Chapter 8

Scientists and Engineers

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From Silicon Valley to Route 128, from laboratories in major research universities to private think-tanks, Asian Pacific American scientists and engineers have made enormous contributions to the U.S. economy. A few have risen to the pinnacles of their professions as Nobel Prize winners, presidents of universities, and executives of "high-tech" corporations. Far more important are the hundreds of thousands who receive less public recognition but nonetheless perform invaluable services. While this infusion of Asian Pacific Americans has brought im-measurable benefits to this nation, their presence has raised numerous issues that must be resolved to maximize individual potential and the national interest.[1]

To understand the importance of this group of professionals, we start by first summarizing the role of technology, and scientists and engineers (S&Es) in the U.S. economy. Despite a sizeable expansion of the S&E labor force over the last two decades, the United States has failed to produce sufficient numbers during a time when technology has come to play a more important role in determining the competitiveness of nations in the global economy. The next section examines the phenomenal growth and characteristics of the Asian Pacific S&E labor force. Asian Pacific scientists and engineers have very high levels of educational attainment, are concentrated in research and development, and are overwhelmingly comprised of the foreign-born but U.S.-educated. The third section focuses on the supply of immigrants, which is governed by a complex process involving the "Westernization/Americanization" of higher education on a global scale and by immigration regulation. Together, these two factors have created an extremely educated labor pool of Asian

Pacific S&Es who fill critical positions in the U.S. economy. The final section examines how well these professionals are faring. The analysis indicates earnings parity, although immigrants are likely to earn less than non-immigrants. The major issue confronting Asian Pacific Americans in these fields is the "glass ceiling," specifically the barriers to upper management positions.

Scientists and Engineers

The economic well-being of the United States depends on its technological capacities (Porter, 1990; Grossman and Helpman, 1991; Nelson and Wright, 1992; Dollar and Wolff, 1993). Since World War II, investments in higher education and research and development (R&D), and the expansion of a highly-educated labor force have contributed to increasing productivity and a rising standard of living. More recently, technology has taken on importance in terms of international trade. One indication is the fact that America's exporting industries are more technologically intensive than America's manufacturing base as a whole; exporting industries employ a higher proportion of highly-educated workers than the rest of the economy (Abowd and Freeman, 1991, pp. 17-18). The industries where we have an advantage over other nations are those where we have a technological edge.

Scientists and engineers are crucial in determining this nation's technological capacity through their role in the creation of basic knowledge, the transformation of it to practical applications, and designing and operation of complex and sophisticated equipment. Scientists and engineers are central to the innovation of products and production processes. They are the critical personnel for such complex projects such as the Information Superhighway, the Joint International Space Station, the Human Genome Project, and SEMATECH, the joint public-private R&D venture in semiconductors. Their contributions are not limited to these high-profile endeavors. S&Es apply their talents to improving everyday electronic and mechanical equipment, drugs and chemical-based products, and thousands of other goods. As a group, S&Es comprise a significant part of the labor force in what Robert Reich calls the symbolic-analytic services (1992), which constitute the key sector of advanced economies.

While this nation's high-technology labor force has expanded, the growth is less than one might expect given the increasing importance of technology, both domestically and internationally. Between 1970 and 1990, the number of S&Es climbed from 1.8 million to 2.9 million, according to the U.S. Census.[2] Despite this increase, the growth of the S&E labor force (65 percent) only slightly outpaced the growth of the total labor force (51 percent). In other words, S&Es as a percentage of the total workforce increased only marginally (from 2.2 to 2.4 percent). Moreover, changes in the educational levels do not indicate an unambiguous upgrading. On the positive side is a decline in the proportion of S&Es with less than four years of college education, which decreased from 41 percent 1970 to 30 percent in 1990. On the other hand, the proportion with some graduate training has not increased. In 1970, 25 percent had five or more years of college education, while in 1990, 23 percent had post-bachelor's degrees. Other data reveal that the problem is particularly severe at the doctorate level. Total Ph.D. production in S&E increased rapidly after 1960, peaked in 1972, and then declined until the late 1970s; only in the 1980s has the number of science and engineering Ph.D.s increased, but much of this is tied to an increase in the number of foreign students (Atkinson, 1990).

The difficulty this nation faces in producing an adequate supply of S&Es at the right time and in the right place is rooted in the very nature of the labor market for these workers. This country has suffered from niche and cyclical shortages due to changes in public expenditures, rapid expansions or contractions of industries associated with product cycles and business cycles. For example, defense spending, long the single largest source of public expenditure on R&D and the production of high-technology goods, first built up the aerospace industry and then later decimated it, dislocating thousands of aerospace engineers (Ong and Lawerence, 1993). In contrast, the rapid growth in high-technology sectors in micro-electronics has heightened the demand for highly-educated scientific workers, even while this nation has lost production to off-shore and foreign operations (Ong and Mar, 1992).

