchers to high-quality research centers or groups, fostering in them a feeling of belonging to specific scientific communities and encouraging their participation in institutional environments conducive to their growth in science. About 30 percent of the beneficiaries are in the agricultural sciences and technologies (133 individuals), 20.7 percent in the social sciences and humanities (90), 16.1 percent in the health sciences and technologies (70), and 14.7 percent in the basic sciences (64).

Table 10. COLCIENCIAS number of "young researchers" by S&T program, Colombia, 1995-98

	1995		1996		1997		1998[a]		Total	
Program	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	112	100	125	100	157	100	41	100	435	100
Biotechnology	0	0	11	8.8	4	2.5	7	17.1	22	5.1
Agricultural S&T	14	12.5	39	31.2	56	35.7	24	58.5	133	30.6
Health S&T	32	28.6	18	14.4	20	12.7	0	0	70	16.1
Sea S&T	0	0	0	0	1	0.6	0	0	1	0.2
Basic sciences	31	27.7	19	15.2	12	7.6	2	4.9	64	14.7
Environment and habitat	3	2.7	3	2.4	16	10.2	0	0	22	5.1
Social and human science	32	28.6	18	14.4	40	25.5	0	0	90	20.7
Industrial technology development and quality	0	0	13	10.4	2	1.3	6	14.6	21	4.8
Electronics, information, and telecommunications	0	0	0	0	6	3.8	0	0	6	1.4
Education	0	0	0	0	0	0	0	0	0	0
Energy and mining	0	0	4	3.2	0	0	2	4.9	6	1.4

[a] Data are through May 31, 1998.

SOURCE: The Colombian Institute for the Development of Science and Technology (COLCIENCIAS).

Another pillar of the COLCIENCIAS program toward the consolidation of the national scientific community is support of the infrastructure and development of National Doctoral Programs in those fields where it is possible to develop good-quality centers in the country. These programs are supported through the funding of research programs and the consolidation of their infrastructure. In 1998, there were 31 doctoral programs in Colombia, 17 in the exact and natural sciences and health (5 in physics, 4 in chemistry, 1 in mathematics, 7 in biology and biomedical sciences); 3 in engineering and technology; 2 in agricultural sciences and technologies; and 8 in the social sciences and humanities (1 in law, 2 in education, 2 in

Currently, there are 103 groups and centers recognized by COLCIENCIAS to which financial aid has been given to help in their maintenance. It is estimated that COLCIENCIAS ought to support an increasing number of units, assuming a reasonable increment of 10 centers and groups per year until 2003.

Through its various mechanisms, COLCIENCIAS is having an impact on the institutional culture with regard to the processes of preselection of candidates who apply to the national fellowship program. Institutions are increasingly giving guaranteed acceptance to young persons with deserving scientific and academic qualifications. It also helps formulate and implement institutional plans for human resource training on the part of universities and other institutions in less developed regions of the country.

International Mobility

The Researchers' Mobility Program has supported a modest number of people in the 1995-98 period, 35 in all. Nonetheless, through requirements of study-loans (return to the country, high domestic and international scientific productivity, establishment of links between Colombian institutions and their research groups with counterparts abroad where the graduate student is receiving his or her training), effective international linkages have been made on behalf of domestic institutions and research groups.

The Colombian government pays great attention to its science and technology community abroad: "diaspora" is the term chosen by the official program about the Colombian Network of Scientists and Engineers Abroad—CALDAS Network. This program was established at the end of 1991 by COLCIENCIAS as intrinsically tied to the international dynamics of the national community. The program's underlying philosophy has been that a network of skilled expatriates is an extension of, and not a substitute for, the national community. Colombian intellectuals linked by this program were in the recent past spread in up to 43 countries, with the largest contingent in the United States. It is a highly qualified community: 71 percent of its members have obtained or are pursuing doctoral studies, and 80 percent have a master's degree or equivalent. A recent analysis of the program suggests that there is a bottleneck in higher education at the level of doctoral studies in the country; this would help explain why three-fourths of those who left did so to pursue graduate studies abroad. Emigration, however, does not seem permanent but rather of the delayed return kind. Although the program does not have the necessary depth of time to allow us to assess this aspect, the final outcome will most likely depend on country conditions. Half the population surveyed had student status, of which 74 percent had enrolled in a Ph.D. program, 18 percent in a master's program, and 8 percent in undergraduate studies. Two-thirds were under professional contract, one-fourth were both studying and working, and 83 percent declared that they were involved in research activities either as advanced students or professionals (Meyer et al. 1997).

Of course, not all expatriates belong to the CALDAS Network, and a population of expatriate individuals does not automatically constitute a diaspora. According to the definition given to this notion by COLCIENCIAS, "an expatriate population becomes a diaspora when it is a community whose members are in communication, have built and institutionalized a collective autonomy, and share some goals and activities. This the CALDAS Network provides through its electronic list, local nodes, and joint projects." According to governmental sources, the Colombian science and technology diaspora comprises around 2,000 people. This represents a little less than half of the people officially involved in R&D activities in Colombia.

Venezuela

Recent Reforms and Trends

The Venezuelan higher education system has experienced an enormous expansion in the last 30 years. Many initiatives for change from different segments linked to higher education popped up in recent years, spurred by internal factors like the aging of the community of researchers, the retirement of an important fraction of university academic staff, the move of many others abroad or to industry and services without their posts being replenished at the same rate, a deterioration of academic staff salaries, and reduction in the number of university students in the basic sciences. Nonetheless, the profound transformations visible in other Latin American countries in response to changed world conditions have been slower to come by in this country. The main external factors of higher education change observed in Venezuela are evaluation, funding, the research issue, and the development of a coordination model. All of these are deeply affected by the crisis of the state.

The funding of higher education has been incremental on the basis of previous budget assignments, although in the last decade criticisms became more intense in view of the system's inability to incorporate incentives for the improvement of the system's internal efficiency and quality, as well as criticisms of the excessive weight of corporate and political parties' pressures, which have undermined public higher education. Institutions have strongly resisted evaluation and accreditation of graduate education. There has been limited financial support for self-evaluation processes, which—along with a centralized system of quota distribution which has introduced rigidities—has promoted conflicts with the student body and become difficult to change.

The evaluation process in Venezuela has been based on a corrective notion; that is, it has been restricted to certain problems, and careful not to change funding structures. Evaluation has been accepted as long as it does not affect existing budget and financial structures. The creation of the Consultative Council of Graduate Studies in 1983 as an advisory organ of the National Universities Council (CNU) enabled the creation of a National System of Graduate Accreditation in 1986. Although the impact and effectiveness of this council have been very modest (up to now, only 20 percent of all graduate programs have submitted to the evaluation procedure of accreditation), nonetheless it deserves to be mentioned as a policy initiative that has to some extent institutionalized a form of specialized evaluation. Also in 1983, CNU established a Universities Institutional Evaluation Commission; in the ensuing decade, some evaluation took place with the participation of the Nucleus of Universities' Planning Directors. Given CNU's past difficulties in articulating the interests of government and universities, it is currently moving toward a new evaluation policy that is more responsive to contextual features. The Presidential Commission for the Development of Higher Education is in charge of designing the Inter-American Development Bank's Venezuelan Program for the Improvement of Higher Education, envisaging two components: a fund for the reform of higher education, and a fund for the institutional support of the reforms.

In 1990, after a decade of efforts by members of the scientific community to get it established, the Consejo Nacional de Investigaciones Científicas y Tecnológicas (CONICIT) created the System for the Researcher's Promotion (PPI). PPI emerged as a national structure of accreditation for researchers through the usual evaluation mechanisms of the scientific community, with the aims of giving them visibility in the domestic context and providing a monetary incentive which, by comparison with the equivalent Mexican SNI, never became really significant in relation to the beneficiaries' salaries. PPI was created as a mechanism that tried first to compensate for a deficit in the collective recognition of the researcher's status and role—which in the past had resulted in a very fragile relationship of research and its fruits with Venezuelan society—and second, to foster the participation of Venezuelan science in the international scientific system (Vessuri and González 1992, and Vessuri 1996). The limitations of this program have been said to lie in its fostering a relative isolation of the individual scientist from other social priorities, as well as the promotion of certain patterns of work organization, particularly solo rather than group research, which is more easily found in basic academic science and which in the long run might be counterproductive for science for development. Meanwhile, other evaluation tools have began to emerge in many universities—though still precariously. These include the Academic Benefit, an incentive created by CNU; and incentive programs implemented by several public universities, such as the Program of Incentives to Research for university academic staff.

It will be necessary to specify what the future role and position of PPI will be, and how the various incentives can be made complementary rather than contradictory. Because the roles of the researcher and research are not yet sufficiently consolidated in Venezuelan society, PPI, although it cannot be permanent, may continue to be necessary for some time. The researcher population of approximately 1,500 may be considered the core of the domestic scientific community, suggesting that a small but very qualified stratum of researchers has become consolidated. Depending on whether strict or broad criteria are used, it may be estimated that the number of people in R&D includes between two and five times that number. The consolidated information about PPI members in 1998 is included in tables 11 and 12.

Table 11. Number of researchers in Venezuela's PPI program, Venezuela, 1998

Institution	Physical, chemical, & mathematical science	Medical, biological & agricultural science	Social science	Engineering, technology & Earth science	Total
Total..........	360	640	310	240	1,550
UCV.......	65	188	103	49	406
ULA.......	88	93	62	37	281
LUZ.......	34	90	57	36	217
USB.......	83	31	43	70	207
Others...	90	238	45	48	439

KEY: PPI= Program for the Promotion of Researchers
ULA= Universidad de Los Andes
USB= Universidad Simón Bolívar
UCV= Universidad Central de Venezuela
LUZ= Universidad del Zulia

SOURCE: National Council of Science and Technology Studies, (CONICIT), *Sistema de Promoción del Investigador,* Caracas,1998.

Table 12. Number of researchers, according to promotion research program (PPI) level, 1990-97

Level	1990	1991	1992	1993	1994	1995	1996	1997
General total..........	760	922	941	929	1,056	1,213	1,302	1,435
Candidate..........	111	171	220	167	197	241	310	322
I.....................	390	482	407	472	519	614	632	755
II.....................	150	173	213	180	243	262	251	246
III....................	89	96	101	110	82	81	94	97
Emeritus.........	0	0	0	0	15	15	15	15

SOURCE: National Council of Science and Technology Studies, (CONICIT), Indicadores de la capacidad de investigción y desarrollo de Venezuela. Periodo 1990-98. Sistema de Promoción del Investigador, Caracas,1998.

Some fields show a greater weight, as in catalysis, where there are at least 152 active Ph.D. level researchers in 11 institutions (Vessuri 1996). But it is increasingly evident that the traditional way of understanding and doing research in the country—structurally weak, isolated from economic and social processes, and individualized to a large extent—must be drastically changed to make it more effective. Thus, it may be said that Venezuela is in a transitional stage.

CONICIT has undergone internal transformation to ease the modernization of the science and technology system. Since 1994, it has established four main fields of programmatic action for the support of research, innovation processes, policies for the strengthening and coordination of the national effort in science and technology, and internal management and institutional modernization. With regard to the first aim, with which we are more directly concerned here, among the strategic lines of action are training, incorporation, and permanence of more and better researchers; and, linked to these, the strengthening of research in domestic graduate programs. Several actions were started or redefined in the last 3 years:

- Funding was provided for the training of researchers, with some 300 new graduate fellowships envisaged for the 1996-98 period.

- New researchers were incorporated, facilitating the hiring of young researchers in research and teaching activities in higher education institutions, and aiming at 375 graduates.

- Researcher mobility was encouraged. The target was to fund 1,333 new applications, facilitating the participation of active researchers in international events, as well as linking Venezuelan researchers settled abroad with the domestic community and starting a networking program for Venezuelan scientists and engineers resident abroad (the Perez Bonalde Program).

- Research technicians are being trained, with a target of 58 technicians (CONICIT 1996).

- Within the Special New Technologies Program, 20 fellowships in Venezuela and 129 fellowships abroad are being provided; also envisaged are 15 updating courses and the participation of scientists in 10 national events.

- As in Colombia, special lines of action include the support of research groups and the strengthening of domestic graduate programs.

The main emphasis is ensuring that the nation's R&D capacities become a substantial part of its economic and social processes, bringing solutions and opportunities to the productive sector and society in general.

Enrollment and Degrees

Higher education enrollment in Venezuela increased 30 times over the last 30 years. In 1994, higher education accounted for 43.6 percent of the national educational budget, which in turn was 15.36 percent of the national budget. The schooling ratio of higher education went from 6 percent in 1965 to 24 percent in 1990. In 1995, there were 603,217 students enrolled in higher education, 76.2 percent of them in universities. The number of graduates that year was 50,160, 65.6 percent from universities. The total ratio of graduates from higher education in 1995 was generally low—37 percent (50,160 graduates, 136,092 newly enrolled in 1990). Contrary to common expectations, public universities have a higher terminal efficiency than private universities—49 percent: 28,402 graduates in 1995, 57,989 newly enrolled in 1990; versus 26 percent: 4,489 graduates in 1995, 16,955 newly enrolled in 1990—and continue to receive a much larger student enrollment. The situation differs in nonuniversity institutions. In this grouping, the graduate ratio is 20 percent in the public sector (4,269 graduates in 1995, 21,528 newly enrolled in 1990) and 33 percent in the private sector (12,973 graduates in 1995, 39,620 newly enrolled in 1990) (Parra 1998, based on OPSU 1997).

Historically, higher education in Venezuela has been devoted mostly to undergraduate education, although in the last 10 years it has expanded its number of academic graduate programs. In 1972, there were only 89 graduate programs; by 1994, there were 1,047, comprising 7 percent doctoral programs, 46 percent master's, and 47 percent specialization programs. Public universities account for more than half of the graduate programs; of these, the Central University of Venezuela (UCV) has 32 percent of all graduate programs.

Fellowships

Although official initiatives to support domestic graduate education go back to at least the mid-1970s, emphasis was placed on graduate fellowship programs to study abroad. However, results were not as effective as expected in terms of a multiplying effect of returning graduates on growth of the local research community; also, it was estimated that a considerable number of students abroad were lost to "brain drain." Therefore, more recent initiatives—developed by CONICIT, FUNDAYACUCHO (Gran Mariscal de Ayacucho Foundation), and several university councils for the development of science, technology, and the humanities—have focused on renewed support of domestic graduate education in fields of domestic strength, combined with a policy for graduate training abroad in strategic fields and in those that are weak at the local level.

The main fellowship programs are those of FUNDAYACUCHO and CONICIT. Between 1984 and 1997, the two combined made available an average of 688 fellowships per year to Venezuelan graduates. Until the current decade, FUNDAYACUCHO's fellowship program was numerically much larger than CONICIT's, having granted a total of 55,484 fellowships from 1975 to 1996 at both the undergraduate and graduate levels. Since 1984, it granted 8,202 graduate fellowships, compared to 1,439 fellowships from CONICIT. The latter specialized in research fellowships on a much smaller scale. Since 1991, however, CONICIT has increased its efforts, and, in 1995-97, its fellowships represented about a third of FUNDAYACUCHO's loans. Throughout the period, the average number of fellowships abroad from the two agencies combined was 47 percent, with a high of 77.74 percent in 1993 and a low of 10.52 percent in 1987. (See appendix table 11.)

Table 13. Number of fellowships and educational loans granted by CONICIT and FUNDAYACUCHO in Venezuela and abroad, 1984-97

Year	General total	Total Venezuela	Total abroad	(%)	CONICIT			FUNDAYACUCHO		
					Total	Venezuela	Abroad	Total	Venezuela	Abroad
1984	667	348	319	(47.8)	30	21	9	637	327	310
1985	813	664	149	(18.3)	1	1	0	812	663	149
1986	282	215	67	(23.8)	54	37	17	228	178	50
1987	1,178	1,054	124	(10.5)	35	22	13	1,143	1,032	111
1988	213	174	39	(18.3)	37	20	17	176	154	22
1989	127	60	67	(52.8)	3	3	0	124	57	67
1990	657	454	203	(30.9)	80	56	24	577	398	179
1991	987	427	560	(56.7)	124	60	64	863	367	496
1992	554	199	355	(64.1)	154	42	112	400	157	243
1993	921	205	716	(77.7)	209	59	150	712	146	566
1994	565	157	408	(72.2)	24	0	24	541	157	384
1995	473	214	259	(54.8)	152	92	60	321	122	199
1996	865	338	527	(60.9)	251	144	107	614	194	420
1997	1,339	600	739	(45.8)	285	159	126	1,054	441	613

SOURCE: National Council of Science and Technology Studies, (CONICIT), Indicadores de la capacidad de investigción y desarrollo de Venezuela. Periodo 1990-98 Sistema de Promoción del Investigador, Caracas,1998.

The public universities also have fellowship programs to qualify their own academic staff, administered through their science, technology, and humanities development councils. There are no global figures about this universe of fellowships. However, their significance in the overall effort can be grasped from the evolution of the UCV fellowship program. On the whole, from the creation of the mechanism in 1958 through 1996, UCV granted 603 graduate fellowships, of which 21.9 percent were distributed among the social sciences and the humanities. The largest concentration of graduate fellowships was awarded to science faculty staff (25 percent), followed by the agronomy faculty (15.6 percent) and medicine (13.2 percent). The largest concentration of fellowships (47.42 percent) occurred in the 1977-86 period; significantly, the number of doctoral fellowships represented 54.57 percent of the total. This trend continued in the 1987-96 period, with 51.46 percent of all fellowships awarded for doctoral studies.

Note that most doctoral and master's fellowships from FUNDAYACUCHO are for studies abroad, with the largest contingents of students in economics and the social sciences, followed by engineering and technology. The basic sciences, with 22.2 percent in the domestic doctoral programs and 14 percent in foreign ones, have a better representation at this level than at lower levels. At the master's level, 71.1 percent of domestic fellowships go to students in economics and the social sciences; and, although the proportion is lower among master's level fellowships abroad in these disciplines, the proportion continues to be considerable (59.1 percent).

A larger proportion of FUNDAYACUCHO doctorate fellowships are destined for Spain than for any other country (38.2 percent), followed by the United States and the United Kingdom. The remaining destinations show a great dispersion. At the master's level, 68 percent of all fellowships abroad are for the United States; Spain and the United Kingdom trail far behind, with 10.3 percent and 9.6 percent, respectively.

CONICIT has granted a comparable number of fellowship in the 1994-97 period (712). This agency emphasizes the doctorate degree level, which every year has accounted for more than 40 percent of all fellowships granted. A new modality that is growing slowly is that of the postdoctorate. Table 16 provides some indication of destination trends based on the history of CONICIT fellowships. The United States was the destination of 42.9 percent of all fellowships, followed by the United Kingdom with 21.6 percent and France with 14.8 percent.

International Mobility

In recent years, Venezuela has been developing several programs to identify Venezuelan expatriates. CONICIT has initiated a modest scheme, the Perez Bonalde Program, which brings Venezuelan scientists settled abroad in country for short visits to local research institutions and groups in order to fulfill a work agenda geared to increase contacts and international mobility of local scientists; it also aims to incorporate those expatriate researchers in the domestic dynamics of science and technology. Fundación Polar is collecting information about

Table 14. FUNDAYACUCHO educational loans granted at the graduate level, Venezuela and abroad by field of study, 1994-98 (PRCE budget)

Field	Venezuela					Abroad				
		Master's		Doctorate			Master's		Doctorate	
	Total	Number	Percent	Number	Percent	Total	Number	Percent	Number	Percent
Total	393	384	100.0	9	99.9	1,252	1,074	99.4	178	100.1
Basic sciences	5	3	0.8	2	22.2	43	18	1.7	25	14.0
Engineering	61	61	15.9	0	0.0	318	276	25.7	42	23.6
Agricultural and sea science	8	8	2.1	0	0.0	22	13	1.2	9	5.1
Health	10	9	2.3	1	11.1	65	49	4.6	16	9.0
Education	29	26	6.8	3	33.3	60	46	4.3	14	7.9
Economic and social sciences	275	273	71.1	2	22.2	694	635	59.1	59	33.2
Humanities, literature and fine arts	5	4	1.0	1	11.1	50	37	3.5	13	7.3

KEY: PRCE = Educational Credit Reform Budget, Venezuela, World Bank.

NOTE: For the year 1998, the first semester only was considered.

SOURCE: Gran Mariscal de Ayacucho Foundation (FUNDAYACUCHO).

Table 15. FUNDAYACUCHO educational loans granted at the graduate level according to geographical destination, Venezuela, 1994-98 (PRCE budget)

Level/Country	Total	Master's Number	Doctorate Number
Total	1,645	1,458	187
Total abroad	1,252	1,074	178
Total Venezuela	393	384	9
Argentina	2	1	1
Australia	11	5	6
Belgium	3	1	2
Brazil	6	6	0
Canada	20	19	1
Chile	4	4	0
China	1	1	0
Colombia	2	1	1
Costa Rica	29	23	6
France	43	25	18
Germany	4	2	2
Holland	6	6	0
Israel	0	0	0
Italy	7	7	0
Mexico	16	16	0
Nicaragua	9	9	0
Peru	0	0	0
Puerto Rico	3	3	0
Russia	1	0	1
Spain	179	111	68
Sweden	1	1	0
Switzerland	3	1	2
United Kingdom	138	103	35
United States	763	728	35
Uruguay	1	1	0

KEY: PRCE = Educational Credit Reform Budget, Venezuela, World Bank.

NOTE: For the year 1998, the first semester only was considered.

SOURCE: Gran Mariscal de Ayacucho Foundation (FUNDAYACUCHO).

Venezuelan scientists abroad, trying to distinguish those who are pursuing studies from those who are working on a more permanent basis. So far, it has identified some 300 Venezuelan scientists and engineers settled abroad on a more permanent basis. The Venezuelan Embassy at UNESCO headquarters in Paris has started an initiative called TALVEN with a similar purpose. In the near future, these programs should coordinate with each other to produce unified information.

Streamlining Academic R&D in Mexico, Colombia, and Venezuela

The recent reforms introduced in the academic world of the three countries considered here, like those in other Latin American countries, seem to point to the rationalization, disciplining, and greater efficiency of higher education. Since the tools of reform have been basically financial and administrative and not often supplemented with more integral changes, the results remain pending. There is no doubt that groups of researchers have been mobilized around new funding modalities and opportunities. But the bulk of university staff (teachers and research assistants) seem to have received the impact of the reforms in different manners. Some groups feel they have been ill-treated by the imposition of quantitative research evaluation criteria that apply to the tradition of the physical sciences but are not pertinent to the agricultural sciences, technologies, social sciences, and humanities; they feel these are even less able to measure yields in teaching, the effectiveness of adjustment to market demands, etc. Operational measures assumed to make research more efficient, such as supporting large research groups for more or less extended periods (3 to 4 years), may reflect optimal research conditions for some disciplines, but not necessarily for others.

Table 16. Number of fellowships by academic level CONICIT, Venezuela, 1994-97

Year	Fellowships		Master		Doctorate		Postdoctorate		Does not indicate	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Total	712	100.0	342		332		32		6	
1994	24	3.4	4	16.7	15	62.5	4	16.7	1	4.2
1995	152	21.4	75	49.3	69	45.4	5	3.3	3	2.0
1996	251	35.3	127	50.6	111	44.2	11	4.4	2	0.8
1997	285	40.0	136	47.7	137	48.1	12	4.2	-	0

KEY: (-) = not applicable

SOURCE: National Council of Science and Technology Studies, (CONICIT) n.d. <<http://www.conicit.gov.ve>>.