The sudden fluctuation in demand throws the market into disequilibrium. In the short term, the supply of S&Es is unable to adjust quickly. This is caused in part by a limitation on the transferability of skills across fields; consequently, a shortage in one industry cannot be easily relieved by recruiting individuals working in other industries. Moreover, the number of new entrants cannot be rapidly expanded. The effective number of new entrants is determined by the number of students who entered higher education years earlier, when the relative attractiveness of the field could have been very different. In other words, response to changes in demand takes years, by which time the need could have reversed or shifted to other sectors.[3]

Producing S&Es with advanced training suffers from not only fluctuations in demand but also from a more basic market imperfection. Research and development, as a public good, generates social benefits that may not be captured as profits by private industry. One consequence is that investments in R&D can be lower than optimal from a societal perspective. This flaw has been the basis for government incentives to R&D, but despite these efforts R&D expenditures as a percentage of GND declined throughout much of the 1970s and 1980s.[4] The inability of private enterprise to completely internalize the benefits of R&D translates into lower salaries for highly-trained workers and dampens the demand for graduate degrees in technology fields. Northrup and Malin (1985) find that since the mid-1960s the starting salaries of Ph.D., master and bachelor graduates with engineering and technology degrees have converged; between 1966 and 1982, the relative difference between the monthly starting salary of a Ph.D. and master's and between master's and baccalaureate declined by more than one-half.

An analysis of 1990 Census data show that the returns to advanced degrees may not be sufficiently high to attract individuals to pursue graduate studies.[5] For both scientists and engineers, earning a master's degree increases hourly wages by 14 to 15 percent, which is considerably higher than working two additional years, generating a 3 to 4 percent increase annually.[6] These estimates are likely to be biased upward because the admissions process creams the most talented, so some of the increase should be attributed to the screening and not just to the education. There appears to be sufficient incentives despite the trends in starting salaries of S&Es with master's versus those with bachelors. For those who continue with their education, completing a doctorate would increase wages by about another 9 percent for scientists and 15 percent for engineers relative to those with a master's degree. Nonetheless, difficulties in completing the required course of study and uncertainty over employment opportunities make the venture risky and lead to a lower expected rate of return (Ehrenberg, 1992). It takes at least another four years after completion of a master's degree to complete a doctorate, time that can be used to acquire on-the-job experience that also increases wages. The adjusted net returns to a doctorate, then, do not appear to offer enough financial incentives for many to continue. Of course, factors other than financial reward contribute to the decisions of those who do pursue advanced studies, but at the aggregate level, they do not completely offset the shortcomings inherent in the labor market.

Characteristics of Asian Pacific Engineers and Scientists

No other minority group has contributed more to the technological capacity of this nation than Asian Pacific Americans. Although the S&E labor force is still largely non-Hispanic white, Asian Pacific Americans have become an increasing presence. They accounted for less than 2 percent in 1970 but nearly 7 percent by 1990. This increase has been driven by an incredible growth of the Asian Pacific S&E labor force. During the two decades, the number jumped from about 21,000 to 150,000, an increase of 603 percent. Extrapolating from recent trends, it is likely that there are now over a quarter-million Asian Pacific scientists and engineers. Like the larger Asian Pacific population, the S&Es come from ethnically diverse groups. Chinese comprise the largest ethnic group (34 percent), followed by Asian Indians (23 percent), Japanese (12 percent), and Filipinos (10 percent).

The presence of Asian Pacific Americans varies considerably by field and level of education, as well as by place of employment and activity. Table 1 summarizes estimates from the 1980 and 1990 Censuses.[7] While Asian Pacific Americans are underrepresented among those without a bachelor's degree, they are extremely overrepresented among those with graduate degrees.[8] They comprise one-sixth of those with either a master's or professional degree. Their greatest presence is among engineers with a doctorate degree, comprising over one-fifth of this group. Moreover, Asian Pacific S&Es are highly concentrated at the centers of high-technology. For example, in Silicon Valley, America's premier site for the production of semi-conductors and other related electronics products, they comprise one-quarter of all scientists and engineers, and over one-third of those with advanced degrees.[9]

Along with higher levels of education, Asian Pacific Americans are more likely to participate in research and development. Table 2 summarizes the primary activities of white and Asian Pacific

Table 1. Racial Distribution of Engineering and Scientific Labor Force, 1980 and 1990

	NH-White	Asian Pacific	Others
1980, All			
Total	90%	4%	6%
Less than BA	90%	2%	8%
BA	91%	4%	5%
MA/Prof.	87%	8%	5%
Ph.D.	83%	14%	3%
1990, All			
Total	85%	7%	8%
Less than BA	87%	3%	10%
BA	87%	6%	7%
MA/Prof.	81%	12%	7%
Ph.D.	81%	15%	4%
1990, Engineers			
Total	86%	7%	7%
Less than BA	89%	2%	8%
BA	87%	7%	6%
MA/Prof.	80%	14%	7%
Ph.D.	73%	22%	6%
1990, Scientists			
Total	85%	7%	9%
Less than BA	84%	3%	13%
BA	86%	6%	8%
MA/Prof.	83%	11%	6%
Ph.D.	84%	13%	4%

Estimated from U.S. Bureau of the Census, 1990 1% Public Use Microdata Sample.

The total may not equal 100 percent because of rounding.

S&Es with at least a bachelor's degree.[10] One distinctive difference is that Asian Pacific Americans have a lower probability of being in management positions; this phenomenon will be discussed later. The other important racial difference is the relatively high numbers whose primary activity is R&D, 34 percent compared to 24 percent for whites. This is not unexpected given the educational characteristics of Asian Pacific Americans. Having an advanced degree increases the odds of participation in R&D (for all S&E, the figures are 18 percent for those with a bachelor's, 27 percent for those with a master's or professional degree, and 41 percent for those with a doctorate). Variations in educational composition, however, account for only about one-third of the racial difference.[11] Within degree categories, Asian Pacific Americans exhibit a higher probability of doing research and development, and the greatest difference is among those with a doctorate degree,

Table 2. Primary Activity of Those Employed as Scientists and Engineers

	R&D	R&D Management	Other Management	Other
1982, All				
White	24%	6%	13%	57%
Asian Pacific	34%	5%	8%	54%
1982, Bachelor's				
White	18%	5%	15%	61%
Asian Pacific	21%	3%	10%	66%
1982, Master/Prof.				
White	27%	8%	12%	53%
Asian Pacific	33%	6%	9%	52%
1982, Ph.D.				
White	40%	7%	4%	49%
Asian Pacific	54%	6%	1%	39%
1989, Ph.D.				
White	36%	8%	9%	47%
Asian Pacific	52%	8%	3%	37%

Source: U.S. Department of Commerce, Survey of Natural and Social Scientists and Engineers, 1989; National Science Foundation (1991a)

14 percentage points.

Another unique characteristic of the Asian Pacific S&E labor force is the prominence of immigrants. While 92 percent of non-Asian Pacific S&Es in 1990 were born in the U.S., only 17 percent of Asian Pacific S&Es were. Nearly half of the foreign-born (47 percent) arrived during the 1980s. The composition by nativity varies by degree level, with the percentage of U.S.-born falling with higher educational attainment. While 27 percent of those without a bachelor's degree were U.S.-born, only 6 percent of those with a doctorate were U.S.-born. Being an immigrant, however, does not imply being foreign-educated. In fact, the vast majority are educated in the United States, as documented by Table 3.[12] This is particularly true for those with advanced degrees.

The Supply of Immigrant S&Es

Given the dominance of immigrants among Asian Pacific S&Es, it is important to examine this particular supply more closely. INS (Immigration and Naturalization Service) data reveal the magnitude of the flows. Between 1972 and 1985, over 50,000 S&Es from the major Asian Pacific sending sources (India,

Table 3. Scientists and Engineers in 1982 by Nativity and Place of Education

	U.S.-Born	Foreign-Born U.S.-Educated	Foreign-Born Foreign-Educated
NH-White	94%	4%	2%
Asian Pacific	21%	63%	16%
Others	75%	19%	5%
Asian Pacific American by Education			
Bachelor's	36%	31%	33%
Master/Prof.	16%	78%	6%
Ph.D.	8%	83%	9%

Source: U.S. Department of Commerce, Survey of Natural and Social Scientists and Engineers, 1989

South Korea, the Philippines, Taiwan, Hong Kong, and China) became permanent immigrants (Ong, Cheng, and Evans, 1992, p. 545). More recent data show that another 17,000 became permanent immigrants between 1989 and 1991. Several factors contribute to the influx of Asian Pacific immigrant S&Es. A necessary condition is the "Westernization" of higher education in the technical fields, which creates an international labor pool, and the United States has played the key role in this process in recent decades (Ong, Cheng, and Evans, 1992). This is manifested in the adoption of Western and American curriculum in the technical fields by universities throughout Asia and other parts of the Third World. Frequently, the courses are taught by professors trained in the U.S.[13] This process has created an international class of workers receiving roughly the same basic education in the sciences and engineering. However, given the limitations of higher education in Asia, this applies primarily to undergraduate education.

The "Americanization" process works in another and even more important way. Given this country's preeminence in technology during much of the post-World War II period, the U.S. emerged as the most desirable place to study for students from developing nations.[14] Between the academic years of 1954-55 and 1990-91, the foreign-student population in the U.S. grew from 34,232 to 407,529. There are more foreign students studying in this country than the total for the next three leading host countries. Over one-half of the foreign students in the U.S. are from Asia, and another fifth are from other Third World nations. In engineering and science, the number of foreign students increased from 18,545 in 1959-60 to 145,740 in 1990-91, with the vast majority coming from the Third World.

Foreign students are particularly noticeable in graduate programs. For example, while foreign students comprised less than one-tenth of the engineering undergraduates in 1985, they made up over one-quarter of those in master's programs and over two-fifths in doctorate programs (Falk, 1988, p. 58). Although the figures in the sciences are less dramatic, foreign students nevertheless comprise a significant number of the graduate students in these fields as well. In the two fields taken together, the percentage of non-U.S. citizens receiving doctorates from U.S. universities more than doubled from 16 percent in 1960 to

34 percent in 1990. By 1990, 7,444 foreign-born earned doctorate degrees in science and engineering, up from only 3,295 in 1970 (National Science Foundation, 1991a). The increase has continued despite both the fluctuations in the total number of science and engineering doctorates granted during the 1970s and the improvement of educational institutions in developing countries.

Asians make up the largest contingent of foreign students studying in the U.S. The total number from Asia grew from less than 10,000 in the mid-1950s to 130,000 by 1989-90 (Zikopoulos, 1991, p. 14). For the latter year, nearly one-half were in engineering and scientific fields (46 percent), and among the Asians in these fields, over two-thirds were graduate students. With this heavy concentration, it is not surprising that Asians comprised a large majority of all foreign students in science and engineering — 63 percent of all foreign students and 74 percent of those in graduate studies.[15] Almost one-quarter (23 percent) of all science and engineering Ph.D.s conferred in 1990 were awarded to Asian-born students (National Science Foundation, 1991a).

The countries of origin among foreign-born Asian science and engineering doctorates have shifted over the years. In 1960, over half of the doctorates awarded to foreign-born Asian students went to individuals born in China and India (59 percent). Among the remaining Asian countries, Korea and Japan were the countries of origin for roughly 8 percent each. By 1990, an increasing number of students entered from Taiwan and Korea. Seventy-one percent of foreign-born Asian Pacific scientists and engineers in 1990 were from four countries — the People's Republic of China (20 percent), Taiwan (20 percent), Korea (19 percent), and India (14 percent).