Table 17. Number and percentages of fellowships granted by CONICIT, Venezuela, by country of destination, not including domestic fellowships, 1970-97

Country	Number	Percent
Total	898	100
Australia	3	0.3
Belgium	7	0.8
Brazil	25	2.8
Canada	23	2.6
Cuba	1	0.1
Czechoslovakia	2	0.2
France	133	14.8
Germany	14	1.6
Holland	3	0.3
Israel	1	0.1
Italy	5	0.6
Japan	3	0.3
Mexico	4	0.4
New Zealand	1	0.1
Poland	1	0.1
Puerto Rico	3	0.3
Russia	3	0.3
Spain	80	8.9
Sweden	4	0.4
United Kingdom	194	21.6
United States	385	42.9

SOURCE: National Council of Science and Technology Studies, (CONICIT) n.d. <<http://www.conicit.gov.ve>>.

The industrial sector emerges as a strategic partner to facilitate change; its difficulties in the current process of economic aperture and the vulnerability of domestic financial markets affect R&D stability and potential for expansion. The three countries have learned that expansion of high-quality academic research does not necessarily create conditions for high-quality industrial R&D. Academic research policy, therefore, should not be dissociated from industrial firms' applied R&D policy and practice, where the means of government influence are much more indirect, complex, and controversial.

Although in the last decades the range of organizations and institutions has been growing and diversifying in the three countries, the institutional fabric still presents thinly covered holes and empty spaces. In addition to the institutional and organizational insufficiency and marginality of science and technology research with regard to the main route of knowledge production and distribution, confidence in government management—considered in the past to be the natural agency in charge of responding to problems of collective development—has declined. The preexisting export industrial base fed on governments that supported—at least in the early stages—the industrialization process, with policies of exchange rates, restriction of domestic demand, real salary restrictions, export subsidies, export processing zones, and performance requirements for exports, as well as investments in research, training and support infrastructure. Maintenance of industrial growth requires fresh, sustained investments for capacity development.

In countries like these, distant from the technological edge, the returns associated with facilitating technology transfer are much higher than those linked to engaging in original R&D. An important policy to facilitate such transfer is to invest in human resources, especially in higher education. As far as graduate education is concerned, we have seen that total enrollment is very low relative to the numbers graduating from undergraduate programs; the graduate-undergraduate ratio shows the need to prioritize growth of graduate education. There is a definite insufficiency in the level, quality, and variety of human resources required for technological upgrading. The knowledge gap grows dramatically, especially in aspects related to the integration of human resources in innovation systems.

The fact that the majority of teaching/research posts in the public sector corresponds to the status of *funcionario público* (public official) induces too much stability of employment for those who are in the system and an exceedingly high turnover of "marginal" professionals who remain outside the system; this prevents an adequate balance between institutional continuity and renewal. Large segments of public higher education have experienced serious deterioration in a process accompanied by growth of the private sector in education, which covers a portion of the excess demand with a bias toward the commercial sciences and less emphasis on engineering and the exact and experimental sciences. This has direct consequences for R&D, which is carried out mainly in public universities and related research centers. Most programs for the promotion of R&D have been reactive, serving to promote and strengthen what already exists, but unable to give a radical lead in the attainment of objectives or the type of actors involved and their ways of working. Strong inertial trends prevail in the fragmented interests of the scientific communities, without their becoming articulated in broader strategies involving varied and dynamic partnerships. Needless to say, this indicates the lack of density of the socioeconomic tissue.

The number of linkage mechanisms in the academic world and the science and technology public sector has multiplied in the 1990s. But support institutions and policies will not be effective unless there is a significant increase in private investment in R&D without a reduction of already limited public funds. A continuous supportive government presence is needed, but should be focused on what only it can do in the different fronts linked to the industrial and technological processes, while leaving direct production and technology transfer to the private sector.

Technological activity carried out through cooperative schemes is an option increasingly used everywhere, because it facilitates the speed of technical progress and market redistribution. The various forms of partnership between firms, and between these and research institutions and universities, allow some current obstacles to the establishment of innovation capabilities to be overcome. In the three countries discussed here, this kind of interaction is very new. Often, the entrepreneur does not take advantage of results generated by potential partners due to a lack of knowledge of the existence of relevant products and processes for the firm. It is therefore indispensable to multiply the channels and forms of access to technological information and business opportunities available to the entrepreneurial segment.

Education ought to be revitalized at all levels, including not only the training of scientists, engineers, and the technical workforce, but also of managers and entrepreneurs—so that they may gain a better understanding of the importance of innovation and its main components—as well as shopfloor technicians and blue-collar workers who must have a higher level of schooling and skills for raising their flexibility and capacity to adapt to continuing technical change. Although there are valuable schemes in vocational training, especially ones provided by public institutions in close partnership with the private sector—such as Servcio Nacional de Aprendizaje in Colombia, Direccion General de Educacion Tecnologica Industrial in Mexico, and Instituto Nacional de Cooperacion Educativa in Venezuela—they are clearly insufficient. So far, it has not been possible to extend them more widely, for the role of the firms in this field should be much greater. Continuing education and training ought to be stimulated, recognizing that, particularly in scientific and technical fields, education must be a life-long activity.

Although some critics adhering to a narrowly technical and developmental view deplore the pretension of scientific leadership to publish internationally, as if such activity would distance them from domestic relevance, it may reasonably be argued that the change in publishing behavior from locally oriented media to international journals is necessary for a country's technological development. To benefit from worldwide technical and scientific developments, the local researcher must know and understand them; and, therefore, to some extent, contribute actively in those developments. In a global world, information and communication do not recognize national boundaries.

It should be stressed that the importance of supporting basic science in countries with small scientific communities is in the resulting externalities, for it allows access to the international pool of knowledge, skills, and information. When it is argued that the effort should be reoriented because an enormous reservoir of technical and scientific knowledge already exists, this does not mean to cease supporting the scientific and technical communities in those countries. On the contrary, given the level of complexity and sophistication of contemporary knowledge, today more than ever communities of researchers and engineers are needed who are well-versed in the most advanced knowledge and who may read and interpret results and guide strategic decisions of a technical nature.

The short-term focus that has prevailed in the privatization process brings uncertainty to the viability of the reforms aimed at saving and optimizing R&D capacities in the three countries. It is not clear whether the new industrial structures will stimulate the establishment of research facilities in small and medium-sized firms. It is unlikely that the numbers of scientific and technological personnel will grow much in the near future. For the same reasons, the capacity to train R&D staff in national systems will probably remain limited, unless there are deep changes in conception and structure. The numbers of students in key disciplines might remain equally limited.

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APPENDIX

Appendix table 1. Mexican graduate population by level, 1987-97								
Year	Total		Specialization		Master		Doctorate	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1987	38,214	100.0	13,084	34.2	23,751	62.2	1,379	3.6
1988	39,505	100.0	13,526	34.2	24,676	62.5	1,303	3.3
1989	42,655	100.0	14,757	34.6	26,561	62.3	1,337	3.1
1990	43,965	100.0	15,675	35.7	26,946	61.3	1,344	3.0
1991	44,946	100.0	16,367	36.4	27,139	60.4	1,440	3.2
1992	47,539	100.0	17,576	37.0	28,332	59.6	1,631	3.4
1993	50,781	100.0	17,440	34.4	31,190	61.4	2,151	4.2
1994	54,910	100.0	17,613	32.1	34,203	62.3	3,094	5.6
1995	65,615	100.0	18,760	28.6	42,342	64.5	4,513	6.9
1996	75,392	100.0	20,852	27.6	49,356	65.5	5,184	6.9
1997	87,696	100.0	21,625	24.7	59,913	68.3	6,158	7.0

SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). *Anuario Estadístico. Población escolar de posgrado.* México, D.F.

Appendix table 2. Doctoral student population in Mexico by field, 1997

Field	1st Enrollment & re-enrollment			Graduates 1996		
	Total	Men	Women	Total	Men	Women
Total	6,158	4,038	2,120	734	457	277
Agricultural sciences	420	326	94	48	35	13
Agronomy	270	209	61	29	23	6
Veterinary & zootechnics	150	117	33	19	12	7
Health sciences	456	240	216	103	67	36
Biomedicine	118	54	64	31	16	15
Pharmacology	25	12	13	4	2	2
Medicine	91	68	23	41	32	9
Dentistry	19	10	9	1	0	1
Other specialties	203	96	107	26	17	9
Basic & natural sciences	1,621	1,127	494	123	84	39
Astronomy	14	7	7	1	0	1
Biophysics	4	4	0	0	0	0
Biology	522	315	207	48	33	15
Sciences	15	12	3	0	0	0
Biochemistry	13	12	1	0	0	0
Chemistry	291	181	110	14	6	8
Earth sciences	97	76	21	3	0	3
Sea sciences	72	48	24	2	1	1
Ecology	67	41	26	6	2	4
Physics	413	345	68	39	34	5
Mathematics	113	86	27	10	8	2
Administration & social sciences	1,574	998	576	236	143	93
Administration	83	63	20	24	20	4
Anthropology & archeology	246	123	123	57	31	26
Political sciences	27	20	7	7	6	1
Social sciences	342	212	130	44	25	19
Law	478	340	138	62	38	24
Economy & development	158	124	34	9	7	2
Latin american studies	90	44	46	10	7	3
Geography	34	19	15	1	1	0
Taxes & finances	34	25	9	0	0	0
Psychology	66	20	46	19	6	13
International relations	16	8	8	3	2	1
Education & humanities	1,085	574	511	162	76	86
Education	668	370	298	50	32	18
Philosophy	79	53	26	15	8	7
History	206	98	108	57	24	22
Literature	102	43	59	28	10	18
Linguistics	30	10	20	12	2	10

See SOURCE at end of table.

Appendix table 2. Doctoral student population in Mexico by field, 1997 (Continued)

Page 2 of 2

Field	1st Enrollment & re-enrollment			Graduates 1996		
	Total	Men	Women	Total	Men	Women
Engineering & technology	1,002	773	229	62	52	10
Architecture & design	112	76	36	7	7	0
Biotechnology	191	121	70	9	4	5
Sciences	172	131	41	5	5	0
Computer sciences	49	41	8	1	1	0
Ambiental engineering	6	3	3	0	0	0
Civil engineering	150	131	19	13	11	2
Electric engineering & electronics	175	162	13	12	12	0
Extractive eng., metal. & energy	39	30	9	8	5	3
Industrial engineering	22	16	6	6	6	0
Mechanical engineering	14	13	1	0	0	0
Chemical engineering	23	21	2	1	1	0
Planning	13	11	2	0	0	0
Nutrition technology	36	17	19	0	0	0

SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). *Anuario Estadístico,* 1997.

Appendix table 3. Master's student population in Mexico by field, 1997

Field	1st Enrollment & re-enrollment			Graduates 1996		
	Total	Men	Women	Total	Men	Women
Total	59,913	36,128	23,785	11,164	6,702	4,462
Agricultural sciences	1,368	1,032	336	431	347	84
Common cycle	15	9	6	0	0	0
Agronomy	786	610	176	271	224	47
Forestry development	69	54	15	22	15	7
Veterinary & zootechnics	498	359	139	138	108	30
Health sciences	2,032	1,007	1,025	536	263	273
Biomedicine	161	76	85	67	29	38
Nursing	39	2	37	32	2	30
Pharmacology	97	31	66	18	6	12
Medicine	445	257	188	74	49	25
Nutrition	35	17	18	27	11	16
Dentistry	143	72	71	38	18	20
Other specialties	446	206	240	96	52	44
Psychiatry	21	12	9	4	3	1
Public health	633	332	301	180	93	87
Natural & basic sciences	3,028	1,842	1,186	616	396	220
Astronomy	15	9	5	1	0	1
Biophysics	4	1	3	0	0	0
Biology	727	335	392	124	66	58
Biochemistry	105	52	53	8	3	5
Sciences	75	39	36	19	8	11
Chemistry	432	199	233	89	40	49
Earth sciences	244	205	39	37	32	5
Sea sciences	230	133	97	53	36	17
Ecology	197	109	88	31	15	16
Physics	623	490	133	190	149	41
Mathematics	377	270	107	64	47	17
Social & administration sciences	29,469	18,204	11,265	4,505	2,788	1,717
Administration	27	12	15	2,669	1,814	855
Anthropology & archeology	16,923	11,128	5,795	58	25	33
Archives & library sciences	171	87	84	4	3	1
Political sciences	72	22	50	86	51	35
Social sciences	603	324	279	180	90	90
Communication sciences	518	251	267	54	25	29
International trade	116	68	48	1	1	0
Accounting	510	299	211	19	10	9
Law	2,851	1,828	1,023	349	216	133
Economy & development	2,104	1,430	674	354	230	124
Latin american studies	169	80	89	21	12	9
Taxes & finances	2,425	1,623	802	246	166	80

See SOURCE at end of table.

Appendix table 3. Master's student population in Mexico by field, 1997 (Continued)

Field	1st Enrollment & re-enrollment			Graduates 1996		
	Total	Men	Women	Total	Men	Women
Psychology	2,248	640	1,608	398	102	296
Advertising	47	17	30	5	2	3
Industrial relations	98	50	48	0	0	0
International relations	54	25	29	3	2	1
Tourism	31	16	15	0	0	0
Sales & marketing	172	101	71	55	37	18
Education & humanities	13,792	6,253	7,539	3,051	1,380	1,671
Fine arts	265	107	158	50	24	26
Sports sciences	58	51	7	12	7	5
Education	10,455	4,716	5,739	2,053	916	1,137
Normal education	1,449	651	798	567	258	309
Philosophy	453	280	173	110	68	42
History	454	206	248	84	38	46
Humanities	99	37	62	34	16	18
Languages	12	5	7	21	5	16
Literature	438	154	284	82	31	51
Linguistics	109	46	63	38	17	21
Engineering & technology	10,224	7,790	2,434	2,025	1,528	497
Common cycle	12	7	5	0	0	0
Architecture & design	1,150	770	380	139	103	36
Biotechnology	324	174	150	96	43	53
Sciences	95	57	38	24	9	15
Computation sciences	1,976	1,478	498	461	351	110
Environmental engineering	497	332	165	119	71	48
Civil engineering	1,424	1,188	236	259	213	46
Electric engineering & electronics	1,116	992	124	240	211	29
Extraction engineering, metal.& energy	185	151	34	34	27	7
Physics engineering	15	15	0	4	4	0
Hydraulic engineering	122	96	26	43	33	10
Industrial engineering	1,404	1,114	290	227	185	42
Mechanical engineering	513	491	22	113	107	6
Fishing engineering	38	26	12	17	11	6
Chemical engineering	416	289	127	73	55	18
Transports engineering	74	57	17	34	32	2
Planning	592	441	151	55	38	17
Nutrition engineering	251	96	155	87	35	52
Wood technology	20	16	4	0	0	0

SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). *Anuario Estadístico,* 1997.

Appendix table 4. Specialization student population in Mexico by field, 1997

Field	1st Enrollment & re-enrollment			Graduates 1996		
	Total	Men	Women	Total	Men	Women
Total	21,625	11,895	9,730	8,305	4,451	3,854
Agricultural sciences	82	69	13	53	48	5
Agronomy	16	13	3	24	23	1
Veterinary & zootechnics	66	56	10	29	25	4
Health sciences	12,391	7,196	5,195	3,812	2,194	1,618
Surgery	811	682	129	193	179	14
Nursing	181	11	170	166	9	157
Pharmacology	22	8	14	0	0	0
Medicine	6,714	4,008	2,706	1,940	1,187	753
Nutrition	17	8	9	0	0	0
Dentistry	988	419	569	411	180	231
Other specialties [a]	3,310	1,868	1,442	980	570	410
Psychiatry	66	33	33	29	19	10
Radiology	160	87	73	44	27	17
Public health	122	72	50	49	23	26
Natural & basic sciences	168	91	77	59	31	28
Biology	17	12	5	10	8	2
Biochemistry	31	9	22	12	3	9
Chemistry	28	20	8	16	9	7
Earth sciences	8	5	3	7	5	2
Mathematics	84	45	39	14	6	8
Social & administration sciences	6,117	3,013	3,104	2,946	1,481	1,465
Administration	1,083	542	541	608	290	318
Political sciences	0	0	0	25	23	2
Social sciences	101	12	89	7	5	2
Communication sciences	30	5	25	7	1	6
International trade	134	71	63	92	60	32
Accounting	84	55	29	12	7	5
Law	1,359	715	644	756	404	352
Economy & development	47	26	21	29	13	16
Geography	0	0	0	8	7	1
Taxes & finances	2,231	1,232	999	912	519	393
Psychology	558	150	408	240	55	185
Advertising	55	12	43	22	0	22
Sales & marketing	435	193	242	228	97	131
Education & humanities	1,513	618	895	704	235	469
Education	1,467	588	879	658	221	437
Philosophy	0	0	0	3	2	1
History	35	25	10	9	5	4
Languages	1	0	1	6	1	5
Literature	10	5	5	28	6	22

See explanatory information and SOURCE at end of table.

Appendix table 4. Specialization student population in Mexico by field, 1997 (Continued)

Page 2 of 2

Field	1st Enrollment & Re-enrollment			Graduates 1996		
	Total	Men	Women	Total	Men	Women
Engineering & technology	1,354	908	446	731	462	269
Architecture & design	96	54	42	34	14	20
Biotechnology	8	6	2	9	3	6
Computation sciences	202	31	71	26	15	11
Environmental engineering	98	72	26	60	41	19
Civil engineering	145	125	20	73	66	7
Electric engineering & electronics	34	27	7	3	3	0
Extraction engineering, metal. & energy	42	37	5	14	14	0
Hydraulic engineering	13	13	0	14	13	1
Industrial engineering	591	362	229	482	284	198
Fishing engineering	44	42	2	0	0	0
Textile engineering	12	7	5	9	5	4
Nutrition engineering	64	27	37	7	4	3
Wood technology	5	5	0	0	0	0

[a] 63 Specialties

SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior (ANUIES). *Anuario Estadístico,* 1997.

Appendix table 5. Graduates by level of study, Mexico, 1984-96

Level	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Total	6,634	7,047	6,896	7,869	9,916	11,159	9,885	11,548	12,097	12,060	13,632	18,291	16,276
Basic & natural sciences	268	390	324	561	382	347	618	615	536	658	802	863	798
Agricultural sciences	192	217	245	340	250	377	323	324	317	387	494	472	532
Engineering	864	1,018	862	1,227	1,033	836	1,168	1,318	1,445	1,490	2,112	2,603	2,818
Health	1,813	1,913	1,896	2,027	4,503	5,286	3,807	4,211	4,035	3,110	3,024	4,109	4,451
Social sciences	3,497	3,509	3,569	3,714	3,748	3,313	3,969	5,080	5,764	6,415	7,200	10,244	7,677
Specialization	2,749	2,793	3,036	2,939	2,939	5,553	4,525	5,835	6,035	5,616	5,963	7,764	7,601
Basic & natural sciences	25	18	11	69	75	26	47	47	51	110	114	123	59
Agricultural sciences	19	42	72	47	47	43	25	68	53	106	116	79	53
Engineering	195	239	218	226	226	270	198	268	409	463	727	934	731
Health	1,535	1,622	1,572	1,657	1,657	4,133	3,538	3,931	3,680	2,814	2,609	3,517	3,812
Social sciences	975	872	1,163	940	940	1,012	717	1,521	1,842	2,123	2,397	3,111	2,946
Master's	3,640	4,077	3,704	4,758	4,185	4,401	5,091	5,475	5,749	6,092	7,181	10,008	8,113
Basic & natural sciences	231	343	285	448	280	296	487	499	405	465	568	633	616
Agricultural sciences	170	173	164	290	184	328	294	253	255	276	368	373	431
Engineering	669	776	642	994	760	702	962	1,039	1,009	995	1,345	1,614	2,025
Health	268	270	319	340	338	262	234	239	319	254	362	533	536
Social sciences	2,302	2,515	2,294	2,686	2,623	2,813	3,114	3,445	3,761	4,102	4,538	6,855	4,505
Doctorate	245	177	156	172	178	204	269	238	313	352	488	519	572
Basic & natural sciences	12	29	28	44	27	25	84	69	80	83	120	107	123
Agricultural sciences	3	2	9	3	3	6	4	3	9	5	10	20	48
Engineering	0	3	2	7	3	3	8	11	27	32	40	55	62
Health	10	21	5	30	32	48	35	41	36	42	53	59	103
Social sciences	220	122	112	88	113	122	138	114	161	190	265	278	236

SOURCE: Asociacíon Nacional de Univeridades e Instituciones de Educación Superior ANUIES, *Anuarios Estadísticos de Posgrado,* 1985-96.

Appendix table 6. Statistical profile of U.S. doctorate recipients from Mexico, by major field of doctorate, 1988-96

Item	Total all fields		Total S&E	Physical sci.	Earth/ atmos/ ocean sci.	Mathematics	Computer/ info. sci.	Engineering	Bio. sci.	Agric. sci.	Psych/ social sci.	Non-S&E	Humanities	Education	Health sci.	Prof/ other fields
Total Ph.D.s[a]	-	1.4	1.1	102.0	61.0	68.0	26.0	238.0	230.0	198.0	203.0	233.0	91.0	63.0	41.0	38.0
Men	%	80.7	83.3	88.2	93.4	92.6	100.0	92.0	70.9	88.9	70.9	68.2	65.9	58.7	68.3	89.6
Women	%	19.3	16.7	11.8	6.6	7.4	0.0	8.0	29.1	11.1	29.1	31.8	34.1	41.3	31.7	10.6
Permanent visa	%	18.0	15.7	15.7	19.7	16.2	16.4	13.0	13.9	15.7	19.7	28.8	38.5	23.8	19.6	23.7
Temporary visa	%	82.1	84.3	84.3	80.3	83.8	84.6	87.0	86.1	84.3	80.3	71.2	61.5	76.2	80.5	76.3
Married	%	65.6	65.9	54.9	63.9	61.8	53.8	70.2	63.9	81.3	57.1	63.5	57.1	65.1	68.3	71.1
Not married	%	30.0	29.6	42.2	29.5	32.4	38.5	26.9	33.0	13.1	36.5	32.2	39.6	30.2	25.8	23.7
Unknown	%	4.5	4.5	2.9	5.6	5.9	7.7	2.9	3.0	5.6	6.4	4.3	3.3	4.8	4.9	5.3
Median age at Ph.D.	Yrs.	34.5	34.0	31.8	35.5	32.3	32.5	33.2	33.7	36.0	35.2	36.3	36.2	37.7	34.8	36.2
Percent with dependents	%	60.6	61.0	52.0	62.3	67.4	60.0	63.4	56.5	81.3	50.2	58.4	52.7	54.0	63.4	73.7
Sources of support[b]																
Personal	%	46.9	43.0	40.2	32.8	27.9	60.0	46.6	39.6	38.4	66.7	65.7	78.0	54.0	53.7	68.4
Foreign government	%	45.0	48.8	31.4	41.0	48.5	57.7	46.6	50.4	70.2	38.4	26.6	11.0	36.5	51.2	21.1
University	%	77.8	78.4	94.1	73.8	89.7	76.9	85.7	77.4	58.6	80.3	74.7	84.6	58.7	73.2	78.9
Technology assistant	%	44.0	42.5	68.6	32.8	70.6	42.3	45.8	34.3	15.2	54.7	61.5	76.9	30.2	22.0	57.9
Research assistant	%	48.9	52.9	80.4	67.2	30.9	50.0	66.4	50.9	48.0	34.0	29.2	15.4	25.4	63.4	31.6
Other university	%	22.5	21.5	17.6	18.0	25.0	30.8	17.2	21.7	14.1	34.0	27.5	38.5	23.8	17.1	18.4
Other	%	21.9	20.9	13.7	18.0	10.3	19.2	14.3	22.2	14.6	41.4	27.0	16.5	34.9	29.3	36.8
Unknown	%	3.8	3.9	2.9	8.2	2.9	3.8	3.4	3.0	3.5	5.4	3.4	1.1	3.2	4.9	7.9
Median time lapse from baccalaureate to Ph.D.																
Total time	Yrs.	10.3	9.9	8.6	11.5	8.1	8.9	10.0	9.1	11.8	10.1	12.0	10.0	13.3	12.4	14.0
Registered time	Yrs.	6.5	6.4	6.8	7.3	5.8	5.4	6.4	6.5	5.8	6.8	7.3	7.3	7.0	8.4	7.3
Planned location after Ph.D.																
Permanent visas	%	244.0	177.0	16.0	12.0	11.0	4.0	31.0	32.0	31.0	40.0	67.0	35.0	15.0	8.0	9.0
U.S. total	%	71.3	68.9	81.3	58.3	81.8	D	67.7	75.0	48.4	75.0	77.6	85.7	73.3	62.6	66.7
Study	%	26.4	34.4	38.5	42.9	44.4	D	33.3	54.2	13.3	26.7	7.7	10.0	9.1	0.0	0.0
Employment	%	70.1	62.3	61.5	57.1	55.6	D	61.9	33.3	86.7	73.3	88.5	83.3	90.9	100.0	100.0
Unknown	%	3.5	3.3	0.0	0.0	0.0	D	4.8	12.5	0.0	0.0	3.8	6.7	0.0	0.0	0.0
Non-U.S.	%	18.9	22.0	12.6	33.3	18.2	D	12.9	18.8	48.4	12.5	10.4	8.6	13.3	25.0	0.0
Unknown location	%	9.8	9.0	6.3	8.3	0.0	D	19.4	6.3	3.2	12.6	11.9	5.7	13.3	12.5	33.3

See explanatory information and SOURCE at end of table.