While most came under the assumption that they would return and contribute to the development of their home country, many, perhaps a majority, stayed in this country after completing their education. This is particularly true for those with advanced degrees. A little more than one-third (35 percent) of all non-U.S.-citizens receiving doctorates in 1990 planned to seek employment or further training outside of the U.S.; the majority intended to remain in the U.S., perhaps largely in hopes of gaining permanent immigrant status (National Science Foundation, 1991a). Data on Taiwanese students indicates how extreme this no-return phenomenon can be. Between 1961 to 1981, only 15 percent of the

86,000 persons who went abroad to study returned, and the large majority of these emigrated to the United States (Liao and Hsieh, nd). Even among those who do return to their native countries, many eventually come back to the United States. The stayers, along with the returnees who re-migrate and emigrants trained in their native country constitute the total supply of Asian Pacific immigrant S&Es.

Several factors contribute to the flow of highly-educated Asian Pacific Americans. The first is that the sending countries are less attractive places for these students to pursue their career. These countries have not achieved a level of economic development that would generate the necessary demand for these types of workers, lack the technological infrastructure needed to support sophisticated research and development, and generally offer low salaries. Although these disadvantages slowly wane as development proceeds, the United States still offers far superior employment and career opportunities. Because the frame of reference that influenced educational and career choices is international, the low rate of return for advanced degrees within the U.S. labor market, which was discussed at the beginning of this chapter, is not a disincentive for Asian foreign students. Indeed, receiving such a degree can offer a high rate of return because it increases the probability of working in the U.S. for these individuals.

The odds of becoming a permanent resident are shaped by immigration regulations. After the enactment of the 1965 Immigration Law, Asian Pacific Americans have qualified for occupation-based visas, which have been made available to those who can fill positions where there is a labor shortage.[16] Given the shortages of the S&E labor market, the immigration law has created a major avenue for migration of those with college and university degrees in science and engineering, especially those with advanced degrees. Although the regulations were tightened in the mid-70s, there are still nonetheless large flows of Asian S&Es.

This can be seen in Table 4. Adjusters, those who had entered the country on temporary visas, comprised nearly half of all immigrants, and most received permanent residency through one of the occupational categories. Among the adjusters, 44 percent held F1 visas (student), and another 39

Table 4. Immigrant Scientists and Engineers, 1989-91

	Engineers	Math/ Computer Science	Scientists	Total
Total Asian Pacific	13,063	2,504	1,433	17,000
% of All Immigrants	46%	52%	38%	46%
Country of birth				
India	32%	26%	41%	32%
Taiwan	16%	31%	14%	18%
China	14%	14%	18%	15%
Hong Kong	6%	9%	4%	6%
Mode of Entry				
Adjusters, occup.	34%	61%	50%	40%
Non-adjusters, occup.	13%	12%	13%	12%
Other adjusters	8%	12%	13%	9%
Settlement by State				
California	37%	28%	21%	34%
New York	10%	16%	17%	11%
New Jersey	8%	20%	9%	10%
Illinois	6%	6%	5%	6%
Texas	5%	5%	7%	5%

Estimates from U.S. Immigration and Naturalization Service, Immigrant Public Use Tapes, 1989 to 1991 Fiscal Years.

percent held H1 visas (temporary worker). The presence of so many H1s indicate that many students underwent an intermediate step in becoming a permanent resident. The data also indicate that one-quarter of the non-adjusters entered through the occupational categories. Thus, over half of these new immigrants entered to fill positions in areas of labor shortages.

The flow of Asian Pacific immigrants has helped meet the demand for S&E workers in the U.S. Moreover, regulations help screen workers so that immigrants tend to help fill niches within shortage areas. These immigrants are not necessarily first in the hiring queue. U.S. employers prefer hiring permanent residents or citizens. The literature cites a number of reasons for this preference. First, the labor certification process, the process in which employers document that they have made a good-faith effort to hire U.S. citizens before hiring immigrants, may impose additional costs on employers in the form of tedious paperwork and delays, costs that could be avoided if employers hire permanent residents or U.S. citizens (Finn, 1988; Cannon, 1988). Second, many foreign graduates from U.S. universities have difficulties obtaining security clearances and may, therefore, be unsuitable candidates for employment in defense-related industries (National Research Council, 1988). And finally, a preference for U.S.-born workers may ultimately rest on racial or ethnic prejudices.

Despite the above factors, about half of U.S. firms that use S&Es hire foreign-born employees (National Science Foundation, 1986). Frequently, this hiring occurs when there are few or no other applicants in the labor queue for a position. This is particularly true when the opening is for those with graduate training. It is this latter factor that helps explain why the educational levels of Asian Pacific S&Es tend to be very high.