Appendix table 6. Statistical profile of U.S. doctorate recipients from Mexico, by major field of doctorate, 1988-96 (Continued)

Item		Total all fields	Total S&E	Physical sci.	Earth/ atmos/ ocean sci.	Mathematics	Computer/ info. sci.	Engineering	Bio. sci.	Agric. sci.	Psych/ social sci.	Non-S&E	Humanities	Education	Health sci.	Prof/ other fields
Temporary visas	%	1.1	949.0	86.0	49.0	57.0	22.0	207.0	198.0	167.0	163.0	166.0	56.0	48.0	33.0	29.0
U.S. total	%	30.9	31.1	55.8	26.5	22.8	50.0	39.1	35.4	12.0	23.9	29.5	37.5	20.8	33.3	24.1
Study	%	54.1	59.7	79.2	69.2	46.2	18.2	46.9	92.9	50.0	20.5	20.4	9.6	20.0	54.6	0.0
Employment	%	44.8	39.0	20.8	23.1	53.8	81.8	53.1	5.7	50.0	74.4	79.5	90.5	80.0	45.5	100.0
Unknown	%	1.2	1.4	0.0	7.7	0.0	0.0	0.0	1.4	0.0	5.1	0.0	0.0	0.0	0.0	0.0
Non-U.S.	%	61.2	61.4	40.7	65.3	70.2	40.9	49.3	61.1	77.8	69.9	59.6	55.4	68.8	54.5	58.6
Unknown location	%	8.0	7.5	3.5	8.2	7.0	9.1	11.6	3.5	10.2	6.1	10.8	7.1	10.4	12.1	17.2
Planned location in the U.S. after Ph.D.	n	518	417	51	20	22	14	102	94	35	69	101	51	21	16	13
Definite postdoc. study	%	28.8	33.8	47.5	35.0	22.7	14.3	23.5	62.8	22.9	10.1	7.9	5.9	9.5	18.8	0.0
Definite employment	%	33.8	30.2	14.8	20.0	50.0	42.9	43.1	7.4	34.3	47.8	48.5	54.9	28.6	31.3	76.9
Seeking postdoc. study	%	16.0	18.5	23.0	25.0	22.7	0.0	20.6	20.0	11.4	13.0	5.9	3.9	4.8	18.8	0.0
Seeking employment	%	19.5	15.6	14.8	15.0	4.5	42.9	11.8	5.3	31.4	26.1	35.6	31.4	57.1	31.3	23.1
Postdoc. plans unknown	%	1.9	1.9	0.0	5.0	0.0	0.0	1.0	4.3	0.0	2.9	2.0	3.9	0.0	0.0	0.0
Definite employment plans in U.S. after Ph.D.	n	175	126	9	4	11	6	44	7	12	33	49	28	6	5	10
Primary work activity																
R&D	%	45.1	53.2	88.9	D	18.2	100.0	56.8	42.9	83.3	33.3	24.5	14.3	50.0	D	20.0
Teaching	%	35.4	27.0	11.1	D	72.7	0.0	20.5	28.6	0.0	42.4	57.1	60.7	50.0	D	70.0
Administrative	%	2.9	1.6	0.0	D	0.0	0.0	2.3	0.0	0.0	3.0	6.1	10.7	0.0	D	0.0
Professional services	%	5.7	7.9	0.0	D	9.1	0.0	9.1	14.3	8.3	6.1	0.0	0.0	0.0	D	0.0
Other	%	1.7	2.4	0.0	D	0.0	0.0	2.3	14.3	0.0	3.0	0.0	0.0	0.0	D	0.0
Unknown	%	9.1	7.9	0.0	D	0.0	0.0	9.1	0.0	8.3	12.1	12.2	14.3	0.0	D	10.0
Type of employer																
Educ. institution[c]	%	59.4	49.2	11.1	D	90.9	16.7	43.2	42.9	41.7	56.7	85.7	85.7	100.0	D	90.0
Industry/Business	%	29.7	38.9	66.7	D	9.1	83.3	52.3	42.9	50.0	6.1	6.1	7.1	0.0	D	0.0
Government	%	4.0	5.6	11.1	D	0.0	0.0	4.5	0.0	8.3	9.1	0.0	0.0	0.0	D	0.0
Non-profit	%	1.7	0.8	11.1	D	0.0	0.0	0.0	0.0	0.0	0.0	4.1	3.6	0.0	D	10.0
Other and unknown	%	5.1	5.6	0.0	D	0.0	0.0	0.0	14.3	0.0	18.2	4.1	3.6	0.0	D	0.0

[a] This table includes all citizens of Mexico who indicated a visa status (permanent of temporary visa). Those with unknown visa status are not included.

[b] In this table a recipient counts once in each source category from which he or she received support. Since students indicate multiple sources of support, the vertical percentages sum to more than 100 percent. "Personal" includes a recipient's own eamings, family support, and loans. Federal research assistants are aggregated with university research assistants.

[c] Includes 2-year and 4-year colleges and universities, medical schools, and elementary/secondary schools.

KEY: D = Data withheld to avoid potential disclosure of confidential information.

SOURCE: National Science Foundation/Division of Science Resources Studies, *Survey of Eamed Doctorates.*

Appendix table 7. Fellowships administered by CONACYT, 1980-96

Year	Fellowships		
	Total	National	Foreign
1980	4,618	3,049	1,569
1981	4,340	2,309	2,031
1982	1,801	826	975
1983	2,540	2,072	468
1984	2,033	1,611	422
1985	2,608	2,032	576
1986	1,843	1,468	375
1987	2,220	1,822	398
1988	2,235	1,791	444
1989	1,677	1,368	309
1990	2,135	1,660	475
1991	5,570	4,181	1,389
1992	6,665	5,103	1,562
1993	9,492	6,988	2,504
1994	11,703	9,170	2,533
1995	16,200	12,840	3,360
1996/p	18,079	14,333	3,746

KEY: /p = Preliminary figures

SOURCE: National Council of Science and Technology Studies (CONACYT), Mexico.

Appendix table 8. Fellowships administered by CONACYT by study level, 1980-96

Year	Total	Master's	Doctorate	Postdoctorate	Other[a]
1980	4,618	2,138	311	9	2,160
1981	4,340	1,677	368	23	2,272
1982	1,801	377	88	3	1,333
1983	2,540	1,481	319	20	720
1984	2,033	1,135	303	19	576
1985	2,608	1,256	364	14	974
1986	1,843	821	268	12	742
1987	2,220	1,083	317	11	809
1988	2,235	1,006	351	21	857
1989	1,677	873	286	19	499
1990	2,135	1,142	453	17	523
1991	5,570	3,448	1,749	22	351
1992	6,665	4,412	2,184	13	56
1993	9,492	6,534	2,569	43	346
1994	11,703	8,056	3,167	53	427
1995	16,200	11,776	4,424	0	0
1996/p	18,079	12,479	5,269	0	331

[a] Includes specialization scholarships, interchange, actualization, language, technical training, and special projects. Data are preliminary.

KEY: /p = Preliminary figures

SOURCE: National Council of Science and Technology Studies (CONACYT), Mexico.

Appendix table 9. The 50 universities in greatest demand by CONACYT fellowship-holders

University	Country
1. The University of Arizona	United States
2. Harvard University	United States
3. Universidad Complutense de Madrid	Spain
4. Stanford University	United States
5. University of Texas at Austin	United States
6. Texas A&M	United States
7. Cornell University	United States
8. Columbia University	United States
9. University of Manchester Institute of S&T	United Kingdom
10. University of Warwick	United Kingdom
11. MIT	United States
12. New Mexico State University	United States
13. University of Essex	United Kingdom
14. Universidad Autónoma de Barcelona	Spain
15. Imperial College of S/T and Medicine	United Kingdom
16. Georgetown University	United States
17. Universidad Politécnica de Cataluña	Spain
18. U.London the London School of Econ. & Pol.Science	United Kingdom
19. University of Michigan	United States
20. UCLA	United States
21. UC Berkeley	United States
22. University of Illinois at Urbana Champaign	United States
23. UC Davis	United States
24. University of Pennsylvania	United States
25. New York University	United States
26. Northwestern University	United States
27. Universidad de Barcelona	Spain
28. University of McGill	Canada
29. Yale University	United States
30. University of Edinburough	United Kingdom
31. University of Cambridge	United Kingdom
32. University of Sheffield	United Kingdom
33. University of Oxford	United Kingdom
34. University of Reading	United Kingdom
35. University of Sussex	United Kingdom
36. University of Toronto	Canada
37. University College London	United Kingdom
38. Universite Pantheon Sorbonne-Paris I	France
39. University of Southampton	United Kingdom
40. Universidad de Salamanca	Spain
41. Universidad Autónoma de Madrid	Spain
42. University of British Columbia	Canada
43. University of Laval	Canada
44. Institut National Polytechnique de Grenoble	France
45. Ecole de Hautes Etudes en Sciences Sociales	France
46. Institut National Polytechnique de Toulouse	France
47. Université Pierre et Marie-Curie-Paris VI	France
48. Universidad Politécnica de Madrid	Spain
49. Université de Paris Sud Paris XI	France
50. Université Paris VI	France

SOURCE: National Council of Science and Technology Studies (CONACYT), *Programa de CyT 1995-2000,* Mexico.

Appendix table 10. Estimated cost of fellowships in Colombia and abroad, 1998

	Maintenance	Enrollment Fees	Pasantía[a]	Total
Abroad................................	1,100 x 48 = 52,800	6,000 x 8 = 48,000		100,800
Colombia[b]..........................	725 x 42 = 30,450	2,140 x 8 = 17,120	1,100 x 6 = 6,600	54,170

a Visit to a foreign university.

b For the calculation of the value of a scholarship in Colombia, an exchange rate of 1,400/dollar and a monthly maintenance allowance equivalent to five minimum salaries was used. For domestic fees, it is assumed that the value in constant pesos is a little less than half the cost in foreign prestigious universities. The costs of travel, installation, books, computer, etc., cancel each other, for the domestic scholarship incudes a pasantía of some 6 months in a foreign university.

SOURCE: The Columbian Institute for the Development of Science & Technology (COLCIENCIAS), Comité Externo de Asesoramiento y Seguimiento - CEAS, 1998.

Appendix table 11. FUNDAYACUCHO educational loans and fellowships, 1990-96

Year	Total	Venezuela	Abroad
1990.................	577	398	179
1991.................	863	367	496
1992.................	400	157	243
1993.................	712	146	566
1994.................	541	157	384
1995.................	321	122	199
1996.................	614	194	420

SOURCE: Gran Mariscal de Ayacucho Foundation (FUNDAYACUCHO).

Appendix table 12. Fellowships by the UVC Science & Humanities Development Council by level, 1958-96

Level	Total	1958-66	1967-76	1977-86	1987-96
Total.......................	603	24	124	284	171
Specialization....	118	23	38	25	32
Master's.............	187	0	39	99	49
Doctorate...........	292	1	47	155	88
Postdoctorate....	1	0	0	0	1
Research...........	5	0	0	5	1

SOURCE: Science & Humanities Development Council (CDCH) and the Central University of Venezuela (UCV).

Appendix table 13. Fellowships by the UVC Science & Humanities Development Council (CDCH) by faculty, 1958-96

Faculty	Total		1958-66	1967-76	1977-86	1987-96
Total..	603	(100.0)	24 (4.0)	127 (21.1)	286 (47.4)	166 (27.5)
Agronomy...	94	(15.6)	1	34	41	18
Archeology & urbanism......................	18	(3.0)	1	2	8	7
Sciences..	152	(25.2)	2	38	68	44
Economic science..............................	41	(6.8)	5	4	18	14
Juridical science................................	4	(0.7)	0	1	1	2
Veterinary...	28	(4.6)	2	1	22	3
Pharmacy...	16	(2.7)	0	2	12	2
Humanities & education.....................	69	(1.4)	3	8	30	28
Engineering..	57	(9.5)	4	14	28	11
Medicine..	80	(13.3)	5	14	37	24
Odontology..	44	(7.3)	1	9	21	13

SOURCE: Science & Humanities Development Council (CDCH) and the Central University of Venezuela (UCV).

Mobility Programs for Scientists and Engineers in Latin America

Hebe Vessuri

Although Latin American and Caribbean countries have made systematic efforts to develop a framework for cooperation and integration, few of the existing frameworks have contributed significantly toward financing science and technology (S&T) cooperation. However, there is growing awareness of the need to increase national support for innovation; in addition, multilateral institutions (especially banks) have played a significant role in Latin America in shaping technological development. The Inter-American Development Bank and the World Bank are key players in funding S&T development projects.

Other multilateral organizations have been active, given the resources available to them, in supporting the S&T base in the region as well; these include the United Nations Educational, Scientific, and Cultural Organization (UNESCO), the Ibero-American Program of Science and Technology Development (CYTED—described below), the Inter-American Organization for Higher Education based in Quebec City, and the Inter-American Association of Associations for the Advancement of Science (Interciencia). All of these organizations have a program component addressing mobility of scientists and engineers. Additionally, numerous bilateral programs exist among the various Latin American countries, notably through their National Organizations for the Promotion of S&T (ONCYTs).

This brief paper highlights some of the most significant organizations and initiatives involving mobility programs for scientists and engineers in Latin America.

Multilateral Organizations

CYTED. Created in 1984 by an agreement signed by 21 Ibero-American countries, CYTED's main objective is to foster cooperation among research groups at universities, research and development (R&D) centers, and innovative firms in Ibero-American countries to achieve transferable S&T results for productive systems and social policy. It also aims to be a bridge for S&T cooperation between Latin America and the European Union through Spain and Portugal. It is made up of 16 thematic subprograms that range from aquaculture to S&T management. It also comprises thematic networks; these are associations of research units of public or private organizations in CYTED countries whose S&T interests and activities are related to the particular network's theme. Although the creation and specialization of human resources is not CYTED's primary aim, it does conduct considerable activity in this area. CYTED's human resource creation activities are mainly directed at network and project components and, secondarily, to other collectives of researchers, teachers, and professionals. These formation activities within CYTED are co-funded. Only those oriented to the improvement of capacity building of the groups participating in CYTED projects may be funded entirely through subprogram funds.

Regarding scientific cooperation, one of the most recent and interesting efforts involves the establishment of Latin American Science Networks in several major fields. These networks are sponsored by UNESCO and the International Council of Scientific Unions through the Committee on Science and Technology in Developing Countries/International Biosciences Networks; they also receive support from the Latin American Academy of Sciences. They have formed a coordinating committee for the discussion of policies and problems affecting the entire scientific community in the region, as well as interdisciplinary topics and projects. For their members, the networks have drawn largely on existing scientific societies and a variety of organizations that bring scientists of the region together in the different disciplines, which means that they are highly representative and well-equipped to work with the respective communities. One of their main activities has been to foster interregional exchanges among young scientists. They are also administering government support and seeking to generate regional mechanisms for the integration and financing of joint efforts in S&T.

Examples of these networks of research and exchange follow.

Latin American Astronomy Network (RELAA). This network has a long-standing tradition of cooperation with members of the International Astronomical Union. Following a recent impetus from the International Council of Scientific Unions and UNESCO, more systematic cooperation has been established among the member countries, namely Argentina, Brazil, Chile, Mexico, Uruguay, and Venezuela.

Latin American Biological Sciences Network (RELAB). This is the oldest of the S&T networks, launched in 1975 with the sponsorship of the United Nations Development Programme (UNDP) and UNESCO. It currently has 14 national, 6 regional, and 2 associate members. RELAB has integration projects at various stages of implementation, including the Regional Program of Biotechnology. Launched with support from UNDP, UNESCO, and the United Nations Industrial Development Organization in 1987, this program has been operating since 1996 with funds from various donors and countries. From the outset, the program has supported the establishment of the Argentine-Brazilian Center for Biotechnology.

Latin American Biotechnology Network. An offshoot of RELAB operating since 1992 with the support of national committees, this network has contributed to policymaking, the establishment of infrastructure, and an increase in investment in biotechnology.

Latin American Physics Network (RELAFI). There is a long-standing practice of cooperation in physics through the Latin American School of Physics, a biennial event held since 1959, and the Latin American Center for Physics (CLAF), which has systematically supported regional activities. In 1994, the Latin American Network of Physics Societies (RELASOFI) was created, comprising CLAF and the 16 physics societies or groups that make up the Latin American Federation of Physics Societies (FELASOFI). In 1996, the Ibero-American Union of Physics Societies was created in response to the need for Spanish and Latin American organizations to present a united front in negotiations within international structures.

Latin American Chemical Sciences Network (RELACQ). Since 1959, the best promoter of academic exchanges in chemistry has been the Latin American Federation of Chemistry Associations. In 1995, it was decided to create RELACQ to give fresh impetus to cooperation; this network has yielded its first tangible products and has good prospects for growth. RELACQ has a counterpart, the Latin American Electronic Network for Chemistry, supported by the Organization for American States (OAS).

Mathematical Union of Latin America and the Caribbean (UMALCA). This union was created at the same time as RELACQ; its predecessor was a regional program supported by the French government. UMALCA carries out and supports a series of activities at the regional level, including the Latin American School of Mathematics and the Regional Mathematics Network, which aims to foster cooperation in research and advanced education.

Latin American Association for Space Geophysics (ALAGE). This network is very young—it was created in 1993—but very active. There is also an embryonic Latin American Network for Earth Sciences (RELACT), which aims to encompass surveys of geology, mineral resources, and water supply being carried out in the basin of the La Plata River in the context of the Southern Cone Common Market (MERCOSUR).

Network for the Popularization of Science and Technology in Latin America and the Caribbean (RED-POP). This network was established with UNESCO support and involves most centers in the region in an exchange of information and experience.

Planning and Management of Science & Technology in Latin America Graduate Programs Network (RED-POST). This network was created in 1989 under UNESCO auspices by formally established Latin American university graduate programs granting master's and doctoral degrees; its purpose is to explicitly promote and channel cooperation and exchange among programs in this field.

UNESCO-UNITWIN. UNESCO has implemented a worldwide system of chairs for the introduction of new themes and subjects in different countries and regions, often through the pairing of universities, whereby both teachers and students circulate and are concentrated in particular sites. In Latin America, the number of UNESCO and UNITWIN chairs has been growing considerably, and the International Latin American and Caribbean Institute for Higher Education in Caracas is firmly committed to expanding these as a mechanism.

LATINDEX. The purpose of this regional cooperation project in the field of scientific information and documentation is to create a computerized system based on a regional network of information centers in order to keep up to date a catalogue and index of the scientific journals published in Latin America and the Caribbean.

Bilateral Programs

Inter-American University Organization (OIU). Since its foundation in 1980, OIU has fostered exchange activities between educational institutions in the Americas. In 1983, it created the Institute for University Management and Leadership (IGLU) with the aim of developing training activities, career development activities, etc., for the university and other higher education leaders belonging to this organization.

Organization of Ibero-American States for Education, Science and Culture (OEI). This intergovernmental organization was created in 1955, with of aim of strengthening cultural identity in the integration process, through the promotion of capabilities linked to the social, cultural, and economic development of Ibero-America. The target group for 1999-2002 will be the 14- to 19-year-old age group, although interventions might also be planned for other populations. Emphasis will be placed on supporting policy design and management; as an Ibero-American organization, OEI will try to reinforce its role as an agent between the European Union and Latin America. Its funding is covered by obligatory quotas from the governments of the member states, as well as from contributions for particular projects made by institutions, foundations, and other interested organizations.

Collaboration on University Management: A Bridge Between Universities and Scholars in Europe and Latin America (COLUMBUS). Since its creation in 1987, this nongovernmental organization made up of affiliated public and private universities from both Latin America and Europe has supported the modernization of higher education and institutional development in Latin America, facilitating the exchange of successful experiences, systematically exploring critical areas of institutional management, training senior university officials, and organizing support services and specific management projects. It has greatly enhanced international and intraregional mobility of university authorities and has effectively contributed to the introduction of an evaluatory culture in higher education institutions in the region.

Academic and Professional Programs for the Americas (LASPAU). This nonprofit organization affiliated with Harvard University designs, develops, and implements academic and professional exchange programs on behalf of individuals and institutions in the United States, Canada, Latin America, and the Caribbean. LASPAU places a high value on the role of exchange in institutional development and on access to exchange programs by all individuals, regardless of socioeconomic level, geographical location, sex, or race. The organization offers a strong regional focus, administrative expertise, and a foundation in the Harvard community. Drawing on extensive knowledge of the Latin American and Caribbean academic communities, LASPAU has collaborated with the United States Information Agency since 1975 in the administration of a Faculty Development Program which brings more than 150 educators each year from Latin America and the Caribbean to the United States.

Fulbright-LASPAU Partnership. The success of the LASPAU Faculty Development Program has encouraged other associations between the Fulbright Program and LASPAU, including the Central American Program of Undergraduate Scholarships (CAMPUS), the Amazon Basin Scholarship Program, the Caribbean and Central American Ecology Program, cost-sharing initiatives by Fulbright commissions and United States Information Science (USIS) offices, and a series of workshops and seminars offered to Fulbright grantees and alumni both in the United States and abroad. Today, LASPAU actively partners with U.S. and Latin American universities, Fulbright commissions, and USIS offices to design flexible programs that meet the needs of countries, institutions, and the grantees themselves.

International Development Research Center (IDRC). In addition to its important cooperation program with Latin America for the development of a scientific base in the region, IDRC has supported close to 200 Latin American and Caribbean scholars in the past 10 years. Chile, Peru, and Colombia have the largest percentages of students currently funded.

Montevideo Group (AUGM). The association of universities in the Montevideo Group has accumulated cooperation and exchange experiences since 1991, and has developed the Common Academic Space Program (ESCALA) to promote the creation of a kind of subregional virtual university. The mobility of teachers and researchers in an early phase and the later widening of the program to cover student mobility within the southern subregion is playing a crucial role in the development of a "subregional integrating dimension" of higher education, supported and stimulated by MERCOSUR. Higher institutions linked to the program have begun to take this mobility into account in establishing their structures and aims.

OAS Common Market for Scientific and Technological Knowledge Program (MERCOCYT). Modeled in part on the European Union Framework Program for R&D, this program is a mechanism to promote S&T capacity building in the region and has been in operation since the beginning of the 1990s. Among its main components are projects of scientific and technological integration (such as exchanges and training of highly qualified personnel, research and management of technology and networks of centers of excellence, and data intercommunication).

Latin American Faculty of Social Sciences (FLACSO). Established in 1957 with headquarters in Santiago, Chile, and UNESCO support, FLACSO is an autonomous cooperative initiative of UNESCO and the governments of the region aimed at promoting education, research, and technical cooperation in the social science field throughout the subcontinent. The organization's autonomy and regional character are ensured by the participation of all member countries and eminent intellectuals in its governing bodies and by the Latin American origins of its academic, student, and administrative body, which carries out activities in its 10 academic units and in the general secretariat. Its Latin American nature is also strengthened by the content and scope of its teaching and research programs, which are geared to the region's scientific and social needs. Assistance comes from financial contributions by member country governments and from an extensive network of cooperation agreements with various institutions in the public and private sectors of this and other continents. FLACSO's basic functions are to provide training in the social sciences through postgraduate and specialization courses; perform research in the social science field on Latin American problems; disseminate by all available means, and with the support of governments and appropriate institutions, advances in the social sciences, particularly its own research results; promote the interchange of social science teaching materials in and for Latin America; and, by means of extension and cooperation work, collaborate with university institutions and similar international, regional, and national bodies, both governmental and private, to encourage development in the social sciences.

Latin American Social Sciences Council (CLACSO). Since its creation in 1966, CLACSO has formed the most extensive coordination body for social science research centers in Latin America and the Caribbean, and currently includes 117 member centers. Its executive secretariat has always operated in Buenos Aires. CLACSO has developed a basic work program that strengthens interchange mechanisms in order to bring about a greater integration of Latin American social sciences. It protects the working conditions of social scientists at member centers and other institutions in the region whose academic activities and/or personnel were marred by years of authoritarian repression. Its postgraduate program deals with two major areas: the Southern Cone Research Program, which, with financial support from CLACSO, provided aid in the countries of the subregion to researchers experiencing work difficulties because of their political and/or theoretical views; and, in cooperation with UNDP and UNESCO, the Young Researchers Training Program, since it had become apparent that the main problems in the region were a lack of funds for research and the difficulties experienced by young university graduates in obtaining funds from international agencies.

In recent years, the council's academic activity has been directed at its own medium- and long-term planning against a background of institutional reorganization, rethinking the Commissions and Groups Program to counteract the effects of thematic/organizational dispersion, and continuing action in subject matter areas of particular importance for the analysis of democratization and adjustment processes in the region. CLACSO's 26 working groups and commissions have a membership of some 3,000 researchers in a program of academic exchange, debate, and publication. In 1994, special attention was devoted to nine central themes (commissions) involving the working groups. In view of the increasing development of various Latin American information networks, the Network of Networks (Red de Redes) project was established with IDRC support to improve end user access to existing information resources by linking up 18 regional information networks. During the 1992-95 period, CLACSO was responsible for general coordination of the International Development Information Network for the social sciences, Phase II. That project encouraged the coordinators of each association to develop mechanisms and strategies for new forms of telecommuting. IDRC in Ottawa provided financial support; additional technical support came from the Organisation for Economic Co-operation and Development.

Other

No listing of mobility mechanisms for scientists and engineers in Latin America would be complete without mentioning the fellowship and other collaborating programs set up by several developed countries through their embassies: the United States, the United Kingdom, France, Germany, the Netherlands, Japan, Italy, and Spain, among others. Another important recent initiative is that of the European Union, through its Alfa-Program of collaboration with Latin America.

U.S. Graduate Education

Jean M. Johnson, Alan Rapoport, and Mark Regets

Trends in Graduate Enrollment

Enrollment in U.S. graduate science and engineering (S&E) programs grew for almost 20 years, reached a peak of 436,000 students in 1993, and then began to shrink. From 1975-93, the overall number of students in graduate programs increased steadily at an average annual rate of 2 percent. Subsequent declining enrollment from 1993-97 has averaged 1.6 percent annually. Fewer students enrolling in engineering, mathematics, and computer sciences account for most of the decline. Engineering, mathematics, and computer science enrollments grew at a rate of almost 4 percent annually from 1975-92, but declined 3 percent annually from 1992-95. Engineering enrollment has continued to decline, while enrollment in mathematics and computer sciences increased slightly in 1996 and 1997. Trends differ when examining subfields: within the natural sciences, the physical sciences have decreasing graduate enrollment, while the biological sciences have increasing enrollment (NSF 1999a).

Graduate student enrollment in S&E, although shrinking, is becoming more diverse. In 1977, women represented only one-quarter of S&E graduate enrollment; by 1997, they represented 40 percent of enrollment. The increasing enrollment of minorities in graduate S&E programs partially stems from changing demographics—the higher growth rate in the minority population relative to the white population. While women and minorities continued a decade-long trend of increased enrollment in graduate S&E programs, foreign students and U.S. citizen white males began a downward trend in their enrollment levels. (See appendix tables 1 and 2 and NSF 1999a.) The decline in foreign student enrollment in U.S. institutions is likely influenced by the increasing educational opportunities in other countries.

Master's Degrees

The overall trend in U.S. S&E programs at the master's degree level shows rapidly increasing numbers of earned degrees throughout the 1980s and an even stronger growth in the 1990s. This growth is mainly accounted for by rising numbers of earned degrees in the social sciences and engineering, with relatively stable numbers in the natural sciences, mathematics, and computer sciences. (See appendix table 3.)

By Sex

Over the 20-year period 1975-95, males accounted for the strong growth in master's degrees in engineering, mathematics, and the computer sciences. Females were primarily responsible for the strong growth in social sciences; they also obtained a larger share of degrees in the natural sciences. The proportion of master's degrees earned by females increased considerably in the last two decades—not only in the natural sciences, but in engineering as well. In 1975, females earned 21 percent of the natural science degrees at the master's level and almost 3 percent of the engineering degrees. By 1997, females accounted for 43 percent of the natural science degrees and 16 percent of engineering. (See appendix table 3.)

By Race/Ethnicity

In the 1990s, minority groups in the United States earned, in most cases, increasing numbers as well as increasing shares of master's degrees in S&E fields. The number of S&E degrees earned by Asian/Pacific Islanders consistently increased, especially in engineering, mathematics, and the computer sciences. The number of S&E master's degrees obtained by blacks grew modestly in most fields, with strong growth in the social sciences. Hispanics earned a moderately increasing number—and proportion—of degrees in the social sciences, as well as in engineering. White students showed modest growth in natural science and engineering degrees in the 1990s and strong growth in the social sciences. Notwithstanding these gains, the share of master's degrees earned by white students in all fields declined during the 1977-97 period. (See appendix table 4.)

By Citizenship

Analysis of master's degrees by citizenship shows a trend toward a larger proportion of degrees going to foreign students in engineering, mathematics, and the computer sciences. In 1977, foreign students earned 22 percent of the engineering degrees and 11 percent of the mathematics and computer science degrees. By 1995, foreign representation at the master's level was 34 percent in engineering and 35 percent in mathematics and computer sciences. The rate of growth of overall S&E

master's degrees obtained by foreign students slowed somewhat in the 1993-96 period, mainly due to a leveling off of their earned degrees in mathematics and the computer sciences. (See appendix table 4.) Engineering degrees awarded to foreign students declined in 1997, echoing the decline in foreign graduate enrollment in engineering from 1993-96. (See appendix table 2.)

Doctoral Degrees

A decade of relatively stable production of S&E doctoral degrees granted in the United States from 1975-85 was followed by a decade of increasing production of such degrees; in 1996, over 27,000 S&E doctorates were awarded. Large increases in the numbers of earned degrees were evident in engineering, mathematics, and the computer sciences. The number of degrees in these fields doubled from 1985-96. (See figure 1.) The natural science fields—particularly the biological sciences—also contributed to the rising number of degrees during this period, increasing by 25 percent (NSF, 1999d).

By Sex

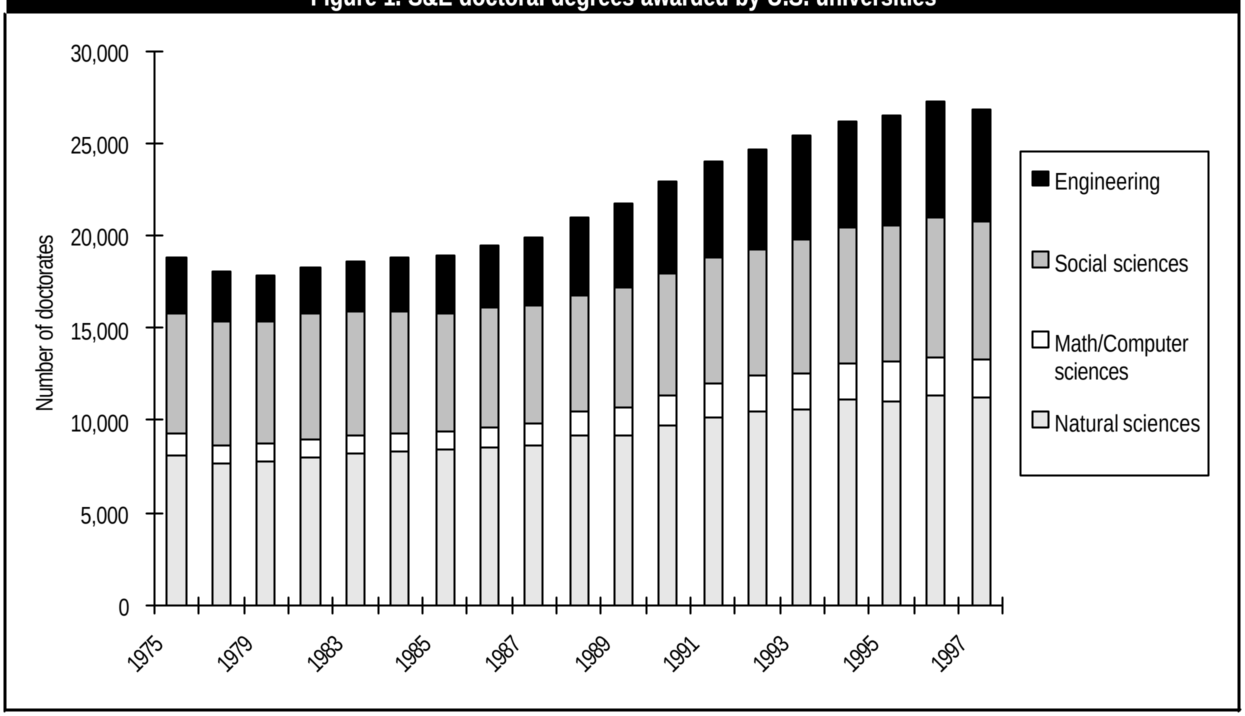
Male doctoral students accounted for much of the growth in engineering, mathematics, and the computer sciences; female doctoral recipients were largely responsible for the increasing number of natural science degrees. Within the past two decades, the share of S&E doctorates earned by women doubled, rising from almost 16 percent in 1975 to 33 percent in 1997. The proportion of increase has differed by field. By 1997, females earned half of the doctoral degrees in the social sciences and 40 percent in the biological sciences. Growth in the proportion of degrees awarded to women was greatest in engineering subfields. By 1997, women earned 12 percent of all engineering degrees, and 16 to 18 percent of doctoral degrees in chemical and material engineering. (See appendix table 5.)

By Race/Ethnicity

Underrepresented minorities within U.S. universities received over 7 percent of all S&E doctorates awarded to U.S. citizens and permanent residents in 1995; this was up slightly from 4 percent in 1977. As a group, these minorities received 6 percent of earned degrees in the natural sciences, 4 percent in mathematics and the computer sciences, 10 percent in the social sciences, and 6 percent in engineering.[1] For black Ph.D. recipients, the largest numerical increases in the past decade have been in the

[1]When considering the total number of earned S&E doctoral degrees (including those to foreign students), the percentages earned by underrepresented minorities are smaller. See NSB (1998), chapter 2.

Figure 1. S&E doctoral degrees awarded by U.S. universities



SOURCE: See appendix table 5.

biological and social sciences. The largest percentage increases have been in the biological sciences and engineering. (See appendix table 6.)

Graduate Education Reforms in the United States

Needs for Reform

The Committee on Science, Engineering, and Public Policy (COSEPUP) of the National Academy of Sciences recently reviewed U.S. graduate programs in S&E. The resulting report, *Reshaping the Graduate Education of Scientists and Engineers* (COSEPUP 1995), recommends broadening the education of doctoral students to better meet their actual career needs. The report noted that the current focus of doctoral programs on research training in a narrow discipline gradually evolved over previous decades when the demand for research was rising. U.S. R&D spending increased rapidly from the late 1970s to the latter part of the 1980s; consequently, doctoral R&D employment increased by almost 5 percent annually. Today, however—the report goes on to explain—an even smaller minority than previously will enter academic research. Only one-third of future doctoral recipients in S&E will enter the tenured academic system; two-thirds will be employed in nonacademic settings. The report concludes that doctoral course offerings should be expanded to reflect the diversity and complexity of these employment options. What these options will all require is the ability to apply an advanced understanding of science and engineering to societal needs. Consequently, S&E doctoral students will need:

- education in the broad fundamentals of their fields,
- familiarity with several subfields,
- the ability to communicate complex ideas to nonspecialists, and
- the ability to work well in teams.

Focus of Reforms

A variety of graduate reforms predated or stemmed from the recommendations of the COSEPUP report. These reforms focus on the education needs of students. Graduate programs are being expanded to include not only multidisciplinary coursework, but also to answer to students' needs for business and teaching skills. The Council of Graduate Schools has held a series of national discussions with graduate deans about the need to prepare students more effectively for their roles as future faculty. Subsequently, the 1997 meeting of the National Science Board on the Federal Role in Graduate and Postdoctoral Programs recommended Federal encouragement to universities to increase diversity and the appropriate broad training of the S&E labor force (NISE 1998).

Forces for Change

Underlying these policy studies are a variety of forces for graduate education reform. These include recent demographic, economic, technological and social changes, as well as the increasing complexity of viable solutions to real-world problems.

Among the demographic forces for change is a larger number of women and minorities earning bachelor's degrees in S&E fields for potential recruitment into graduate S&E programs (along with a declining population and enrollment of whites and declining enrollments of foreign students). Emerging reforms that build on this demographic trend are graduate enhancement programs for underrepresented minority students and recruitment and retention programs for women in science and engineering. For example, Rice University initiated a graduate program for increasing diversity in computational sciences, and the University of Arizona and Notre Dame University promote the Graduate Education for Minorities Consortium (GEM) of industries, colleges, and universities to increase minority recruitment and retention (NISE 1998).

Economic and technological forces are combining to influence changes in graduate education. Spiraling education costs—which are increasing faster than the cost of living—are contributing to the growth of proprietary (for-profit) universities with cost-effective programs. The capital expense of major research programs is necessitating shared research facilities. Collaborative agreements among consortia of universities are being made to ensure efficient use of resources and expertise of graduate faculty. For example, in a new doctoral program in technology management, a consortium of nine universities across eight states links the top laboratories and faculty of key technical specializations (such as digital communication systems and industrial composite materials). This arrangement allows the participants to ensure the broad education needed to manage such advanced technologies (NISE 1998).

Another force for change is technology. Information technologies and distance learning technologies are changing how instruction can be given. For example, Engineering Research Centers supported by the National Science Foundation (NSF) are developing multidisciplinary engineering curricula through interactive instructional modules. (These centers are briefly described below under "Background: Federal Support for S&E.") These modules can assist in teaching principles of diverse subjects using graphics, diagrams, and animation to convey key concepts, along with interactive exercises for practicing the principles' application. Through alternative instructional delivery systems, both graduate students in university classrooms and researchers within private companies can use this software.

The growing demand for public accountability is driving the U.S. educational system to improve instruction in mathematics and science. At the graduate education level, this demand for accountability is focused on the improvement of teaching, with an increased focus on the educational and career needs of students rather than the research needs of faculty. Several universities have initiated efforts to improve both graduate and undergraduate instruction in science and engineering, such as Preparing Future Faculty programs and training for teaching assistants (NISE 1998).

Another dynamic for change is an emerging demand for broadly educated Ph.D. recipients who are able to address the complexity of real-world problems and contribute to their solution. For example, at a recent forum for graduate education reform, the director of research for the U.S. Department of Energy explained that the department—which is one of the largest Federal supporters of basic research in the natural sciences—needs an S&T workforce that can flexibly cross disciplines to solve complex problems in several mission areas. Issues that need to be addressed by the department include the security of existing nuclear stockpiles, the development and use of new energy technologies, the health and environmental effects of energy use, and structural genomics (which combines the disciplines of biology and informatics) in the human genome program (NISE 1998).

The above innovations—as well as new multidisciplinary programs and other efforts to broaden the preparation of graduate students—were addressed at a recent National Institute for Science Education, University of Wisconsin at Madison, forum on graduate education. For more information, see NISE (1998).

S&E Graduate Support

During the course of their graduate careers, most S&E students are likely to be involved in some type of research activities.[2] S&E graduate students thus play a unique role in the U.S. academic research system, in that they are both an input to and an output of this system. U.S. research universities have traditionally coupled advanced education with research, thereby generating new knowledge and producing advanced S&E talent. This complex, symbiotic relationship is exemplified by the va-

Background: Federal Support for S&E

Scientists played a key role in World War II within Federal defense research sites; following the war, policymakers chose to support scientists within universities. The Vannebar Bush Report stated that an increasing number of highly qualified scientists and engineers would be crucial to the U.S. economy, and recommended public support of advanced students in science and mathematics within universities. That policy produced significant Federal support for university-based S&T research and the training of scientists and engineers. These funds increased further following Sputnik, the Cold War, and the creation of the National Institutes of Health (NIH) and the National Science Foundation. By the early 1960s, NIH funding of university research exceeded total funding of university-based research by the Department of Defense.* This compact between the Federal Government and universities has continued to the present, with Federal academic R&D reaching $21 billion (in 1992 constant dollars) in 1996 (NSB 1998).

*Cited by Robert Rosenzweig, former president of the Association of American Universities, see *Stanford Today* (1998).

[2]See chapter 5, "Integration of Research with Graduate Educa-

riety of support mechanisms and sources through which financial resources are provided to S&E graduate students.[3] Support mechanisms include fellowships, traineeships, research assistantships, and teaching assistantships.[4] Sources of support include Federal agency; non-federal support (from academic institutions, state and local governments, foreign governments, nonprofit institutions, and industrial firms); and self-support (from loans or personal or family financial contributions). Most graduate students are supported by more than one source and mechanism during their time in graduate school; they also often receive support from several different sources and mechanisms in any given academic year.

Trends in Support

The recent enrollment declines reported earlier for all S&E graduate students affected the number of full-time students in 1995. For the first time in almost two decades, enrollment of full-time S&E graduate students declined slightly in 1995. A 12-year trend of steady increases in enrollment of full-time graduate students whose primary source of support was the Federal Government also ended, as did an even longer upward trend in the number of graduate students whose primary source of support was from non-federal sources.[5] For more information on Federal support, see sidebar on Background: Federal Support for S&E. The number of self-supported graduate students also declined for the first time since 1988. (See appendix table 7.)

Since 1980, there have been significant shifts in the relative usage of different types of primary support mechanisms. (See figure 2.) These shifts have been due more to rapid growth in some support mechanisms than to an absolute decline in the number of students supported by any of these mechanisms. The proportion of graduate students with research assistantships as their primary support mechanism increased from 22 to 27 percent between 1980 and 1995. This increase was offset by drops in the proportions of students supported by traineeships (from 7 to 5 percent) or by teaching assistantships (from 23 to 20 percent). Most of these changes had occurred by the late 1980s, with proportional shares being relatively stable during the first half of the 1990s. The proportion supported by fellowships fluctuated between 8 and 9 percent between 1980 and 1995; that with self-support as the primary mechanism fluctuated between 28 and 32 percent. These overall shifts in support mechanisms were evidenced for both students supported primarily by Federal sources and for those supported by non-federal sources. (See appendix table 7.)[6]

Patterns of Support by Institution Type

The proportions of full-time S&E graduate students with primary support from various sources and mechanisms differ for private and public universities. (See figure 3.) A larger proportion of full-time graduate students rely primarily on self-support in private academic institutions as opposed to those in public institutions—39 versus 30 percent in 1995.

Non-federal sources are the primary source of support for a larger proportion of students in public institutions (50 percent) than in private ones (41 percent). At both private and public institutions, about 20 percent of students receive their primary support from the Federal Government.

A larger proportion of students attending public academic institutions rely on research assistantships and teaching assistantships as their primary support mechanism (30 and 23 percent, respectively) than those attending private institutions (21 and 13 percent, respectively). This is balanced by greater reliance on fellowships and traineeships in private institutions (14 and 8 percent, respectively) than in public ones (7 and 4 percent, respectively).

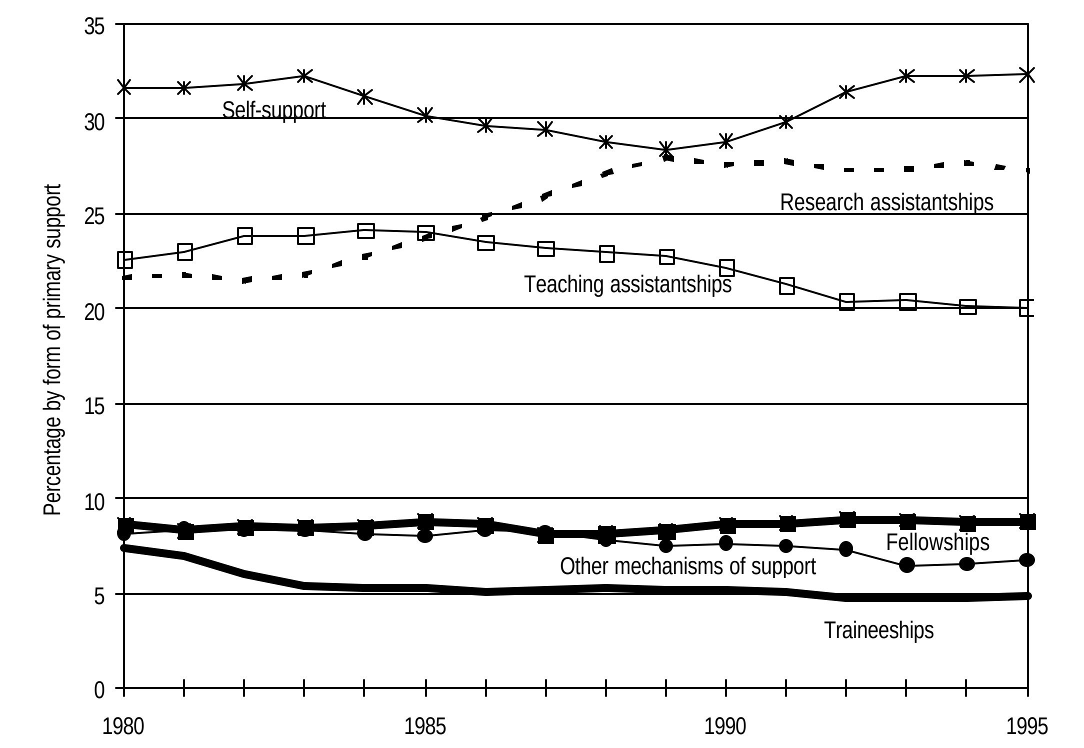
[3]All the data presented here on mechanisms and sources of support for S&E graduate students are from the NSF-NIH annual fall Survey of Graduate Students and Postdoctorates in Science and Engineering. In this survey, departments report the primary (largest) source and mechanism of support for each full-time degree-seeking S&E graduate student. No financial support data are collected for part-time students. Many of the full-time students may be seeking master's degrees rather than Ph.D.s, particularly in the engineering and computer science fields. Throughout this section on support, S&E include the health fields (medical sciences and other life sciences.)

[4]A *fellowship* is any competitive award (often from a national competition) made to a student that requires no work of the recipient. A *traineeship* is an award given to a student selected by the university. An *assistantship* is classified as research or teaching depending on the duties assigned to the student.