In some cases, the matching of jobs and immigrants can alleviate shortages at the aggregate level. Fields in which employers most frequently report shortages to the National Science Foundation tend to be the fields with high inflows of foreign nationals (Finn, 1988). For example, in 1980-81 employers reported few shortages of recently graduated Ph.D. students in the life and social sciences; consequently, the percentage of foreign nationals in these two fields was small, 8 percent and 6 percent respectively. However, within engineering, the relationship between immigration and areas of relative aggregate shortage is not so apparent because foreign nationals constituted between one-third and one-half of all new Ph.D.s entering the U.S. workforce regardless of the relative degree of shortage in a particular sub-field of engineering. In these areas, the matches are defined at the level of individual positions.[17]

Earnings and Glass Ceilings

How well Asian Pacific scientists and engineers fare can be measured by their earnings and their representation in management positions. Aggregate measures of earnings indicate a convergence of earnings between Asian Pacific Americans and NH-whites. For example, the median annual salary for Asian Pacific doctoral S&Es as a percentage of the median for whites grew from about 93 percent in the early 1970s to 100 percent in the later 1980s (National Science Foundation, 1991). The latter figure is consistent with an analysis of 1990 Census data, which yield an earnings ratio of 99 percent between Asian Pacific Americans and NH-whites. For scientists and engineers at all educational levels, the ratio is 97 percent. There is also rough parity when the data is analyzed by broad occupational categories (see Table 5).

The above comparisons, however, do not reveal if Asian Pacific Americans earn the same as NH-whites after accounting for factors such as education, occupation, and immigrant status that should influence wages. Data indicate that the two populations are not comparable because Asian Pacific Americans are more likely to hold advanced degrees, to work as engineers, and to be immigrants. When the 1990 data is disaggregated by degree and broad occupational groupings, the results show that Asian Pacific Americans generally earn less than their NH-white counterparts, in some cases about one-tenth less. Several factors, such as type of activity, age and years of professional experience, gender, nativity, place of education, and place of employment can account for observed differences. Moreover, discrimination also affects earnings.[18]

Analyzing "pure" racial difference is best done by examining U.S.-born scientists and engineers because any discrepancy in pay for immigrants may be due to cultural and linguistic factors rather than racial differences. Our analysis indicates that U.S.-born Asian Pacific scientists earned more than their NH-white counterparts after controlling for observable factors, but finds no inter-group difference among engineers.[19] The higher earnings of Asian Pacific scientists may be due to differences in the quality of education since they are more likely to have attended elite universities. In other words, there may be some bias against this group that is not detected due to our inability to control for quality of education. Although we do not know of any study of engineering which controls for this factor, one study of recent college graduates in all fields that controls for the quality of

Table 5. Median Annual Earnings, 1989 (x1,000)

	Engineers		Scientists	
	Non-Hispanic Whites	Asian Pacific	Non-Hispanic Whites	Asian Pacific
All Ed. Level	$40.5	$40.8	$35.0	$34.6
Less Than Bachelor's	$36.5	$36.0	$30.6	$26.0
Bachelor's	$40.8	$37.0	$34.9	$32.0
Master's/Prof	$49.6	$45.0	$40.0	$40.0
Ph.D.	$57.2	$54.0	$48.0	$44.0

Estimates from U.S. Bureau of Census, 1990 1% Public Use Microdata Sample.

education finds lower earnings for Asians, *ceritis paribus* (Weinberger, 1993).

Among Asian Pacific Americans, there are significant differences of wages by nativity, time of entry into this country, and place of education. An analysis of 1990 data indicates that recent Asian Pacific immigrants (in the country for five years or less) in the sciences earn about one-fifth to one-quarter less in hourly wages than their U.S.-born counterparts, and that recent immigrants in engineering earn about one-third less than their U.S.-born counterparts.[20] The gap declines with additional time in the U.S., and disappears after 20 to 25 years. The wage differences are even greater in terms of annual earnings, indicating recent immigrants not only receive a lower wage but also work fewer hours. Moreover, wage differences may be due to the increase in the number of Asian Pacific scientists and engineers who enter the U.S. without an American education; thus, the lower earnings of recent immigrants may reflect unobserved differences in the quality and type of education among immigrant cohorts. An analysis of the 1989 Survey of Natural and Social Scientists and Engineers, which contains information on place of education, indicates that those with a foreign education earn about 10 percent less than those with a U.S. education, and that there are no differences in the wages between the U.S.-born and foreign-born employees with a U.S. education after controlling for other factors.[21]

Immigration regulations may contribute to the low wages of new immigrants. In order to hire an alien, employers must prove that no U.S. worker is qualified and available for that position and that the job offer meets prevailing wages. The positions that are least likely to be filled are those where the offering wage fails to attract domestic applicants.[22] Foreign scientists and engineers may be willing to accept lower salaries in order to obtain full-time employment in the U.S., a prerequisite for permanent residency (Gruenwald and Gordon, 1984).[23] For example, Asian Pacific doctoral scientists and engineers who are temporary residents earn only 82 percent of the median annual salaries of those with permanent residency (National Science Foundation, 1991). However, the low salaries can only be a short-run phenomenon because when residency is established, the worker is no longer bound to their first place of employment. As they operate more freely in the labor market, their wages would begin to converge with their U.S.-born counterparts.

Despite the improvement in earnings of immigrants with length of residence in the U.S., Asian Pacific Americans continue to confront a "glass ceiling" that denies them entry into top managerial positions. The statistics in Table 2 clearly show that they have a substantially lower probability of being in management; and this finding remains true within degree levels. When they do enter management positions, they do so within the area of Research and Development. Few rise to executive positions in this area of employment. For example, in 1992 there was not a single Asian Pacific executive in the large computer and semi-conductor firms in Silicon Valley, despite the fact that Asian Pacific Americans comprised the largest minority group in the high-technology industries of that region (Pollack, 1992). The glass ceiling also exists within academia. According to a 1985 survey by the National Research Council, less than 9 percent of Asian Pacific American faculty at four-year institutions listed administration as their primary work activity, compared with 17 percent of the entire faculty (Miller, 1992). Asian Pacific Americans have been noticeably absent, at least until very recently, from leadership positions as deans, institute heads, and advisory board members.

This lack of upward mobility is not due to a lack of economic incentives or interest. In both the sciences and engineering, S&Es whose primary activity is managerial earn about one-fifth more than S&Es with other duties.[24] Moreover, a majority of Asian Pacific S&Es express a desire to move up to administrative positions (Wong and Nagasawa, 1991). Even those who state that they do not want administrative positions may be discouraged by the poor prospects facing Asian Pacific Americans; thus they have adjusted their expectations accordingly. If the explanation is based on neither economic nor individual motivation, then what is the cause?

One clue comes from our analysis of the 1989 Survey of Natural and Social Scientists and Engineers, which indicates that the difference in composition by nativity plays a major role in the racial gap. The first column in Table 6 reports the unadjusted Asian Pacific-to-NH-white odds ratios of being in management. The value of .67 means that Asian Pacific Americans are only two-thirds as likely to be in a management position as NH-whites. Given the earlier discussion, it is not surprising that the odds are better for R&D management but worse for other managerial positions. The second column reports the odds ratios after adjusting for a number of independent factors, including immigrant status and whether one is educated in the U.S.[25] With these controls, the odds ratios increase significantly, and when past managerial experience is included, the ratios indicate parity. The results reveal that immigrants were considerably less likely to hold non-R&D management positions. Compared to U.S.-born, immigrants with U.S. educations are one-fifth less likely to hold R&D management positions, and immigrants with foreign education are one-half less likely to hold these positions. Since Asian Pacific Americans are more likely to be immigrants, this has contributed to their lower representation in management positions.

One interpretation for why immigrants face poorer prospects centers on cultural and language differences (Miller, 1992; Hoy, 1993). Despite a functional command of English, many may lack key verbal and communication skills. Moreover, many may lack assertiveness skills that are deemed necessary for leadership positions. Whether or not they actually lack these attributes, the characterizations are widely held by employers and senior executives. In one survey of industry leaders, "language difficulties were repeatedly mentioned as factors" in lowering the prospects of foreign engineers moving into upper management (Cannon, 1988, p. 110). However, foreign engineers have an excellent chance of gaining access to management positions in R&D organizations, where access to technical management is based on professional criteria (Cannon, 1988, p. 113). In other words, Asian Pacific Americans are viewed as good technicians but not managers (Park, 1992).

Table 6. Asian Pacific-to-NH-White Odds Ratios of Being in Management

	Unadjusted	Adjusted by current characteristics	Adjustment including prior management experience
Management	.67	.91	1.00
R&D Management	.84	.96	1.09
Other Management	.58	.90	.97

See text for explanation of estimates.

Source: 1989 Survey of Natural and Social Scientists and Engineers.

It is not clear how much cultural and language differences really adversely affect managerial ability and how much the perception is used to rationalize decisions based on other biases.[26] Moreover, there is a danger that these perceptions form the basis for racial stereotypes that create "statistical" discrimination, a form of discrimination where individual Asian Pacific Americans are judged on the basis of the "group mean" rather than on their own merits. Such racial stereotypes can potentially harm not just immigrants but also U.S.-born.

The glass ceiling has two consequences. One, it forces some Asian Pacific Americans to pursue the entrepreneurial path. This has been true in several cases in Silicon Valley (Park, 1992). While this may be a factor in some individual cases, it is not clear that the glass ceiling has had a significant impact on entrepreneurial activity at the aggregate level.[27] Data from the 1989 Survey of Natural and Social Scientists and Engineers show that the self-employment rates of Asian Pacific Americans and NH-whites are both 6 percent. Of course, the Asian Pacific rate might have been lower in the absence of the glass ceiling, but nonetheless, actual entrepreneurship is not a major phenomenon among Asian Pacific scientists and engineers.

The second consequence of the glass ceiling is reverse migration.[28] Ong and Hee (1993) argue the following:

> Several factors contribute to the reverse migration. The newly industrialized economies now have the resources to pay globally competitive salaries, and have the scientific and technical infrastructure that allows the highly educated to continue their career. At the same time, there is a sense that the United States is not the land of the unlimited opportunity. Certainly the existence of the glass ceiling is causing some Asian Pacific Americans to reconsider the pursuit of their career goals in the U.S. (p. 150).

While reverse migration is still a minor flow and its role in the transfer of technology across international boundaries is limited, the phenomenon is indicative of the potential and far-reaching consequences of the unequal opportunities facing Asian Pacific American scientists and engineers.

Concluding Remarks

The evidence clearly shows that Asian Pacific scientists and engineers, particularly those with advanced degrees, have helped this nation fill a crucial labor need. Without the growth of Asian Pacific S&Es, particularly the immigrant component, the shortages of highly-educated labor in the technical fields, and the corresponding losses to the economy, would have been enormous. Future developments will create a need for an even larger Asian Pacific S&E labor force.

As other nations have developed their technological infrastructure, increased their R&D expenditure, and benefitted from the international flow of knowledge, we have entered into an era of worldwide technological competition. During the last two decades we have seen that capturing or maintaining technological leadership is a pivotal factor in defining a nation's comparative advantage and the competitiveness of firms. In the new global economic order, trade is increasingly based on nations specializing in selective technology-based industries. Although the United States still holds or shares the lead in several fields, it is no longer preeminent in all areas.