[5]Total Federal support of graduate students is likely to be underestimated since reporting includes only direct Federal support to a student and support to research assistants financed through the direct costs of Federal research grants. This omits students supported by departments through the indirect costs portion of research grants; such support would appear as institutional (non-federal) support, since the university has discretion over how to use these funds.

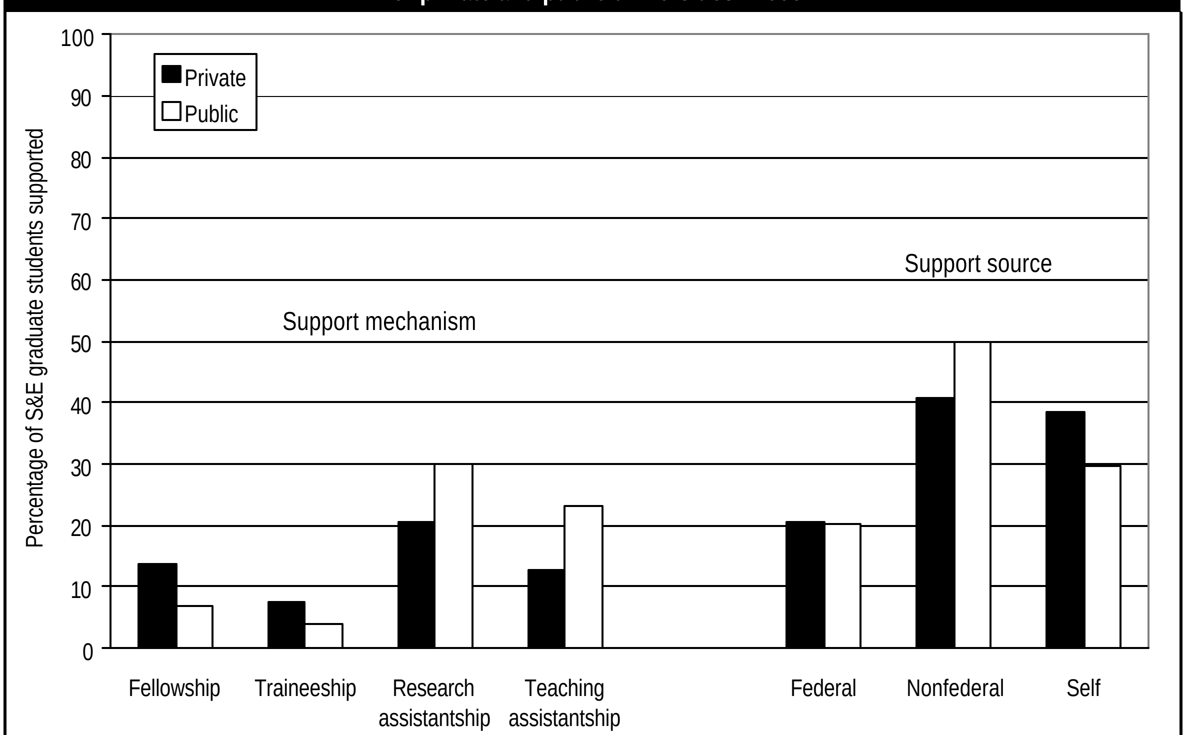
[6]For additional details on trends in support mechanisms by

Figure 2. Support for full-time science and engineering graduate students



SOURCE: See appendix table 7.

Figure 3. Percentage of S&E graduate students by mechanism and source of primary support, for private and public universities: 1995



NOTE: Mechanism percentages do not total 100 because other mechanisms are not included.

SOURCE: National Science Board, *Science & Engineering Indicators-1998,* NSB 98-1 (Arlington, VA: National Science Foundation), appendix table 5-35.

Primary Mechanism and Source of Support by S&E Field

Research Assistantships. Although research assistantships accounted for 27 percent of all primary support mechanisms in 1995, their role differed across S&E fields. They comprised more than 50 percent of the primary support mechanisms for graduate students in astronomy, atmospheric sciences, oceanography, agricultural sciences, chemical engineering, and materials engineering. They accounted for less than 20 percent in all the social sciences, mathematical sciences, and psychology. (See appendix table 8.)

Just as the significance of research assistantships differs across fields, so too does that of the Federal Government as the primary source of support for research assistantships. Overall, the Federal Government was the primary source of support for about half of graduate research assistants. However, it was the primary source of support for 75 percent of the research assistants in the physical sciences, just over 60 percent in both the environmental and computer sciences, but only 20 percent in the social sciences and 32 percent in psychology. (See appendix table 9.)

Teaching Assistantships. Teaching assistantships accounted for 20 percent of all primary support mechanisms in 1995. But they comprised more than 30 percent of the primary support mechanisms for graduate students in chemistry, physics, mathematics, and earth sciences; and less than 12 percent in the atmospheric sciences, oceanography, agricultural sciences, medical sciences, aeronautical engineering, and materials engineering. (See appendix table 8.) The Federal Government has an almost negligible role in supporting teaching assistantships.

Fellowships and Traineeships. Although fellowships accounted for only 9 percent of all primary support mechanisms in 1995, they are a much more important mechanism of primary support for students in the history of science, anthropology, and astronomy where they comprised 37, 20, and 17 percent of the primary support mechanisms, respectively. Students with traineeships as their primary support mechanism accounted for just under 5 percent of all full-time S&E graduate students in 1995. For students in the biological sciences, medical sciences, and other life sciences, however, traineeships accounted for between 11 and 14 percent of primary support. (See appendix table 8.)

The Federal Government was the primary source of support for about one-quarter of all graduate students with a fellowship as their primary mechanism of support and for about two-thirds of those with a traineeship as their primary mechanism of support. The Federal Government was a more important primary source for fellowships to graduate students in the atmospheric sciences, aeronautical engineering, and astronomy, providing 63, 56, and 50 percent, respectively, of the primary fellowship support. In contrast, it provided only 14 percent of primary fellowship support in the social sciences. The Federal Government provided almost 80 percent of primary support for traineeships in the life sciences, compared to 24 percent in computer sciences and 21 percent in the social sciences. (See appendix table 9.)

Self-Support. About one-third of full-time S&E graduate students were supported primarily by loans or from personal or family financial contributions. The importance of this type of support also differed across S&E fields. About 40 percent of students in the computer sciences, medical sciences, anthropology, and industrial engineering—and more than 50 percent of those in psychology and political science—relied on self-support as their primary support mechanism. Conversely, less than 10 percent of the students in astronomy, chemistry, physics, and the atmospheric sciences relied on self-support as their primary support. (See appendix table 8.)

Impacts of Graduate Support Mechanisms

There has long been great interest in whether the amount and type of financial support given to graduate students has an effect on degree completion rates, time to degree, and productivity and success in the labor market. How effective have the large investments in graduate education made by government, academia, and the private sector been? How do the various modes of support—teaching assistantships, research assistantships, fellowships, and subsidized loans—compare in terms of recipients' educational and career outcomes?

Hypotheses of Relative Merits. The merits of various support mechanisms have been discussed and a number of hypotheses developed about the advantages and disadvantages of different mechanisms. In fact, some of the characteristics of a specific mechanism cited as disadvantages by some individuals are cited as advantages by others. For instance, the portability of fellowships and the independence they give to graduate students are seen by some as a distinct advantage because they provide these students with great freedom to pursue a wide variety of interests. Others argue that students with fellowships are more likely than those supported by traineeships or research assistantships to become isolated from their peers and from the faculty in their departments; they thus may either be less likely to complete their Ph.D. or to take longer to do so. Some argue that although having a fellowship at the beginning of one's graduate career may be detrimental, having one when working on a dissertation is highly advantageous.

Similarly, some hold that since research assistantships are directed to the needs of funded research projects, doctoral students can become so involved on a specific project that they have little time for independent exploration or other educational activities, thus limiting the areas in which they acquire experience. A counter argument is that the research skills and experience students acquire by focusing on a specific project are indispensable to the high-quality, state-of-the-art research being conducted at U.S. universities and industrial laboratories; students with research assistantships thus may complete doctoral dissertations more frequently and faster than those with other forms of support. Some argue that strong reliance on research assistantships can bias research and graduate training toward those areas that have long track records rather than to new and innovate areas, and that they also may prevent beginning faculty from attracting graduate students. Others argue that it is the widespread availability of research grants that provides young faculty the opportunity to work closely with graduate students.

Lack of Quantifiable Data. Unfortunately, it is extremely difficult to examine many of these hypotheses analytically either because of the absence of data or the inability to capture the hypothesized outcomes quantitatively.[7] In addition, most graduate students depend on multiple sources and mechanisms of support while in graduate school, and frequently on different sources and mechanisms in different phases of graduate work. This makes it quite difficult, if not impossible, to identify a one-to-one relationship between a student and a support source or mechanism.

Furthermore, there is a selection problem that is not easily overcome. Most external organizations and graduate institutions award financial support based on merit. In addition, the type of support that a student receives is affected by a graduate department's view (and perhaps sometimes by the student's own view) of the student's relative ability to teach or to support research. If students receiving support have more ability or motivation than other students, the former are likely to be more successful than the latter irrespective of the effects of support mechanisms. To the extent that graduate support allocation decisions are successful in sorting students by merit and aptitude, it becomes more difficult to statistically isolate the effect of receiving graduate support from the effects of other student differences.

General Conclusions. Despite these difficulties, various studies have looked at some aspects of graduate support and student outcomes. A recent review of this literature summarized the results as follows (Bentley and Berger 1998):

- The bulk of the evidence suggests that students receiving support enjoy higher completion rates and shorter time to degree than students without support.
- The evidence of the differential effects of alternative support mechanisms on completion rates is inconsistent. However, students holding fellowships appear to finish doctoral programs more quickly than teaching and research assistants.
- Several scholars present evidence that research assistants are more productive scholars than other students, both in graduate school and later in their careers.
- Only one study included in this review attempts to determine whether the dollar amount of support matters. That study did not find evidence that increasing the amount of support improves outcomes.

[7]National Science Board (NSB). 1996 Report from the Task Force on Graduate and Postdoctoral Education NSB/GE 96-2. Arlington, VA: National Science Foundation. This task force, established in 1995 to examine the merits, mix, and impact of several modes of funding support used by NSF in graduate and postdoctoral education, concluded that sufficient links between national data and NSF support data did not exist, and so no recommendations could be made on

Employment of Degreed Scientists and Engineers

Appendix table 10 shows the distribution of those in S&E occupations in the United States. Of the 11.5 million people with some kind of S&E degree, only 3.2 million are in jobs strictly labeled as science and engineering.[8] Of these, nearly two-thirds are employed by private, for-profit employers. By this strict occupational measure of S&E workers, Ph.D. recipients make up 13 percent of the U.S. S&E workforce. If the definition were extended to include all workers with S&E degrees, the proportion of doctorate-holders would fall to 4 percent.

International Mobility of Doctoral Students and Recipients: Foreign Doctoral Students in the United States

In the past decade, foreign students have accounted for the large growth in S&E doctoral degrees in U.S. universities. The number of foreign S&E doctoral recipients graduated from U.S. universities doubled from over 5,000 in 1986 to 10,000 in 1996. This doubling translates to an 8-percent average annual increase. In contrast, the rate of increase in doctoral degrees to U.S. citizens averaged less than 2 percent annually (NSB 1998).

Within natural science and engineering fields, the proportion of doctoral degrees earned in U.S. universities by foreign citizens climbed from 25 percent in 1985 to 33 percent in 1994; it has since begun to level off. In 1997, the share of natural science and engineering degrees earned by foreign students decreased slightly to 31 percent. This drop was mainly due to a decline in doctoral degrees earned by South Korean and Taiwanese students. Both of these economies (which are major contributors of foreign graduate students to the United States) have increased their internal capacity for graduate education in S&E, evidenced by the increasing number of in-country doctoral degrees in these fields (NSB 1998).

Even as Asian students entered U.S. graduate programs in record numbers, Asian universities were expanding their own doctoral degree programs in S&E fields. These two phenomena are related. The desire to increase in-country capacity to educate students through the doctoral level necessitated sending students abroad so as to prepare more S&E faculty for expanded graduate programs within Asian universities. For the period 1988-94, the Asian effort to receive doctoral training in U.S. universities was particularly intense, as evidenced by an increase from 2,872 earned degrees in 1989 to 6,229 in 1994. The annual rate of growth in S&E doctoral degrees earned by Asian students during this period was over 17 percent. However, this rate of growth has slowed considerably in the last few years, and in 1997, the number of degrees earned by Asian students within U.S. universities declined.

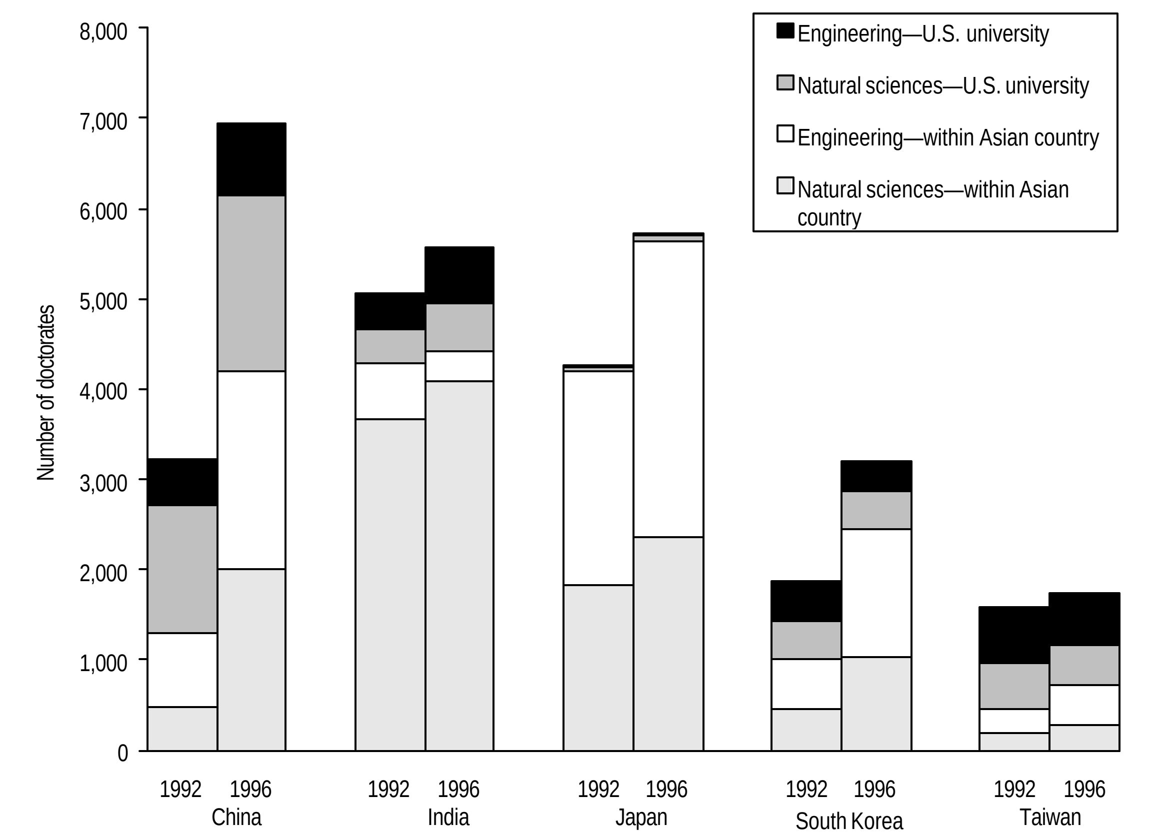
Although Ph.D. production in S&E fields is growing at a faster rate in Asian countries than in the United States, the Asian base is lower. In 1997, 18,513 S&E doctoral degrees were earned in five Asian countries. In that same year, U.S. universities produced almost 27,000 S&E doctorates; however, over 5,500 of these degrees were earned by foreign students from Asia. In 1997, the number of doctoral S&E degrees earned at universities within four Asian economies exceeded the number of such degrees earned by Asian foreign students at U.S. universities. Only for Taiwan do U.S.-earned doctoral degrees outnumber those earned within Taiwanese universities. (See figure 4 and text table 1.)

Patterns of International Mobility and Diffusion of S&T Knowledge

Technology transfer is often said to occur best through people. Thus, the mobility of foreign students throughout Europe, Asia, and the Americas is a significant source of diffusion of S&E knowledge in the world. NSF statistical data are limited to certain patterns of mobility to the United States. The Survey of Earned Doctorates captures the number of S&E doctoral degrees earned by foreign students, students' planned location after completing their degrees, and any firm offers they've received of U.S. postdoctoral study or employment. The Scientists and Engineers Statistical Data System (SESTAT) captures the extent of the contribution of foreign-born scientists and engineers to the U.S. labor force. Little is known,

[8]Other SESTAT survey responses provide strong evidence that many individuals with S&E degrees in non-S&E occupations do use their knowledge from their field of degree and may also be engaged in

Figure 4. Doctoral degrees in natural sciences and engineering awarded within Asian countries and to Asian foreign students within U.S. universities: 1992 and 1996



SOURCE: See text table 1.

Text table 1. Doctoral NS&E degrees awarded within Asian countries and to Asian foreign students within U.S. universities

Field and Location of Degree	Student nationality									
	China		India		Japan		South Korea		Taiwan	
	1992	1996	1992	1994	1992	1996	1992	1996	1992	1996
Total NS&E degrees	3,229	6,955	5,064	5,570	4,270	5,734	1,866	3,197	1,596	1,744
Natural sciences—within Asian country	473	1,999	3,665	4,077	1,833	2,351	459	1,024	191	282
Engineering—within Asian country	823	2,195	629	348	2,362	3,297	552	1,420	264	435
Natural sciences—U.S. university	1,425	1,960	365	520	50	54	418	430	504	452
Engineering—U.S. university	508	801	405	625	25	32	437	323	637	575

KEY: NS&E = natural sciences and engineering

NOTES: Natural sciences include the physical, biological, agricultural, earth, atmospheric, and oceanographic sciences, as well as mathematics, computer and information sciences. Data are latest available year for within-country degrees in India (1994).

SOURCES: **China**— National Research Center for Science and Technology for Development, unpublished tabulations, 1996; **India**—Department of Science and Technology, *Research and Development Statistics 1994-95* (New Delhi: 1996); **Japan**—Monbusho, Monbusho Survey of Education (Tokyo: annual series); **South Korea**—Ministry of Education, *Statistical Yearbook of Education* (Seoul:1996); **Taiwan**—*Educational Statistics of the Republic of China* (Taipei: 1997); **United States**—National Science Board, *Science & Engineering Indicators-1998,* NSB 98-1 Arlington, VA: National Science Foundation.

however, of the return flow of foreign students and the contribution they make to build the S&T infrastructure in their home countries. Little is also known of those foreign graduate students who do not complete a doctoral degree. For example, Japanese industry sends its research personnel to top U.S. universities for 1 to 2 years of advanced study in particular fields (NSF 1997).

The diffusion of S&T knowledge may also occur through networking, without physical relocation of scientists and engineers for extended stays. Choi (1995) has shown extensive networking by Asian-born faculty and researchers working in the United States to advise, disseminate information, and assist in building their home country S&T infrastructure. This tendency is particularly true for foreign-born faculty in S&E departments. In 1993, foreign-born faculty in U.S. higher education accounted for 37 percent of engineering professors and over a quarter of mathematics and computer science teachers. More research is needed on the extent of this diffusion of S&E knowledge through exchange visits or electronic dissemination.

Cooperative research and information technologies are also diffusing S&T knowledge. International cooperative science programs often provide support for immigrant scientists and engineers to collaborate with home country scientists and to advise on building up a research area in a particular area of interest. For example, many of the grantees in the NSF U.S.-China Cooperative Science Program are Chinese American scientists and engineers who are most able to work effectively within the Chinese environment. Electronic dissemination through the Internet is allowing the dissemination of innovative teaching modules as well as specific information needed by home country S&T institutions.

Stay Rates of Foreign Doctoral Recipients in the United States

Until 1992, around half of the foreign students who earned Ph.D.s in S&E in U.S. universities planned to locate in the United States after completing their degree. A significantly smaller proportion (one-third) received firm offers to remain in the United States for academic or industrial employment. The proportion of foreign doctoral recipients who plan to locate in the United States and accept firm offers differs considerably by country and region. Students from Asia, who are the most numerous, also represent the largest percentage who plan to locate in the United States. In contrast, students from North and South America, who are the least numerous, have a smaller proportion planning to locate in the United States.

For the period 1992-96, the proportions of foreign doctoral recipients planning to remain in the United States increased: over 68 percent planned to locate in the United States, and nearly 44 percent had firm offers to do so. This recent increase in stay rates, which may be temporary, is mainly accounted for by the sharp increase in the percentage of Chinese students with firm plans to stay in the United States. In 1990, 42 percent of the approximately 1,000 Chinese doctoral recipients in U.S. universities had firm plans to stay. By 1996, 57 percent of the nearly 3,000 Chinese doctoral recipients from U.S. universities had firm plans to remain in the United States. The underlying cause for this shift is the large number of Chinese students granted permanent residence status in the United States in 1992, following China's response to student demonstrations. Selected countries in Europe (Eastern Europe) and the Americas (Canada), however, also increased their stay rates after completing advanced degrees from a U.S. university. Their numbers are small in comparison to Asia's: 200 from Eastern Europe and 100 from Canada.

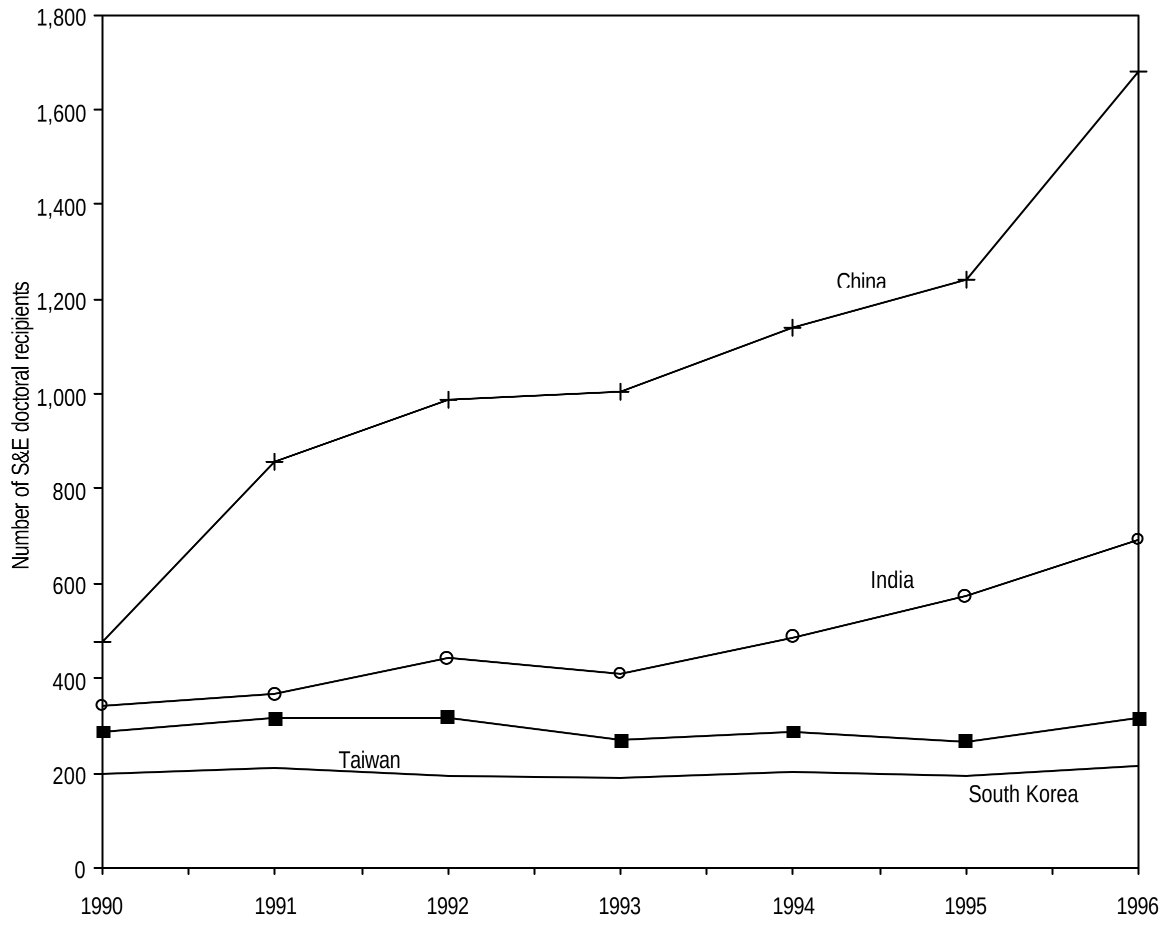
Among Asian countries, China and India apparently have a limited capacity to provide high-level employment to large numbers of returning S&E doctorate-holders. In 1996, 57 to 59 percent of the U.S. S&E doctoral recipients from these countries choose to accept further study or employment in the United States. In contrast, only a small percentage of 1996 doctoral recipients from South Korea and Taiwan (24 and 28 percent, respectively) accepted offers in the United States. The trend in the 1990s has been for relatively few doctoral recipients from these countries to remain in the United States; this is particularly true of South Korean engineering doctoral recipients (NSF 1998). (See figure 5.)

To a large extent, the definite plans of foreign doctoral recipients to remain in the United States revolve around postdoctoral study rather than employment. Among students born in those countries accounting for the largest numbers of foreign doctoral awards, the majority of definite plans to remain in the United States were for further study (58 percent on average between 1988 and 1996); followed by employment in R&D (27 percent); teaching (7 percent), or other professional employment (8 percent).

A recent study of foreign doctoral recipients working and earning wages in the United States (Finn 1997) shows that about 47 percent of the foreign students who earned doctorates in 1990 and 1991 were working in the United States in 1995. The percentages are higher in the physical sciences and engineering, and lower in the life and social sciences. These stay rates differ more by country of origin than by discipline, however. A very large percentage of the 1990-91 foreign doctoral recipients from India and China were still working in the United States in 1995. In contrast, only 10 percent of South Koreans who earned engineering doctorates from U.S. universities in 1990-91 were working in the United States in 1995.

Foreign doctoral recipients from 1970-72 were also examined in the same study. Finn estimated that 47 percent were working in the United States in 1995, and

Figure 5. U.S. S&E doctoral recipients from selected Asian countries with firm plans to remain in the United States



SOURCE: National Science Foundation, Division of Science Resources Studies, Survey of Earned Doctorates, special tabulations.

that the stay rate for that group had fluctuated around 50 percent during the 15 years leading up to 1995. There is no evidence of significant net return migration of these scientists and engineers after 10 or 20 years of work experience in the United States. This does not mean that there is not significant return migration: such migration is known to occur. However, the fairly constant stay rates indicate that any tendency of the 1970-72 cohorts to leave the United States after gaining work experience here has been largely offset by others from the same cohorts returning to the United States after going abroad.

Employment of Foreign-Born Scientists and Engineers

In total, there were 135,000 foreign-born S&E doctoral recipients working in the United States in 1993. (See text table 2 and appendix table 12.) They accounted for 25.6 percent of all U.S.-employed S&E doctorate-holders. Academia is the largest sector of employment for foreign-born S&E doctorate-holders. In industry, however, they actually make up a larger proportion of total S&E doctoral recipients: nearly one-third.

Asia was the place of birth for over half of the foreign-born S&E doctorate-holders working in the United States—76,000. Although this number is for the whole Asian continent, the two largest source countries combined—China and India—provided more S&E Ph.D. recipients to the U.S. labor force than all of Europe.

U.S. Doctoral Recipients Residing Outside the United States

In 1995, at least 19,600 U.S. native-born naturalized citizen and permanent resident Ph.D. scientists and engineers lived outside the United States (text table 3). These included:

Text table 2. Employed foreign-born science and engineering doctoral recipients in the United States

Place of birth	Total employed
All foreign-born	135,000
Percent of foreign-born of total S&E Ph.D.s employed	25.6
Africa	7,000
Asia	76,000
China	21.000
India	21.000
Japan	3.000
Korea	4.000
Taiwan	9.000
Other	18.000
Central/South America	10.000
Argentina	2.000
Brazil	1.000
Chile	1,000
Cuba	2,000
Mexico	1,000
Other	3,000
Europe	38.000
France	1.000
Germany	6.000
Greece	2.000
Italy	2.000
Netherlands	1.000
United Kingdom	10.000
Other	16.000
North America and other	8.000

NOTE: Numbers rounded to nearest 1,000.

SOURCE: National Science Foundation, Division of Science Resources Studies, 1993, Scientists and Engineers Data System (SESTAT) data file.

- 3 percent (13,900) of all native-born S&E doctorate-holders,
- 7 percent (1,400) of all foreign-born S&E doctorate-holders with U.S. citizenship at time of degree, and
- 14 percent (4,300) of all permanent resident S&E doctorate-holders at time of degree.

Not included are U.S. citizen Ph.D. scientists who held only a temporary student visa or work visa when they received their doctorate; it may be reasonable to assume that this group is as likely to work outside the United States as those who had already been naturalized by the time of degree.

The likelihood of foreign residence for U.S. natives is greatest for those with the most recent degrees—ranging from 2 percent of native-born doctorate-holders who received their Ph.D. between 1945 and 1954 to 3 percent of those who received their doctorate between 1985 and 1994. By field, the proportion of native-born Ph.D. recipients resident in foreign countries is greatest in the mathematical and computer sciences and in the social sciences (4 percent for each). It is lowest in the physical sciences.

Good estimates of the number of U.S. scientists and engineers who work abroad are not available, and the numbers presented here should be treated as lower bound estimates.[9]

[9]These estimates are based on a match of administrative data from the NSF 1995 Survey of Doctorate Recipients to individual data from the NSF Doctoral Record File created from the Survey of Earned Doctorates. The National Research Council (NRC) attempted to identify when a nonresponse was caused by the sampled individual residing outside the United States as of the April reference date. To the extent that individuals residing outside the United States are more prevalent in the sample portion never located by NRC than they are in the located sample, these numbers will underestimate the extent of emigration. Note that since a short-term trip abroad would not count as residence and since the Survey of Doctorate Recipients data are collected over several months, there is little danger of miscategorizing a short absence as working abroad. There is, however, a somewhat greater danger of listing a person as living abroad who left the United States for many years and has since returned.

Text table 3. Estimates of U.S. citizens and permanent resident Ph.D. graduates residing outside the U.S.: 1995

Field of Ph.D.	Native born		Foreign-born with citizenship at time of Ph.D.		Permanent resident at time of Ph.D.		Total citizen or permanent resident at time of Ph.D.	
	Number abroad	Percent of total abroad	Number abroad	Percent of total abroad	Number abroad	Percent of total abroad	Number abroad	Percent of total abroad
All S&E	13,900	3.3	1,400	7.4	4,300	13.6	19,600	4.1
Life sciences	3,400	2.7	200	5.0	900	12.0	4,500	3.3
Math and computer	1,000	4.2	100	4.2	200	10.2	1,200	4.6
Physical sciences	2,200	2.5	300	8.7	800	12.6	3,200	3.3
Social sciences	5,900	4.2	300	7.5	1,200	18.0	7,400	4.9
Engineering	1,500	3.0	500	9.1	1,300	13.1	3,300	5.0

NOTE: This should be considered a lower bound estimate since only those definitely identified as being outside the United States were counted.

SOURCE: National Science Foundation, Division of Science Resources Studies, Doctorate Record File and administrative records associated with collection of the 1995 Survey of Doctorate Recipients.

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APPENDIX

Appendix table 1. Graduate enrollment in science and engineering, by field and sex: 1975-97

Field	1975	1977	1979	1981	1983	1985	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	Total enrollment																
Science and engineering	303,190	311,816	319,171	332,086	347,065	358,126	373,341	375,277	382,747	397,135	412,697	430,644	435,886	431,251	422,555	415,363	407,644
Natural sciences [a]	95,489	101,221	100,871	100,617	102,979	104,074	104,963	105,529	107,301	109,364	112,474	116,699	119,489	120,833	120,325	117,677	114,697
Mathematics/computer sciences	25,307	25,160	26,721	32,318	40,691	47,332	50,559	51,304	51,729	54,031	54,562	56,648	56,189	53,707	51,941	52,607	52,769
Social sciences [b]	114,123	116,750	119,851	119,596	112,276	110,729	113,866	115,615	119,674	126,115	132,085	139,262	143,350	143,688	143,090	141,856	139,170
Engineering	68,271	68,685	71,728	79,555	91,119	95,991	103,953	102,829	104,043	107,625	113,576	118,035	116,858	113,023	107,199	130,223	101,008
	Male enrollment																
Science and engineering	NA	233,862	229,860	232,209	240,525	247,464	256,149	254,005	256,849	263,394	271,845	280,397	279,289	272,120	262,341	253,629	245,615
Natural sciences [a]	NA	76,073	72,945	70,721	70,711	70,745	70,685	69,869	70,263	70,800	71,753	73,754	74,086	73,878	72,488	69,951	67,234
Mathematics/computer sciences	NA	19,482	20,376	23,628	28,877	34,417	36,948	37,334	37,756	39,633	39,994	41,644	41,129	39,087	37,554	37,596	37,008
Social sciences [b]	NA	73,322	70,687	66,051	59,625	57,391	57,526	57,097	58,387	60,008	62,237	64,197	64,908	64,181	63,114	61,111	59,080
Engineering	NA	64,985	65,852	71,809	81,312	84,911	90,990	89,705	90,443	92,953	97,861	100,802	99,166	94,974	89,185	84,971	82,293
	Female enrollment																
Science and engineering	NA	77,954	89,311	99,877	106,540	110,662	117,192	121,272	125,898	133,741	140,852	150,247	156,597	159,131	160,214	161,734	162,029
Natural sciences [a]	NA	25,148	27,926	29,896	32,268	33,329	34,278	35,660	37,038	38,564	40,721	42,945	45,403	46,955	47,837	47,726	47,463
Mathematics/computer sciences	NA	5,678	6,345	8,690	11,814	12,915	13,611	13,970	13,973	14,398	14,568	15,004	15,060	14,620	14,387	15,011	15,761
Social sciences [b]	NA	43,428	49,164	53,545	52,651	53,338	56,340	58,518	61,287	66,107	69,848	75,065	78,442	79,507	79,976	80,745	80,090
Engineering	NA	3,700	5,876	7,746	9,807	11,080	12,963	13,124	13,600	14,672	15,715	17,233	17,692	18,049	18,014	18,252	18,715

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

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

KEY: NA= not available

NOTE: For detailed statistical tables on graduate enrollments, see Division of Science Resources Studies home page (http://www.nsf.gov/sbe/srs/stats.htm), Fall 1997 Supplementary Data Releases: Trends in Graduate Enrollment: 1975-1997.

SOURCE: National Science Foundation, Division of Science Resources Studies, *Graduate Students and Postdoctorates in Science and Engineering: Fall, 1997,* NSF 99-325 (Arlington, VA, 1999).

Appendix table 2. Graduate enrollment in science and engineering, by field, race/ethnicity, and citizenship: 1983-97

Field and race/ethnicity	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	Total enrollment														
Science and engineering	347,014	349,875	358,201	368,212	373,425	375,287	382,769	397,135	412,697	430,644	435,886	431,251	422,555	415,363	407,644
Natural sciences [a]	102,968	103,547	103,990	105,541	104,974	105,529	107,301	109,364	112,474	116,699	119,489	120,833	120,325	117,677	114,697
Mathematics/computer sciences	40,713	42,985	47,341	49,316	50,575	51,304	51,729	54,031	54,562	56,648	56,189	53,707	51,941	52,607	52,769
Social sciences [b]	112,236	110,647	110,808	111,499	113,939	115,625	119,696	126,115	132,085	139,262	143,350	143,688	143,090	141,856	139,170
Engineering	91,097	92,696	95,982	101,856	103,937	102,829	104,043	107,625	113,576	118,035	116,858	113,023	107,199	103,223	101,008
	U.S. citizen enrollment														
Total S&E	276,784	277,682	281,388	284,231	284,631	281,672	284,686	294,318	304,063	321,182	330,169	329,095	324,017	317,209	308,835
Natural sciences [a]	84,700	84,712	83,663	82,854	80,562	79,431	79,242	79,521	81,148	84,893	88,164	89,890	90,648	89,276	87,376
Mathematics/computer sciences	30,306	31,532	34,499	35,448	35,669	35,895	35,352	36,561	36,306	38,041	38,135	36,580	35,338	34,991	34,413
Social sciences [b]	98,173	96,644	95,978	96,018	97,831	98,743	102,746	108,810	114,376	121,653	126,279	126,586	126,299	124,748	122,460
Engineering	63,605	64,794	67,160	69,911	70,569	67,603	67,346	69,426	72,233	76,595	77,591	76,039	71,732	68,194	64,586
White, S&E	224,705	224,705	224,705	224,705	224,705	229,037	229,694	238,472	243,602	253,435	256,859	255,719	245,889	238,077	227,936
Natural sciences [a]	74,337	74,046	71,971	71,713	69,100	68,737	68,110	68,736	69,472	71,328	72,552	74,134	73,296	71,777	69,021
Mathematics/computer sciences	23,823	24,040	25,511	26,053	26,806	27,479	26,560	27,897	26,921	27,744	27,332	26,205	24,398	23,644	22,432
Social sciences [b]	77,963	75,787	76,129	76,930	79,157	80,492	83,531	88,632	92,425	96,967	99,535	99,360	96,239	93,544	90,466
Engineering	48,582	48,582	48,582	48,582	48,582	52,329	51,493	53,207	54,784	57,396	57,440	56,020	51,956	49,112	46,017
Asian/Pacific Islander, S&E	9,353	10,172	12,000	12,775	14,572	15,188	15,693	17,155	18,136	21,752	24,059	26,474	25,901	25,947	26,078
Natural sciences [a]	2,378	2,526	2,712	2,761	3,043	3,478	3,604	3,928	4,267	5,035	6,162	6,606	6,778	6,899	6,835
Mathematics/computer sciences	1,666	1,816	2,491	2,770	3,235	3,438	3,430	3,710	3,724	4,362	4,586	5,264	5,174	5,494	5,754
Social sciences [b]	1,903	2,018	1,992	2,130	2,436	2,362	2,648	2,830	3,029	3,863	4,324	4,827	4,941	5,117	5,335
Engineering	3,406	3,812	4,805	5,114	5,858	5,910	6,011	6,687	7,116	8,492	8,987	9,777	9,008	8,437	8,154
Black, S&E	10,903	10,711	10,462	10,470	10,429	11,191	11,775	12,774	13,691	15,445	17,118	17,611	18,283	19,071	19,363
Natural sciences [a]	1,980	2,000	1,982	1,845	1,817	1,972	2,093	2,184	2,302	2,711	3,042	3,007	3,289	3,487	3,558
Mathematics/computer sciences	971	960	1,031	1,151	1,210	1,261	1,311	1,496	1,617	1,687	1,878	1,855	1,844	1,989	1,960
Social sciences [b]	6,574	6,306	6,062	6,022	5,986	6,458	6,755	7,308	7,747	8,673	9,639	9,965	10,294	10,700	10,971
Engineering	1,378	1,445	1,387	1,452	1,416	1,500	1,616	1,786	2,025	2,374	2,559	2,784	2,856	2,895	2,874

See explanatory information and SOURCE at end of table.

Appendix table 2. Graduate enrollment in science and engineering, by field, race/ethnicity, and citizenship: 1983-97 (Continued)

Field and race/ethnicity	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	U.S. citizen enrollment														
Hispanic, S&E	8,811	8,681	8,613	8,660	8,823	9,098	9,436	10,159	11,045	12,246	13,381	13,281	14,117	14,638	14,988
Natural sciences [a]	1,919	1,892	2,092	2,118	2,071	2,228	2,386	2,375	2,552	2,726	3,075	2,933	3,209	3,338	3,574
Mathematics/computer sciences	615	585	750	723	817	844	847	916	980	1,082	1,111	1,002	1,064	1,126	1,152
Social sciences [b]	4,836	4,713	4,290	4,217	4,205	4,307	4,496	4,982	5,389	5,975	6,501	6,485	7,036	7,239	7,451
Engineering	1,441	1,491	1,481	1,602	1,730	1,719	1,707	1,886	2,124	2,463	2,694	2,861	2,808	2,935	2,811
American Indian/Alaskan Native, S&E	911	830	736	743	783	918	860	1,054	1,120	1,243	1,309	1,383	1,516	1,539	1,599
Natural sciences [a]	224	206	167	196	183	216	180	255	251	282	318	336	393	374	412
Mathematics/computer sciences	53	71	79	52	76	71	74	64	62	99	100	79	125	94	103
Social sciences [b]	454	361	368	365	401	488	484	583	622	685	680	726	767	837	846
Engineering	180	192	122	130	123	143	122	152	185	177	211	242	231	234	238
Unknown, S&E	22,101	24,179	25,825	23,961	21,160	16,240	17,228	14,704	16,469	17,061	17,443	14,627	18,311	17,937	18,871
Natural sciences [a]	3,862	4,042	4,819	4,221	4,348	2,800	2,869	2,043	2,304	2,811	3,015	2,874	3,683	3,401	3,976
Mathematics/computer sciences	3,178	4,060	4,637	4,699	3,525	2,802	3,130	2,478	3,002	3,067	3,128	2,175	2,733	2,644	3,012
Social sciences [b]	6,443	7,459	7,145	6,354	5,646	4,636	4,832	4,475	5,164	5,490	5,600	5,223	7,022	7,311	7,391
Engineering	8,618	8,618	9,224	8,687	7,641	6,002	6,397	5,708	5,999	5,693	5,700	4,355	4,873	4,581	4,492
	Foreign citizen enrollment														
Total S&E	70,230	72,193	76,813	83,981	88,794	93,615	98,083	102,817	108,634	109,462	105,717	102,156	98,538	98,154	98,809
Natural sciences [a]	18,268	18,835	20,327	22,687	24,412	26,098	28,059	29,843	31,326	31,806	31,325	30,943	29,677	28,401	27,321
Mathematics/computer sciences	10,407	11,453	12,842	13,868	14,906	15,409	16,377	17,470	18,256	18,607	18,054	17,127	16,603	17,616	18,356
Social sciences [b]	14,063	14,003	14,830	15,481	16,108	16,882	16,950	17,305	17,709	17,609	17,071	17,102	16,791	17,108	16,710
Engineering	27,492	27,902	28,822	31,945	33,368	35,226	36,697	38,199	41,343	41,440	39,267	36,984	35,467	35,029	36,422

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

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

KEY: NA= not available

NOTE: For detailed statistical tables on graduate enrollments, see Division of Science Resources Studies home page (http://www.nsf.gov/sbe/srs/stats.htm), Fall 1997 Supplementary Data Releases: Trends in Graduate Enrollment, 1975-1997.

SOURCE: National Science Foundation, Division of Science Resources Studies, *Graduate Students and Postdoctorates in Science and Engineering: Fall, 1997,* NSF 99-325 (Arlington, VA, 1999).

Appendix table 3. Earned master's degrees, by field and sex: 1975–96

Field	1975	1977	1979	1981	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
All master's degree recipients																		
All degrees	293,651	318,241	302,075	296,798	290,931	285,462	287,213	289,829	290,532	300,091	311,050	324,947	338,498	354,207	370,973	389,008	399,428	408,932
Science and engineering	63,198	67,397	64,226	64,366	67,716	68,564	70,562	71,831	72,603	73,655	76,425	77,788	78,368	81,107	86,425	91,411	94,309	95,313
Natural sciences	14,831	15,360	15,443	14,349	14,380	14,231	13,972	13,910	13,400	13,184	13,218	12,928	12,682	13,232	13,474	14,367	14,793	16,158
Physical	4,298	3,641	3,650	3,366	3,285	3,544	3,605	3,649	3,574	3,708	3,876	3,805	3,777	3,922	3,965	4,263	4,241	4,364
Earth/atm/ocean	1,503	1,659	1,777	1,876	1,959	1,982	2,160	2,234	2,051	1,920	1,819	1,596	1,499	1,425	1,397	1,418	1,483	1,487
Biological/agricultural	9,030	10,060	10,016	9,107	9,136	8,705	8,207	8,027	7,775	7,556	7,523	7,527	7,406	7,885	8,112	8,686	9,069	10,307
Mathematics/computer sciences	6,637	6,496	6,101	6,787	8,160	8,939	9,989	11,241	11,808	12,600	12,829	13,327	12,956	13,320	14,100	14,350	14,495	14,355
Mathematics	4,338	3,698	3,046	2,569	2,839	2,749	2,888	3,171	3,327	3,434	3,430	3,684	3,632	3,665	3,751	3,804	3,932	3,742
Computer sciences	2,299	2,798	3,055	4,218	5,321	6,190	7,101	8,070	8,481	9,166	9,399	9,643	9,324	9,655	10,349	10,546	10,563	10,613
Social/behavioral sciences	26,563	29,529	27,403	26,779	26,290	25,249	25,629	25,584	25,325	25,145	26,635	27,538	28,717	29,537	31,187	33,977	36,391	37,039
Psychology	7,104	8,320	8,031	8,039	8,439	8,073	8,481	8,363	8,165	7,925	8,652	9,308	9,802	9,852	10,412	11,572	13,132	13,043
Social sciences	19,459	21,209	19,372	18,740	17,851	17,176	17,148	17,221	17,160	17,220	17,983	18,230	18,915	19,685	20,775	22,405	23,259	23,996
Engineering	15,167	16,012	15,279	16,451	18,886	20,145	20,972	21,096	22,070	22,726	23,743	23,995	24,013	25,018	27,664	28,717	28,630	27,761
Chemical engineering	1,078	1,179	1,276	1,406	1,545	1,798	1,814	1,641	1,386	1,322	1,321	1,205	1,025	1,145	1,220	1,287	1,369	1,416
Civil engineering	3,268	3,606	3,165	3,428	3,504	3,551	3,542	3,281	3,267	3,134	3,296	3,213	3,404	3,755	4,438	4,918	5,168	5,002
Electrical engineering	3,471	3,788	3,596	3,902	4,819	5,519	5,649	6,147	6,895	7,455	7,849	8,009	7,942	8,274	8,828	8,870	8,743	8,156
Industrial engineering	1,687	1,609	1,502	1,631	1,432	1,557	1,463	1,653	1,728	1,816	1,823	1,834	2,039	2,370	2,745	2,882	2,873	3,027
Mechanical engineering	2,032	2,094	2,012	2,419	2,683	2,964	3,272	3,256	3,380	3,513	3,703	1,834	3,680	3,826	4,169	4,277	4,368	4,009
Other engineering	3,631	3,736	3,728	3,665	4,903	4,756	5,232	5,118	5,414	5,486	5,751	6,104	5,923	5,648	6,264	6,483	6,109	6,151
Engineering technology	371	505	496	532	622	694	816	925	883	980	1,135	1,194	1,188	1,278	1,555	1,547	1,577	NA
Males																		
All degrees	162,115	168,210	153,772	147,431	145,114	143,998	143,716	143,932	141,655	145,403	149,399	154,025	156,895	162,299	169,753	176,762	179,198	180,360
Science and engineering	49,410	50,899	46,614	45,505	46,718	47,033	48,232	48,611	48,759	49,820	50,845	51,230	50,441	52,157	55,454	57,970	58,518	57,860
Natural sciences	11,709	11,633	11,223	10,222	9,814	9,513	9,290	9,133	8,652	8,562	8,383	8,052	7,794	8,118	8,181	8,539	8,730	9,224
Physical	3,645	2,981	2,971	2,691	2,600	2,698	2,775	2,736	2,684	2,817	2,836	2,754	2,703	2,834	2,794	3,030	2,958	2,914
Earth/atm/ocean	1,309	1,433	1,467	1,470	1,515	1,517	1,639	1,717	1,531	1,433	1,337	1,218	1,116	1,057	1,006	994	1,032	1,051
Biological/agricultural	6,755	7,219	6,785	6,061	5,699	5,298	4,876	4,680	4,437	4,312	4,210	4,080	3,975	4,227	4,381	4,515	4,740	5,259
Mathematics/computer sciences	4,871	4,730	4,469	4,939	5,672	6,174	6,941	7,713	8,011	8,759	8,833	9,176	8,709	9,199	9,773	10,128	10,130	9,999
Mathematics	2,910	2,398	1,989	1,692	1,859	1,795	1,877	2,055	2,026	2,057	2,060	2,208	2,146	2,219	2,219	2,311	2,353	2,236
Computer sciences	1,961	2,332	2,480	3,247	3,813	4,379	5,064	5,658	5,985	6,702	6,773	6,968	6,563	6,980	7,554	7,817	7,777	7,763
Social/behavioral sciences	18,035	19,222	16,580	15,222	14,101	13,301	13,273	13,069	12,796	12,581	12,968	13,276	13,282	13,491	13,930	15,009	15,660	15,628
Psychology	4,059	4,316	3,688	3,371	3,254	2,980	3,064	2,937	2,838	2,599	2,814	3,025	2,994	2,929	2,928	3,287	3,735	3,670
Social sciences	13,976	14,906	12,892	11,851	10,847	10,321	10,209	10,132	9,958	9,982	10,154	10,251	10,288	10,562	11,002	11,722	11,925	11,958

See explanatory information and SOURCE at end of table.