In order to remain competitive, this nation must accelerate the growth in its technological workforce and improve the quality of this workforce as well. Those with highly specialized graduate training are essential for research and development, which is in turn necessary to expand the frontiers of technology. The advantage that this nation had enjoyed in this area has waned. Compared to several industrialized nations (Japan, Germany and France), this nation in the 1960s had a substantially higher ratio of scientists and engineers in R&D to the total labor force, and although the U.S. has maintained this ratio over time, the other countries have been closing the gap (Nelson and Wright, 1992). Whether this nation can stop or even reverse this relative decline will depend on its ability to produce a larger supply of S&E workers and to upgrade their education and training.

Unfortunately, the growth patterns described in the beginning of this chapter do not portend a sanguine future. Ensuring a new supply of highly-educated S&Es will be more problematic in the near future. The supply of scientists and engineers at the baccalaureate level will decline over the coming decade due to a drop in the college-age population (Atkinson, 1990). The size of the 22-year-old cohort in the U.S. peaked at about 4.3 million in 1991 and will decline to approximately 3.2 million by 1996. The one hope is that the decline in the college-age population could be offset by an increase in the proportion of students receiving bachelor's degrees in science and engineering.

Asian Pacific Americans have the potential of being a major source to fill this critical need. The supply based on those who are either U.S.-born or U.S.-raised will increase dramatically because their numbers have grown with the overall Asian Pacific population, because they are more likely to attend college, and because they are more likely to major in the sciences and engineering. However, this future "domestic" supply is smaller than the supply of S&E immigrants that prevailed in the 1970s and 1980s.

Unfortunately, there is no guarantee that the flow of S&Es from Asia will remain high. The increased number of slots for occupational immigrants under the 1990 Immigration Act will make it possible for Asian S&E immigrants to migrate. At the same time, other forces are working against this. With increased economic development, Asian countries will become better able to educate their students at home, to create professional opportunities for their graduates, and to pay internationally competitive salaries. The impact can already be seen, for example, in the increase during the 1980s in the rate of return of Asian students who studied in the United States. Several countries are making the transition from being "exporters" of S&E talent to being "re-importers" of highly-educated and highly-experienced personnel. They have established programs that actively recruit Asian Pacific scientists and engineers with work experience, and this bilateral internationalization of the S&E labor market will undoubtedly increase the size of reverse migration. While developments in the sending countries will be important, they by themselves are not likely to decrease the flow of immigrants significantly.

A potentially far more important force that threatens the supply of Asian Pacific S&Es is the current anti-immigrant sentiment. The central but unanswered question is whether this xenophobic political movement will produce new restrictions on immigration from the Third World, which will not only affect scientists and engineers, but all Asian Pacific Americans.

Notes

1. The wording of this sentence is borrowed from a report by the National Research Council entitled *Foreign and Foreign-Born Engineers in the United States — Infusing Talent, Raising Issues* (1988).

2. The 1970 statistics are calculated from Bureau of the Census, 1973. The 1990 statistics are estimated from the 1% Public Use Microdata Sample. There are differences in the definition of educational attainment. The 1970 data are reported by the number of years of education completed for the experienced civilian labor force, while 1990 data are reported by degree received for the total experienced work force.
3. The fluctuations in demand generate disequilibrium between supply and demand, and a "cobweb" effect (Freeman, 1971). Given that short-run supply is inelastic, increased demand translates into higher wages. The initial shortage can lead to a surplus in the future because the current generation of new students respond to the increases in wages by majoring in the field where there is a shortage. If this cohort graduates at a time when the demand for their services has waned, the influx of students can eventually flood the market inducing yet another cycle of falling wages and reduced enrollments.
4. The decline in R&D expenditures is, in part, due to the fact that the problem of public goods is internationalized in a global economy.
5. This is based on standard wage regressions where the log of annual earnings and the log of estimated hourly wages are the dependent variables. The sample was drawn from the 1990 1% Public Use Microdata Sample and contained only U.S.-born respondents in a scientific or engineering occupation who had earned at least $1,000 in 1989. To reduce the ambiguity of what a professional degree means, the sample was restricted to those with either a bachelor's, master's, or doctorate degree. Our model includes independent variables for gender, race, years of experience, educational degree, geographic region, and consolidated metropolitan areas. Separate regressions were estimated for scientists and for engineers.
6. The effects are roughly the same in terms of annual earnings.
7. The estimates are based on those who were in the labor force (employed, or unemployed but looking for work) and were classified in a S&E occupation or taught in a S&E field at the college/university level. The 1990 Census provides educational information by degree, but the 1980 Census does not. We assumed that those with four or five years of college had a bachelor's degree, while those with eight or more years of college, the top reported category, had a doctorate. Those with more than five years but less than eight years of college were classified as having master's or professional degrees. We tested the sensitivity of our definition of those with a bachelor's degree. Using only four years of college led to an unrealistically high estimate of the number with a master's or professional degree. The limitation of the 1980 data probably led to the inclusion of persons without a Ph.D. in the doctorate category.
8. In 1990, 33 percent of the Asian Pacific S&Es had a master's or professional degree, and another 12 percent had a doctorate degree. For all other S&Es, the respective statistics are 17 percent and 5 percent.

9. These estimates are based on the 1990 5% PUMS. Asian Pacific Americans are also overrepresented among production workers (Park, 1992).

10. The 1982 estimates are based on respondents who worked in a scientific or engineer occupation. We use whites rather than non-Hispanic whites in this analysis because the published 1989 report does not provide statistics for the latter group. Because an overwhelming majority of white S&Es are not Hispanic, there is very little difference in the 1982 statistics for NH-whites and whites.