Appendix table 3. Earned master's degrees, by field and sex: 1975–96 (Continued)

Field	1975	1977	1979	1981	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Males																		
Engineering	14,795	15,314	14,342	15,122	17,131	18,045	18,728	18,696	19,300	19,918	20,661	20,726	20,656	21,349	23,570	24,294	23,998	23,009
Chemical engineering	1,051	1,110	1,156	1,230	1,369	1,590	1,529	1,401	1,143	1,107	1,092	1,013	852	914	996	1008	1063	1110
Civil engineering	3,161	3,421	2,951	3,112	3,122	3,136	3,128	2,908	2,792	2,721	2,851	2,693	2,864	3,120	3,607	3,965	4,123	3,938
Electrical engineering	3,413	3,654	3,453	3,681	4,484	5,081	5,154	5,508	6,178	6,642	6,933	7,018	7,008	7,229	7,777	7,721	7,539	6,960
Industrial engineering	1,631	1,534	1,374	1,465	1,226	1,279	1,236	1,374	1,409	1,492	1,465	1,493	1,603	1,898	2,190	2,346	2,361	2,403
Mechanical engineering	2,012	2,039	1,939	2,292	2,517	2,765	3,044	3,002	3,133	3,218	3,377	3,276	3,320	3,455	3,769	3,860	3,918	3,555
Other engineering	3,527	3,556	3,469	3,342	4,413	4,194	4,637	4,503	4,645	4,738	4,943	5,233	5,009	4,733	5,231	5,394	4,994	5,043
Engineering technology	281	389	371	380	519	580	674	710	678	738	892	888	888	971	1,172	1,164	1,136	NA
Females																		
All degrees	131,536	150,031	148,303	149,367	145,817	141,464	143,497	145,897	148,877	154,688	161,651	170,922	181,603	191,908	201,220	212,246	220,230	228,572
Science and engineering	13,788	16,498	17,612	18,861	20,998	21,531	22,330	23,220	23,844	23,835	25,580	26,558	27,927	28,950	30,971	33,441	35,791	37,453
Natural sciences	3,122	3,727	4,220	4,127	4,566	4,718	4,682	4,777	4,748	4,622	4,835	4,876	4,888	5,114	5,293	5,828	6,063	6,934
Physical	653	660	679	675	685	846	830	913	890	891	1,040	1,051	1,074	1,088	1,171	1,233	1,283	1,450
Earth/atm/ocean	194	226	310	406	444	465	521	517	520	487	482	378	383	368	391	424	451	436
Biological/agricultural	2,275	2,841	3,231	3,046	3,437	3,407	3,331	3,347	3,338	3,244	3,313	3,447	3,431	3,658	3,731	4,171	4,329	5,048
Mathematics/computer sciences	1,766	1,766	1,632	1,848	2,488	2,765	3,048	3,528	3,797	3,841	3,996	4,151	4,247	4,121	4,327	4,222	4,365	4,356
Mathematics	1,428	1,300	1,057	877	980	954	1,011	1,116	1,301	1,377	1,370	1,476	1,486	1,446	1,532	1,493	1,579	1,506
Computer sciences	338	466	575	971	1,508	1,811	2,037	2,412	2,496	2,464	2,626	2,675	2,761	2,675	2,795	2,729	2,786	2,850
Social/behavioral sciences	8,528	10,307	10,823	11,557	12,189	11,948	12,356	12,515	12,529	12,564	13,667	14,262	15,435	16,046	17,257	18,968	20,731	21,411
Psychology	3,045	4,004	4,343	4,668	5,185	5,093	5,417	5,426	5,327	5,326	5,838	6,283	6,808	6,923	7,484	8,285	9,397	9,373
Social sciences	5,483	6,303	6,480	6,889	7,004	6,855	6,939	7,089	7,202	7,238	7,829	7,979	8,627	9,123	9,773	10,683	11,334	12,038
Engineering	372	698	937	1,329	1,755	2,100	2,244	2,400	2,770	2,808	3,082	3,269	3,357	3,669	4,094	4,423	4,632	4,752
Chemical engineering	27	69	120	176	176	208	285	240	243	215	229	192	173	231	224	279	306	306
Civil engineering	107	185	214	316	382	415	414	373	475	413	445	520	540	635	831	953	1045	1,064
Electrical engineering	58	134	143	221	335	438	495	639	717	813	916	991	934	1,045	1,051	1,149	1,204	1,196
Industrial engineering	56	75	128	166	206	278	227	279	319	324	358	341	436	472	555	536	512	624
Mechanical engineering	20	55	73	127	166	199	228	254	247	295	326	354	360	371	400	417	450	454
Other engineering	104	180	259	323	490	562	595	615	769	748	808	871	914	915	1,033	1,089	1,115	1,108
Engineering technology	90	116	125	152	103	114	142	215	205	242	243	306	300	307	383	383	441	NA

KEY: NA = not available

SOURCES: National Center for Education Statistics, Earned Degrees and Completion Surveys (Washington, DC: 1996), unpublished tabulations; and National Science Foundation, Division of Science Resources Studies, *Science Engineering Degrees 1966-96,* NSF 99-330 (Arlington, VA).

Appendix table 4. Earned master's degrees, by field, race/ethnicity, and citizenship: 1977–96

Field and race/ethnicity	1977	1979	1981	1985	1987	1989	1990	1991	1992	1993	1994	1995	1996
	All master's degree recipients												
All degrees	318,241	302,075	296,798	287,213	290,532	311,050	324,947	338,498	354,207	370,973	389,008	399,428	408,932
Science and engineering	63,779	59,684	59,598	64,726	66,774	70,333	72,228	72,828	76,184	81,415	86,080	88,431	88,730
Natural sciences [a]	16,234	16,350	15,332	14,045	13,461	13,260	12,966	12,713	13,226	13,462	14,340	14,770	16,093
Mathematics/computer sciences	6,496	6,101	6,787	9,989	11,808	12,829	13,327	12,956	13,549	14,251	14,529	14,522	14,260
Social sciences [b]	24,798	21,723	20,763	19,757	19,448	20,509	21,950	23,152	24,399	26,044	28,504	30,522	30,620
Engineering	16,251	15,510	16,716	20,935	22,057	23,735	23,985	24,007	25,010	27,658	28,707	28,617	27,757
Engineering technology	NA	NA	NA	816	883	1,135	1,188	1,555	1,547	1,577	1,547	1,577	1,651
	U.S. citizens and permanent residents												
All degrees	300,334	281,811	273,184	254,401	246,939	278,927	290,345	300,887	314,555	326,864	342,502	350,672	360,682
Science and engineering	55,963	50,846	49,340	50,751	50,330	55,190	55,890	55,779	58,177	61,265	65,201	67,110	68,151
Natural sciences [a]	14,437	14,410	13,411	11,676	10,721	10,756	10,234	9,857	10,191	10,317	10,929	11,471	12,720
Mathematics/computer sciences	5,760	5,099	5,342	7,385	8,179	9,411	9,729	9,078	9,268	9,334	9,522	9,486	9,308
Social sciences [b]	23,071	19,920	18,785	17,230	15,990	18,035	19,181	20,357	21,607	23,075	25,400	27,232	27,361
Engineering	12,695	11,417	11,802	14,460	15,440	16,988	16,746	16,487	17,111	18,539	19,350	18,921	18,762
Engineering technology	NA	NA	NA	596	712	909	959	1,175	1,256	1,268	10,026	10,191	10,593
White, all degrees	266,109	249,401	241,255	223,649	216,807	230,322	236,874	247,524	257,062	265,668	273,913	277,437	282,713
Science and engineering	50,420	45,748	43,967	43,982	43,360	43,945	44,450	44,513	45,649	47,975	50,711	51,417	51,791
Natural sciences [a]	13,405	13,282	12,411	10,559	9,623	9,262	8,722	8,300	8,393	8,504	8,859	9,242	10,332
Mathematics/computer sciences	5,256	4,625	4,708	6,176	6,729	6,818	7,020	6,705	6,743	6,818	6,665	6,547	6,340
Social sciences [b]	20,315	17,759	16,701	15,061	14,171	15,033	15,849	16,873	17,761	18,733	20,718	21,807	21,546
Engineering	11,444	10,082	10,147	12,186	12,837	12,832	12,859	12,635	12,752	13,920	14,469	13,821	13,573
Engineering technology	NA	NA	NA	526	581	802	830	1,041	994	982	994	982	1,053
Asian/Pacific Islander, all degrees	5,145	5,519	6,304	7,805	8,129	10,174	9,994	11,070	12,293	13,169	14,559	15,906	17,281
Science and engineering	1,749	1,929	2,170	3,285	3,455	4,100	4,055	4,310	4,763	4,846	5,422	5,683	5,942
Natural sciences [a]	388	469	365	450	464	545	504	532	610	615	698	802	933
Mathematics/computer sciences	198	253	376	779	962	1,072	1,125	1,203	1,306	1,303	1,461	1,478	1,472
Social sciences [b]	426	357	350	505	379	491	563	567	624	668	820	831	916
Engineering	737	850	1,079	1,551	1,650	1,992	1,863	2,008	2,223	2,260	2,443	2,572	2,621
Engineering technology	NA	NA	NA	25	46	40	60	40	46	55	46	55	61
Black, all degrees	21,041	19,422	17,152	13,960	13,173	13,455	14,473	15,857	17,420	18,897	20,936	22,954	24,588
Science and engineering	2,321	2,003	1,801	1,742	1,784	1,652	1,847	2,090	2,356	2,554	2,849	3,339	3,518
Natural sciences [a]	351	382	351	290	301	238	225	261	306	310	347	383	402
Mathematics/computer sciences	200	136	137	233	280	257	302	383	393	406	474	498	530
Social sciences [b]	1,530	1,239	1,053	889	800	802	933	1,048	1,191	1,274	1,439	1,793	1,912
Engineering	240	246	260	330	403	355	387	398	466	564	589	665	674
Engineering technology	NA	NA	NA	37	42	55	47	61	72	85	72	85	81

See explanatory information and SOURCE at end of table.

Appendix table 4. Earned master's degrees, by field, race/ethnicity, and citizenship: 1977–96 (Continued)

Field and race/ethnicity	1977	1979	1981	1985	1987	1989	1990	1991	1992	1993	1994	1995	1996
Hispanic, all degrees	7,071	6,470	7,439	7,730	7,781	8,133	8,495	9,684	10,256	11,371	13,177	13,905	15,394
Science and engineering	1,325	1,001	1,237	1,514	1,584	1,585	1,587	1,736	1,806	2,092	2,514	2,585	2,730
Natural sciences [a]	245	227	251	332	310	266	262	281	288	334	436	392	413
Mathematics/computer sciences	91	61	102	149	183	178	169	213	215	240	244	273	264
Social sciences [b]	738	498	599	687	579	673	710	774	815	937	1,115	1,209	1,305
Engineering	251	215	285	346	512	468	446	468	488	581	719	711	748
Engineering technology	NA	NA	NA	6	17	10	19	25	37	40	37	40	47
American Indian/Alaskan Native, all degrees	968	999	1,034	1,257	1,049	1,082	1,050	1,125	1,228	1,344	1,618	1,542	1,693
Science and engineering	148	165	165	228	147	209	181	200	198	253	273	299	304
Natural sciences [a]	48	50	33	45	23	41	31	34	37	46	44	52	41
Mathematics/computer sciences	15	24	19	48	25	45	13	23	19	22	24	27	30
Social sciences [b]	62	67	82	88	61	90	102	103	100	135	145	177	177
Engineering	23	24	31	47	38	33	35	40	42	50	60	43	56
Engineering technology	NA	NA	NA	2	26	2	3	8	3	6	3	6	7
	Foreign citizens												
All degrees	17,345	19,427	22,058	26,952	28,264	32,123	34,602	37,611	39,652	44,109	46,506	48,756	48,250
Science and engineering	7,805	8,544	9,749	12,506	13,045	15,143	16,338	17,049	18,007	20,150	20,879	21,321	20,579
Natural sciences [a]	1,797	1,895	1,864	2,178	2,132	2,504	2,732	2,856	3,035	3,145	3411	3299	3373
Mathematics/computer sciences	736	937	1,368	2,394	2,903	3,418	3,598	3,878	4,281	4,917	5007	5036	4952
Social sciences [b]	1,727	1,752	1,954	2,240	2,229	2,474	2,769	2,795	2,792	2,969	3,104	3,290	3,259
Engineering	3,545	3,960	4,563	5,694	5,781	6,747	7,239	7,520	7,899	9,119	9,357	9,696	8,995
Engineering technology	NA	NA	NA	124	127	131	172	279	291	309	291	309	298

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

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

KEY: NA = not available

NOTES: Data by racial/ethnic group were collected on a biennial schedule until 1990 and annually thereafter. Data by racial/ethnic group are collected by broad fields of study only; therefore, these data cannot be adjusted to the exact field taxonomies used by the National Science Foundation.

SOURCE: National Science Foundation, Division of Science Resources Studies, *Science and Engineering Degrees, by Race, Ethnicity of Recipients: 1989-96,* Early Release Tables, Website, and previous editions.

Appendix table 5. Earned doctoral degrees, by field and sex: 1975–97

Field	1975	1977	1979	1981	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	All doctoral degree recipients																		
All degrees	32,952	31,716	31,239	31,356	31,281	31,337	31,297	31,902	32,370	33,501	34,326	36,067	37,522	38,856	39,771	41,017	41,610	42,415	42,705
Science and engineering	18,799	18,008	17,872	18,257	18,635	18,748	18,935	19,437	19,894	20,933	21,731	22,867	24,019	24,673	25,441	26,202	26,515	27,230	26,847
Natural sciences	8,103	7,676	7,817	7,995	8,194	8,336	8,436	8,483	8,655	9,172	9,185	9,763	10,159	10,435	10,529	11079	11024	11,392	11,256
Physical	3,076	2,721	2,674	2,627	2,814	2,851	2,934	3,120	3,238	3,350	3,261	3,524	3,625	3,780	3,699	3,977	3,840	3,838	3,711
Earth, atmospheric, and oceanographic	625	689	642	583	624	608	599	559	602	695	723	738	815	794	771	824	778	794	862
Biological/agricultural	4,402	4,266	4,501	4,785	4,756	4,877	4,903	4,804	4,815	5,127	5,201	5,501	5,719	5,861	6,059	6,278	6,406	6,760	6,683
Mathematics/computer sciences	1147	964	979	960	987	993	998	1,128	1,190	1,264	1,471	1,597	1,839	1,927	2,026	2021	2188	2,043	2,001
Mathematics	1,147	933	769	728	701	698	688	729	740	749	859	892	1,039	1,058	1,146	1,118	1,190	1,122	1,112
Computer sciences	0	31	210	232	286	295	310	399	450	515	612	705	800	869	880	903	998	921	889
Social/behavioral sciences	6,538	6,720	6,582	6,774	6,673	6,506	6,335	6,450	6,337	6,310	6,532	6,613	6,806	6,873	7,188	7280	7296	7,490	7,538
Psychology	2,751	2,990	3,091	3,358	3,347	3,257	3,118	3,126	3,173	3,074	3,208	3,281	3,250	3,263	3,419	3,380	3,419	3,491	3,489
Social sciences	3,787	3,730	3,491	3,416	3,326	3,249	3,217	3,324	3,164	3,236	3,324	3,332	3,556	3,610	3,769	3,900	3,877	3,999	4,049
Engineering	3,011	2,648	2,494	2,528	2,781	2,913	3,166	3,376	3,712	4,187	4,543	4,894	5,215	5,438	5,698	5,822	6,007	6,305	6,052
Chemical engineering	396	329	315	317	392	409	504	531	584	685	712	658	691	725	737	725	708	798	764
Civil engineering	361	336	302	358	397	408	391	429	477	531	538	553	575	594	624	684	656	697	653
Electrical engineering	714	667	611	549	625	660	716	806	779	1,010	1,137	1,276	1,405	1,483	1,543	1,673	1,731	1,740	1,695
Mechanical engineering	487	372	366	360	379	427	513	536	657	715	760	884	875	987	1,030	1,015	1,024	1,052	1,010
Materials engineering	272	248	236	234	268	271	303	305	392	374	380	440	489	485	535	539	588	572	573
Other engineering	781	696	664	710	720	738	739	769	823	872	1,016	1,083	1,180	1,164	1,229	1186	1300	1,446	1,357
	Males																		
All degrees	25,751	23,858	22,302	21,464	20,748	20,638	20,553	20,595	20,938	21,682	21,813	22,962	23,652	24,436	24,658	25,211	25,277	25,470	25,383
Science and engineering	15,870	14,775	14,128	14,056	13,920	13,956	14,044	14,270	14,582	15,271	15,622	16,498	17,088	17,593	17,789	18,283	18,242	18,584	18,051
Natural sciences	6,960	6,530	6,436	6,409	6,360	6,483	6,452	6,426	6,484	6,779	6,649	7,101	7,320	7,413	7,311	7713	7534	7,681	7,501
Physical	2,812	2,477	2,382	2,318	2,441	2,452	2,467	2,610	2,710	2,783	2,642	2,863	2,946	3,010	2,919	3,149	2,962	2,996	2,878
Earth, atmospheric, and oceanographic	595	630	584	527	529	502	491	464	490	560	575	597	636	606	611	641	608	622	658
Biological/agricultural	3,553	3,423	3,470	3,564	3,390	3,529	3,494	3,352	3,284	3,436	3,432	3,641	3,738	3,797	3,781	3,923	3,964	4,063	3,965
Mathematics/computer sciences	1,038	837	833	822	838	841	859	959	1,000	1,087	1,208	1,329	1,523	1,602	1,624	1648	1737	1,673	1,597
Mathematics	1,038	811	650	616	588	583	582	608	615	628	704	734	840	853	882	882	925	891	852
Computer sciences	0	26	183	206	250	258	277	351	385	459	504	595	683	749	742	766	812	782	745

See SOURCE at end of table.

Appendix table 5. Earned doctoral degrees, by field and sex: 1975–97 (Continued)

Field	1975	1977	1979	1981	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
	Males																		
Social/behavioral sciences	4,913	4,834	4,427	4,396	4,065	3,870	3,765	3,734	3,628	3,504	3,597	3,589	3,497	3,646	3,678	3735	3658	3,701	3,648
Psychology	1,878	1,902	1,831	1,885	1,750	1,626	1,577	1,527	1,475	1,393	1,408	1,368	1,254	1,335	1,331	1,278	1,247	1,163	1,165
Social sciences	3,035	2,932	2,596	2,511	2,315	2,244	2,188	2,207	2,153	2,111	2,189	2,221	2,243	2,311	2,347	2,457	2,411	2,538	2,483
Engineering	2,959	2,574	2,432	2,429	2,657	2,762	2,968	3,151	3,470	3,901	4,168	4,479	4,748	4,932	5,176	5,187	5,313	5,529	5,305
Chemical engineering	391	319	306	306	369	382	463	470	524	620	632	580	608	612	643	612	599	655	641
Civil engineering	356	328	298	348	384	383	371	408	459	501	484	504	534	544	570	604	580	618	573
Electrical engineering	698	646	600	527	612	645	681	768	747	962	1,070	1,192	1,326	1,368	1,418	1,526	1,558	1,571	1,545
Mechanical engineering	483	366	361	354	371	412	487	518	640	686	731	846	818	942	973	946	961	974	923
Materials engineering	267	238	228	217	238	245	271	281	347	341	335	391	412	424	457	456	494	489	467
Other engineering	764	677	639	677	683	695	695	706	753	791	916	966	1,050	1,042	1,115	1043	1121	1,222	1,156
	Females																		
All degrees	7,201	7,858	8,937	9,892	10,533	10,699	10,744	11,307	11,432	11,819	12,513	13,105	13,870	14,420	15,113	15,806	16,333	16,945	17,322
Science and engineering	2,929	3,233	3,744	4,201	4,715	4,792	4,891	5,167	5,312	5,662	6,109	6,369	6,931	7,080	7,652	7,919	8,273	8,646	8,769
Natural sciences	1,143	1,146	1,381	1,586	1,834	1,853	1,984	2,057	2,171	2,393	2,536	2,662	2,839	3,022	3,218	3,366	3,490	3,711	3,755
Physical	264	244	292	309	373	399	467	510	528	567	619	661	679	770	780	828	878	842	833
Earth, atmospheric, and oceanographic	30	59	58	56	95	106	108	95	112	135	148	141	179	188	160	183	170	172	204
Biological/agricultural	849	843	1,031	1,221	1,366	1,348	1,409	1,452	1,531	1,691	1,769	1,860	1,981	2,064	2,278	2355	2442	2,697	2,718
Mathematics/computer sciences	109	127	146	138	149	152	139	169	190	177	263	268	316	325	402	373	451	370	404
Mathematics	109	122	119	112	113	115	106	121	125	121	155	158	199	205	264	236	265	231	260
Computer sciences	0	5	27	26	36	37	33	48	65	56	108	110	117	120	138	137	186	139	144
Social/behavioral sciences	1625	1886	2155	2378	2608	2636	2570	2716	2709	2806	2935	3024	3309	3227	3510	3545	3638	3,789	3,890
Psychology	873	1,088	1,260	1,473	1,597	1,631	1,541	1,599	1,698	1,681	1,800	1,913	1,996	1,928	2,088	2,102	2,172	2,328	2,324
Social sciences	752	798	895	905	1,011	1,005	1,029	1,117	1,011	1,125	1,135	1,111	1,313	1,299	1,422	1,443	1,466	1,461	1,566
Engineering	52	74	62	99	124	151	198	225	242	286	375	415	467	506	522	635	694	776	747
Chemical engineering	5	10	9	11	23	27	41	61	60	65	80	78	83	113	94	113	109	143	123
Civil engineering	5	8	4	10	13	25	20	21	18	30	54	49	41	50	54	80	76	79	80
Electrical engineering	16	21	11	22	13	15	35	38	32	48	67	84	79	115	125	147	173	169	150
Mechanical engineering	4	6	5	6	8	15	26	18	17	29	29	38	57	45	57	69	63	78	87
Materials engineering	5	10	8	17	30	26	32	24	45	33	45	49	77	61	78	83	94	83	106
Other engineering	17	19	25	33	37	43	44	63	70	81	100	117	130	122	114	143	179	224	201

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

Appendix table 6. Earned doctoral degrees by field, race/ethnicity, and citizenship: 1977–97

Field and race/ethnicity	1977	1979	1981	1983	1985	1987	1989	1991	1992	1993	1994	1995	1996	1997
	All doctoral degree recipients[a]													
All degrees	31,716	31,239	31,356	31,281	31,297	32,370	34,326	37,534	38,890	39,801	41,034	41,743	42,415	42,705
Science and engineering	18,008	17,872	18,257	18,635	18,935	19,894	21,731	24,023	24,675	25,443	26,205	26,535	27,230	26,847
Natural sciences [b]	7,676	7,817	7,995	8,194	8,436	8,655	9,185	10,164	10,437	10,530	11,082	11,033	11,392	11,256
Mathematics/computer sciences	964	979	960	987	998	1,190	1,471	1,839	1,927	2,026	2,021	2,187	2,043	2,001
Social sciences [c]	6,720	6,582	6,774	6,673	6,335	6,337	6,532	6,806	6,873	7,189	7,280	7,307	7,490	7,538
Engineering	2,648	2,494	2,528	2,781	3,166	3,712	4,543	5,214	5,438	5,698	5,822	6,008	6,305	6,052
	U.S. citizens and permanent residents													
All degrees	27,487	26,784	26,341	25,634	24,694	24,562	25,026	27,430	27,990	28,708	30,894	32,059	31,506	30,601
Science and engineering	14,881	14,711	14,654	14,518	14,065	14,055	14,591	15,914	15,942	16,573	18,187	18,996	18,628	18,005
Natural sciences [b]	6,427	6,604	6,640	6,706	6,634	6,450	6,628	7,063	7,039	7,092	8,106	8,362	8,067	7,809
Mathematics/computer sciences	769	778	713	664	631	671	824	969	996	1,099	1,200	1,387	1,159	1,122
Social sciences [c]	5,886	5,712	5,830	5,666	5,206	5,021	4,910	5,408	5,387	5,685	5,828	5,905	6,019	5,793
Engineering	1,799	1,617	1,471	1,482	1,594	1,913	2,229	2,474	2,520	2,697	3,053	3,342	3,383	3,281
White, all degrees	23,654	22,396	22,470	22,251	21,306	21,122	21,570	23,185	23,625	24,052	24,594	24,719	24,685	23,789
Science and engineering	12,875	12,314	12,573	12,671	12,169	12,052	12,501	13,323	13,326	13,737	13,889	13,902	13,999	13,623
Natural sciences [b]	5,598	5,620	5,771	5,981	5,903	5,663	5,800	6,111	6,019	5,950	6,123	5,978	5,952	5,866
Mathematics/computer sciences	671	658	610	569	527	548	688	774	803	886	880	988	834	827
Social sciences [c]	5,177	4,879	5,099	4,993	4,551	4,383	4,287	4,601	4,624	4,876	4,866	4,846	4,953	4,668
Engineering	1,429	1,157	1,093	1,128	1,188	1,458	1,726	1,837	1,880	2,025	2,020	2,090	2,260	2,262
Asian/Pacific Islander, all degrees	910	1,102	1,073	1,042	1,070	1,168	1,268	1,531	1,764	2,017	3,546	4,309	3,697	3,140
Science and engineering	745	884	827	780	809	925	986	1,180	1,345	1,610	2,989	3,671	3,091	2,527
Natural sciences [b]	342	377	344	359	346	369	403	474	560	686	1,481	1,858	1,550	1,255
Mathematics/computer sciences	42	55	56	54	50	67	76	123	138	156	259	345	251	205
Social sciences [c]	112	146	142	120	132	162	146	178	196	241	382	435	395	363
Engineering	249	306	285	247	281	327	361	405	451	527	867	1,033	895	704
Black, all degrees	1,191	1,112	1,110	1,005	1,043	910	962	1,166	1,116	1,280	1,279	1,477	1,457	1,476
Science and engineering	342	347	346	338	374	319	366	464	408	469	500	560	576	607
Natural sciences [b]	85	84	89	84	100	95	105	116	107	136	153	171	187	191
Mathematics/computer sciences	9	12	11	6	10	13	9	19	9	14	21	16	20	11
Social sciences [c]	233	231	227	219	230	186	219	274	243	269	272	302	295	308
Engineering	15	20	19	29	34	25	33	55	49	50	54	71	74	97

See explanatory information and SOURCE at end of table.

Appendix table 6. Earned doctoral degrees by field, race/ethnicity, and citizenship: 1977–97 (Continued)

Field and race/ethnicity	1977	1979	1981	1983	1985	1987	1989	1991	1992	1993	1994	1995	1996	1997
Hispanic, all degrees	489	547	529	608	634	708	694	867	909	973	1,030	1,061	1,105	1,181
Science and engineering	203	234	240	284	296	357	382	492	513	542	548	571	623	645
Natural sciences [b]	76	84	93	86	107	138	157	191	208	226	254	234	229	251
Mathematics/computer sciences	12	12	5	7	18	15	15	21	20	23	20	21	26	34
Social sciences [c]	91	114	126	162	149	170	163	220	214	227	208	239	270	265
Engineering	24	24	16	29	22	34	47	60	71	66	66	77	98	95
American Indian/Alaskan Native, all degrees	66	81	85	82	96	115	94	132	149	120	143	149	187	151
Science and engineering	31	29	28	30	41	53	53	56	69	43	64	69	96	71
Natural sciences [b]	14	6	8	13	21	20	25	27	26	17	24	26	34	24
Mathematics/computer sciences	1	1	1	1	0	3	2	1	4	2	3	2	5	2
Social sciences [c]	15	19	15	15	19	23	19	22	28	22	31	31	43	33
Engineering	1	3	4	1	1	7	7	6	11	2	6	10	14	12
	Temporary residents													
Total, all degrees	3,448	3,587	3,940	4,498	5,227	5,612	6,648	9,311	9,953	9,932	9,406	8,810	9,610	8,463
Science and engineering	2,675	2,689	2,983	3,412	4,047	4,468	5,391	7,641	8,092	8,113	7,521	6,994	7,802	6,948
Natural sciences [b]	1,079	1,046	1,140	1,273	1,517	1,704	1,975	2,936	3,213	3,191	2,815	2,501	3,026	2,786
Mathematics/computer sciences	170	181	226	281	327	445	524	846	876	865	791	747	817	730
Social sciences [c]	651	645	675	688	784	787	952	1,226	1,260	1,273	1,262	1,222	1,243	1,036
Engineering	775	817	942	1,170	1,419	1,532	1,940	2,633	2,743	2,784	2,653	2,524	2,716	2,396
	Citizenship unknown													
Total, all degrees	781	868	1,075	1,149	1,376	2,196	2,652	793	947	1,161	734	874	1,299	3,641
Science and engineering	452	472	620	705	823	1,371	1,749	468	641	757	497	545	800	1,894
Natural sciences [b]	170	167	215	215	285	501	582	165	185	247	161	170	299	661
Mathematics/computer sciences	25	20	21	42	40	74	123	24	55	62	30	53	67	149
Social sciences [c]	183	225	269	319	345	529	670	172	226	231	190	180	228	709
Engineering	74	60	115	129	153	267	374	107	175	217	116	142	206	375

[a] Data include all doctorates awarded to U.S. citizens and permanent residents, temporary residents, and people of unknown citizenship.

[b] Natural sciences include physical, earth, atmospheric, oceanographic, biological, and agricultural sciences. Social sciences include psychology, sociology, and other social sciences.

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

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

Appendix table 7. Full-time S&E graduate students, by source and mechanism of primary support: 1980-95

Year	All mechanisms	Fellowships	Traineeships	Research assistantships	Teaching assistantships	Other	Self-support
	Total number of students						
1980	238,492	20,532	17,550	51,567	53,890	19,446	75,507
1981	242,118	20,106	16,777	52,722	55,746	20,210	76,557
1982	244,830	20,873	14,640	52,580	58,334	20,455	77,948
1983	252,092	21,365	13,514	54,904	60,072	20,960	81,277
1984	253,959	21,638	13,465	57,735	61,257	20,697	79,167
1985	257,351	22,576	13,665	60,995	61,822	20,635	77,658
1986	266,197	22,966	13,526	66,011	62,563	22,246	78,885
1987	271,080	21,965	14,096	70,214	62,859	22,166	79,780
1988	275,204	22,361	14,397	74,588	63,071	21,584	79,203
1989	282,741	23,476	14,527	79,059	64,316	21,082	80,281
1990	292,854	25,269	15,212	80,747	64,973	22,265	84,388
1991	307,049	26,697	15,417	85,175	65,229	22,956	91,575
1992	322,753	28,666	15,376	88,032	65,739	23,565	101,375
1993	329,876	29,170	15,452	90,158	67,344	21,378	106,374
1994	332,453	28,976	15,716	92,033	66,900	21,672	107,156
1995	330,235	28,954	16,108	89,983	66,147	22,294	106,749
	Number with primary support from Federal sources						
1980	52,969	4,635	13,306	29,316	662	5,050	-
1981	50,903	4,093	12,176	29,147	619	4,868	-
1982	47,411	4,097	10,077	28,313	428	4,496	-
1983	47,764	4,118	9,114	29,152	498	4,882	-
1984	47,793	4,125	8,970	29,463	400	4,835	-
1985	49,058	4,423	8,954	30,433	549	4,699	-
1986	51,365	4,600	8,688	32,739	495	4,843	-
1987	53,542	4,449	8,922	34,996	444	4,731	-
1988	55,492	4,569	8,664	36,752	504	5,003	-
1989	57,444	5,177	8,682	38,555	490	4,540	-
1990	59,274	6,316	9,242	38,504	609	4,603	-
1991	63,017	7,447	9,630	40,790	476	4,674	-
1992	65,634	7,761	10,055	42,588	643	4,587	-
1993	67,697	7,515	10,188	44,504	846	4,644	-
1994	68,583	6,945	10,418	45,633	780	4,807	-
1995	67,469	6,904	10,314	44,503	732	5,016	-
	Number with primary support from non-federal sources						
1980	110,016	15,897	4,244	22,251	53,228	14,396	-
1981	114,658	16,013	4,601	23,575	55,127	15,342	-
1982	119,471	16,776	4,563	24,267	57,906	15,959	-
1983	123,051	17,247	4,400	25,752	59,574	16,078	-
1984	126,999	17,513	4,495	28,272	60,857	15,862	-
1985	130,635	18,153	4,711	30,562	61,273	15,936	-
1986	135,947	18,366	4,838	33,272	62,068	17,403	-
1987	137,758	17,516	5,174	35,218	62,415	17,435	-
1988	140,509	17,792	5,733	37,836	62,567	16,581	-

See explanatory information and SOURCE at end of table.

Appendix table 7. Full-time S&E graduate students, by source and mechanism of primary support: 1980-95 (Continued)

Year	All mechanisms	Fellowships	Traineeships	Research assistantships	Teaching assistantships	Other	Self-support
	Number with primary support from non-federal sources						
1989	145,016	18,299	5,845	40,504	63,826	16,542	-
1990	149,192	18,953	5,970	42,243	64,364	17,662	-
1991	152,457	19,250	5,787	44,385	64,753	18,282	-
1992	155,744	20,905	5,321	45,444	65,096	18,978	-
1993	155,805	21,655	5,264	45,654	66,498	16,734	-
1994	156,714	22,031	5,298	46,400	66,120	16,865	-
1995	156,017	22,050	5,794	45,480	65,415	17,278	-
	Percentage of students						
1980	100.0	8.6	7.4	21.6	22.6	8.2	31.7
1981	100.0	8.3	6.9	21.8	23.0	8.3	31.6
1982	100.0	8.5	6.0	21.5	23.8	8.4	31.8
1983	100.0	8.5	5.4	21.8	23.8	8.3	32.2
1984	100.0	8.5	5.3	22.7	24.1	8.1	31.2
1985	100.0	8.8	5.3	23.7	24.0	8.0	30.2
1986	100.0	8.6	5.1	24.8	23.5	8.4	29.6
1987	100.0	8.1	5.2	25.9	23.2	8.2	29.4
1988	100.0	8.1	5.2	27.1	22.9	7.8	28.8
1989	100.0	8.3	5.1	28.0	22.7	7.5	28.4
1990	100.0	8.6	5.2	27.6	22.2	7.6	28.8
1991	100.0	8.7	5.0	27.7	21.2	7.5	29.8
1992	100.0	8.9	4.8	27.3	20.4	7.3	31.4
1993	100.0	8.8	4.7	27.3	20.4	6.5	32.2
1994	100.0	8.7	4.7	27.7	20.1	6.5	32.2
1995	100.0	8.8	4.9	27.2	20.0	6.8	32.3
	Percentage with primary support from Federal sources						
1980	100.0	8.8	25.1	55.3	1.2	9.5	-
1981	100.0	8.0	23.9	57.3	1.2	9.6	-
1982	100.0	8.6	21.3	59.7	0.9	9.5	-
1983	100.0	8.6	19.1	61.0	1.0	10.2	-
1984	100.0	8.6	18.8	61.6	0.8	10.1	-
1985	100.0	9.0	18.3	62.0	1.1	9.6	-
1986	100.0	9.0	16.9	63.7	1.0	9.4	-
1987	100.0	8.3	16.7	65.4	0.8	8.8	-
1988	100.0	8.2	15.6	66.2	0.9	9.0	-
1989	100.0	9.0	15.1	67.1	0.9	7.9	-
1990	100.0	10.7	15.6	65.0	1.0	7.8	-
1991	100.0	11.8	15.3	64.7	0.8	7.4	-
1992	100.0	11.8	15.3	64.9	1.0	7.0	-
1993	100.0	11.1	15.0	65.7	1.2	6.9	-
1994	100.0	10.1	15.2	66.5	1.1	7.0	-
1995	100.0	10.2	15.3	66.0	1.1	7.4	-

See explanatory information and SOURCE at end of table.

Appendix table 7. Full-time S&E graduate students, by source and mechanism of primary support: 1980-95 (Continued)

Year	All mechanisms	Fellowships	Traineeships	Research assistantships	Teaching assistantships	Other	Self-support
	Percentage with primary support from non-federal sources						
1980.....................	100.0	14.4	3.9	20.2	48.4	13.1	-
1981.....................	100.0	14.0	4.0	20.6	48.1	13.4	-
1982.....................	100.0	14.0	3.8	20.3	48.5	13.4	-
1983.....................	100.0	14.0	3.6	20.9	48.4	13.1	-
1984.....................	100.0	13.8	3.5	22.3	47.9	12.5	-
1985.....................	100.0	13.9	3.6	23.4	46.9	12.2	-
1986.....................	100.0	13.5	3.6	24.5	45.7	12.8	-
1987.....................	100.0	12.7	3.8	25.6	45.3	12.7	-
1988.....................	100.0	12.7	4.1	26.9	44.5	11.8	-
1989.....................	100.0	12.6	4.0	27.9	44.0	11.4	-
1990.....................	100.0	12.7	4.0	28.3	43.1	11.8	-
1991.....................	100.0	12.6	3.8	29.1	42.5	12.0	-
1992.....................	100.0	13.4	3.4	29.2	41.8	12.2	-
1993.....................	100.0	13.9	3.4	29.3	42.7	10.7	-
1994.....................	100.0	14.1	3.4	29.6	42.2	10.8	-
1995.....................	100.0	14.1	3.7	29.2	41.9	11.1	-

KEY: (-) = not applicable

NOTE: Science and engineering includes the health fields (medical sciences and other life sciences).

SOURCE: National Science Board, *Science & Engineering Indicators--1998,* NSB 98-1 (Arlington, VA: National Science Foundation), appendix table 5-34.

Appendix table 8. Full-time S&E graduate students, by field and mechanism of primary support: 1995

Field	All mechanisms	Research assistantships	Fellowships	Traineeships	Teaching assistantships	Other	Self-support
	Total number of students						
Total S&E	330,235	89,983	28,954	16,108	66,147	22,294	106,749
Total sciences	262,373	62,958	22,921	15,099	55,931	17,289	88,175
Physical sciences	28,892	11,808	2,354	688	11,710	730	1,602
Astronomy	871	439	148	28	225	5	26
Chemistry	16,750	6,466	1,270	445	7,386	372	811
Physics	11,054	4,842	929	215	4,073	349	646
Other	217	61	7	0	26	4	119
Mathematical sciences	13,422	1,451	1,274	222	7,316	675	2,484
Computer sciences	16,564	3,921	924	216	3,364	1,551	6,588
Environmental sciences	11,290	4,661	891	136	2,507	730	2,365
Atmospheric sciences	959	619	67	8	107	69	89
Earth sciences	5,810	2,151	512	59	1,855	334	899
Oceanography	2,228	1,257	195	24	215	166	371
Other	2,293	634	117	45	330	161	1,006
Life sciences	100,132	29,158	8,104	10,942	13,089	6,587	32,252
Agricultural sciences	9,630	5,401	454	146	941	477	2,211
Biological sciences	48,283	19,182	5,395	5,308	9,293	2,143	6,962
Medical sciences	13,863	2,928	1,272	1,661	1,246	1,292	5,464
Other	28,356	1,647	983	3,827	1,609	2,675	17,615
Psychology	35,762	4,626	1,824	1,115	6,152	3,094	18,951
Social sciences	56,311	7,333	7,550	1,780	11,793	3,922	23,933
Anthropology	5,792	452	1,168	132	1,278	344	2,418
Economics	11,746	2,094	1,546	271	3,028	809	3,998
History of science	340	17	127	10	99	18	69
Linguistics	2,486	177	369	50	701	282	907
Political science	17,660	1,624	2,468	777	2,666	1,136	8,989
Sociology	7,353	1,131	915	241	2,145	431	2,490
Other	10,934	1,838	957	299	1,876	902	5,062
Total engineering	67,862	27,025	6,033	1,009	10,216	5,005	18,574
Aeronautical/astronautical engineering	2,693	1,175	262	31	315	377	533
Chemical engineering	5,962	3,100	791	105	907	218	841
Civil engineering	12,248	4,225	924	196	1,850	816	4,237
Electrical engineering	18,303	6,684	1,455	156	3,137	1,439	5,432
Industrial engineering	5,328	1,339	300	37	824	504	2,324
Mechanical engineering	11,119	4,419	942	187	1,950	777	2,844
Materials engineering	3,880	2,535	371	48	352	123	451
Other engineering	8,329	3,548	988	249	881	751	1,912

See SOURCE at end of table.

Appendix table 9. Federal Government as primary source of support, by selected mechanisms and field: 1995

Field	Research assistantships	Fellowships	Traineeships
	Percentage with primary Federal support		
Total S&E	49.5	23.8	64.0
Total sciences	50.6	22.6	65.4
Physical sciences	75.0	33.8	58.0
Astronomy	76.3	50.0	28.6
Chemistry	73.0	31.4	56.0
Physics	77.7	34.7	66.0
Other	52.5	0.0	NA
Mathematical sciences	45.4	23.2	32.4
Computer sciences	61.9	25.6	24.1
Environmental sciences	63.0	33.3	49.3
Atmospheric sciences	81.9	62.7	12.5
Earth sciences	62.3	29.5	47.5
Oceanography	67.5	29.2	58.3
Other	38.0	40.2	53.3
Life sciences	48.1	27.0	77.8
Agricultural sciences	34.5	15.6	10.3
Biological sciences	54.8	29.0	72.6
Medical sciences	39.8	23.6	78.9
Other	30.1	25.6	87.1
Psychology	32.0	17.2	36.6
Social sciences	20.1	13.9	20.6
Anthropology	22.6	18.1	16.7
Economics	25.5	13.3	9.2
History of science	5.9	16.5	40.0
Linguistics	32.8	20.6	34.0
Political science	7.1	10.9	12.5
Sociology	21.0	11.6	51.5
Other	23.4	17.2	25.8
Total engineering	46.8	28.6	43.2
Aeronautical/astronautical engineering	56.9	56.1	58.1
Chemical engineering	45.2	26.3	63.8
Civil engineering	37.4	23.3	16.3
Electrical engineering	49.6	27.8	27.6
Industrial engineering	30.5	20.3	48.6
Mechanical engineering	49.8	33.7	39.6
Materials engineering	54.2	33.4	50.0
Other engineering	47.5	25.0	64.3

KEY: NA = not available

SOURCE: National Science Foundation, Division of Science Resources Studies, Survey of Graduate Students and Postdoctorates in Science and Engineering unpublished tabulations.

Appendix table 10. Number of employed scientists and engineers by sector of employment, broad occupation and highest degree: 1995

Field of Employment	Total	Computer and mathematics scientists	Life scientists	Physical scientists	Social scientists	Engineers
			Total			
All Sectors	3,185,600	949,500	305,300	274,300	317,500	1,339,000
4-year universities and colleges	291,100	41,000	84,300	51,100	71,900	42,800
Other educational institutions	275,200	83,000	64,700	28,500	67,600	31,400
Business/industry for profit	1,970,300	683,200	75,600	138,600	57,600	1,015,300
Self-employed	113,800	23,600	7,400	6,500	42,600	33,800
Non-profit	91,000	27,600	11,000	5,600	33,700	13,200
Federal government	252,400	53,300	37,700	27,600	17,100	116,600
State/local government	191,700	37,900	24,600	16,400	27,000	85,900
			Bachelor's			
All Sectors	1,844,000	625,000	121,500	128,100	60,600	908,800
4-year universities and colleges	63,400	10,500	20,500	11,800	10,800	9,800
Other educational institutions	85,900	34,700	20,000	8,700	8,400	14,200
Business/industry for profit	1,324,800	482,800	39,200	78,800	16,100	708,000
Self-employed	48,800	16,000	3,600	3,100	2,800	23,400
Non-profit	41,100	19,500	4,300	2,200	8,700	6,300
Federal government	150,400	35,100	17,100	12,400	5,700	80,100
State/local government	129,500	26,400	16,800	11,200	8,100	66,900
			Master's			
All Sectors	892,700	268,000	64,000	67,200	135,800	357,900
4-year universities and colleges	45,800	10,000	6,700	7,000	11,400	10,800
Other educational institutions	128,800	39,900	19,900	12,800	42,000	14,200
Business/industry for profit	524,300	179,400	16,700	32,600	26,100	269,600
Self-employed	39,500	6,200	2,100	2,100	21,000	8,100
Non-profit	31,700	6,500	2,200	1,000	16,900	5,200
Federal government	70,800	15,400	10,600	7,400	5,600	31,800
State/local government	51,800	10,600	5,900	4,400	12,800	18,200
			Doctorate			
All Sectors	418,300	53,800	102,400	78,900	113,300	69,900
4-year universities and colleges	181,300	20,400	56,800	32,400	49,700	22,100
Other educational institutions	45,400	8,300	12,900	7,100	14,100	3,000
Business/industry for profit	114,600	18,700	17,800	27,200	14,900	36,000
Self-employed	23,100	1,500	1,300	1,300	16,900	2,100
Non-profit	16,300	1,600	3,900	2,500	6,700	1,700
Federal government	28,400	2,500	8,300	7,700	5,600	4,300
State/local government	9,300	900	1,600	700	5,400	700
			Professional			
All Sectors	30,600	2,700	17,400	200	7,900	2,500
4-year universities and colleges	600	-	400	-	-	100
Other educational institutions	15,100	100	11,900	-	3,100	-
Business/industry for profit	6,600	2,200	2,000	100	600	1,600
Self-employed	2,300	-	300	-	1,900	100
Non-profit	2,000	-	700	-	1,300	-
Federal government	2,800	300	1,700	100	300	400
State/local government	1,200	-	300	-	800	100

KEY: (-) = not applicable

SOURCE: National Science Foundation, Division of Science Resources Studies, Scientists and Engineers Data System (SESTAT) 1995.