11. This is based on calculating the proportion of Asian Pacific S&Es that would be in R&D if they experienced the white participation rate by each of three degree levels — those with a bachelor's degree, those with a master's or professional degree, and those with a doctorate times the proportion of Asian Pacific Americans with a doctorate degree. This hypothetical rate is 27 percent, which is 3 percentage points higher than that for all white S&Es but still 7 percentage points lower than the observed rates for all Asian Pacific S&Es.

12. The statistics are based on respondents with at least a bachelor's degree and who classified themselves as a scientist or engineer by profession (education and experience).

13. For example, in 1988 over two-thirds of the S&E faculty at Seoul National University, South Korea's premier institution, had a foreign doctorate, and nearly three-quarters of this group received their training in the United States (Seoul National University, 1988).

14. The statistics on foreign students come from Zikopoulos, 1991b.

15. The concentration of Asians is not new, but the data show that their relative share has increased over the last few decades. Students from Asian countries received 42 percent of all non-U.S. science and engineering doctorates awarded in 1960-64 and 68 percent in 1990 (NSF, 1991).

16. Prior to 1965, U.S. laws favored highly-skilled individuals; but racial bias in the immigration law prevented large numbers of Asians from taking advantage of these quotas.

17. The immigrant supply also helps address cyclical shortages due to periodic fluctuations in the demand for scientists and engineers.

18. See Harberfeld and Shenhav (1990) for an analysis of salary discrimination of women and black scientists.

19. This is based on the regressions outlined in footnote 2. The results indicate that annual earnings and hourly wages of Asian Pacific scientists were 10 percent higher than for NH-whites. The estimated parameters were significant at only the $p<.10$ level, but this may be due to the small number of U.S.-born Asian Pacific Americans in the sample. The results indicate no statistically significant differences between Asian Pacific and NH-white engineers. The results also show that women and blacks earned less than men and NH-whites, which is consistent with the literature.

20. This is based on standard wage regressions where the log of annual earnings and the log of estimated hourly wages are the dependent variables. The sample was drawn from the 1990 1% Public Use Microdata Sample and contained Asian Pacific respondents in a scientific or engineering occupation who had earned at least $1,000 in 1989. To reduce the ambiguity of what a professional degree means, the sample was restricted to those with either a bachelor's, master's, or doctorate degree. Our model includes independent variables for gender, race, years of experience, educational degree, geographic region, consolidated metropolitan areas, year of entry, and English language ability. Separate regressions were estimated for scientists and for engineers.

21. The earnings regressions include as independent variables gender, race, years of professional experience, age, educational degree, geographic region, year of entry, managerial activity, part-time work, and place of education. Although there is no control for English language ability, the analysis of the 1990 Census data for Asian Pacific scientists and engineers indicate that excluding this variable does not bias the included variable. This is not surprising since Asian Pacific Americans in these fields tend to have at least a fair command of English; thus the estimated parameter for this variable is often insignificant. The sample includes respondents working in a S&E occupation who had at least $1,000 in earnings. Separate regressions are estimated for scientists and for engineers. The sample for scientists is small (n=337) and did not produce robust estimates. The results discussed in the text are based on the analysis of engineers.

22. This individual aspect of the wage-induced shortage of S&Es with advanced degrees is discussed in section one, where there is an adverse effect on the decision to pursue advanced studies.

23. This explanation, however, cannot account for the fact that in 1989 U.S.-born Asian Pacific doctoral scientists and engineers earned only 92 percent of that of white doctoral scientists and engineers (NSF, 1991).

24. This is based on an analysis of the 1989 Survey of Natural and Social Scientists and Engineers. The annual earnings regressions includes as independent variables gender, race, years of professional experience, age, educational degree, the sector of employment, geographic region, year of entry, managerial activity and part-time work. The sample included U.S.-born respondents working in a S&E occupation and had at least $1,000 in earnings.

25. The estimates are based on a sample of only paid workers with income in the U.S., between the ages of 30 and 64, and excludes those working in hospitals, the military, and international agencies. Scientists and engineers are defined by experience and education, which includes individuals who were working outside a scientific or engineering occupation. The analysis uses logit regression, and the list of independent variables also includes gender, degree, marital status, presence of children, age, years of experience in the profession,

geographic region of employment, type of employment organization (public, etc.), and occupational categories.

26. Certainly, the economic advancement made by Asian countries based on a different leadership styles would suggest that behaviors rooted in Asian Pacific culture are not inherently bad for effective management. Partial acceptance of this has come as American corporations adopt some Japanese practices. Of course, managerial styles cannot be completely transplanted given differences rooted in history and larger institutions.

27. Because high-tech industries have been rapidly expanding and changing, they offer Asian Pacific Americans, and others, the opportunity to "get in at the ground level" and build a fortune. Many of the largest Asian Pacific companies are in this sector, including Wang Laboratories, Computer Associates, AST Research, Everex Systems, and Advanced Logic Research (Pollack, 1992).

28. The fascination with "returning" as a solution to the frustration felt by Asian Pacific Americans who are blocked from moving up was captured by the 1986 movie *The Great Wall,* directed by Peter Wang. The movie begins with the protagonist, a Chinese American engineer, being passed over for a management position that he believed he should have received. His response was to return to China for a visit, with a possibility of staying. In the end, however, he realizes that he and his family belong in the U.S.