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Engineering Education and Its Rewards in the United States and Japan

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Interest in Japanese education on the part of American and British writers has increased dramatically in the last few years, especially with respect to engineering and scientific education.[1] Although this interest is gratifying, much of what has been written is at best distorted and at worst completely wrong. Naive writers with little or no knowledge of the Japanese language or the peculiarities of Japanese statistics have compared nominally similar but in fact compositionally different categories. On this basis they have made exaggerated claims for the number of engineers educated, their income and status, and their role in corporate management. They have assumed an undemonstrated relation between their false perception of Japan's engineers and Japanese economic success.

If this misinformation had appeared in obscure journals, it could be ignored. Unfortunately, it has been propagated in publications from the National Science Foundation and repeated in mass circulation magazines.[2] More important, this misinformation has been presented in reports to Congress and to the president and has been used as support for fiscal formulations.[3]

Whether Japanese experience developed when that nation was catching up with the United States can provide lessons for future U.S. (and Japanese) policy is highly debatable. Nevertheless, since Japanese experience through

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[1] Celebration of Japanese education in a number of recent works on American education is noted in Andrew Hacker, "The Schools Flunk Out," *New York Review of Books* 31, no. 6 (April 12, 1984): 35.

[2] I am thinking here primarily of various claims made in National Science Foundation, *Science and Engineering Education for the 1980s and Beyond* (Washington, D.C.: NSF, 1980), pp. 58–61; National Science Board, *Science Indicators 1982: An Analysis of the State of U.S. Science, Engineering, and Technology* (Washington, D.C.: NSB, 1983); and Gene Gregory, "The Engineering Gap," *Far Eastern Economic Review* 122, no. 51 (December 22, 1983): 71–74.

[3] Committee on Science and Technology, U.S. House of Representatives, *U.S. Science and Engineering Education and Manpower: Background; Supply and Demand; and Comparison with Japan, the Soviet Union, and West Germany* (Washington, D.C.: Government Printing Office, 1983).

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the early 1980s is being cited, the information about this experience should at least be accurate. Otherwise, the United States will lose whatever insight might be gained from Japanese experience or even move in a path exactly opposite of that actually pursued by Japan and in one that may further decrease the competitive power of the United States.

This article seeks to show that the United States has had and continues to have more engineers absolutely and relatively than does Japan. These engineers enjoy higher relative income and status than do their Japanese counterparts. Engineering has provided a wider path to high management status in the United States than in Japan. Nevertheless, U.S. strength has declined primarily in manufacturing industries, in which engineers figure prominently. Japan, in contrast, has excelled in manufacturing. This contradiction leads to an examination of differences in engineering education and the employment of new graduates as a possible explanation for the apparently more successful Japanese utilization of a smaller number of engineers.

The Misperceptions

American observers have seen engineering as more popular among Japanese than American students. Gene Gregory, a professor at Sophia University in Tokyo, has noted that "about 20% of all baccalaureates and about 40% of all master's degrees in Japan were granted to engineers with about 5% at such level in the United States."[4]

These percentages are meaningless as measures of popularity or importance. Engineering is primarily a male field in Japan (98.5 percent in 1980), and the country's 4-year colleges are predominantly male (78 percent in 1980).[5] More than 70 percent of Japanese women college students attend junior colleges that are in turn 90 percent female.[6] American institutions, in contrast, have an almost equal sex ratio. Looking only at males raises the U.S. ratio for engineering to 13.1 percent in 1980. If science and engineering are combined, the U.S. ratio becomes 27 percent versus 25 percent for Japan.[7] The United States is, moreover, far ahead of Japan in drawing on the talents of women. By 1982, 16.6 percent of

[4] Gregory, p. 71. Gregory seems prone to exaggeration. The actual figure for 1981 (16.8 percent) was mathematically closer to 15 percent than to 20 percent.

[5] Calculated from Sōrifu Tōkei Kyoku, *Tōkei nenkan* (Tokyo: Nihon Tōkei Kyōkai, Sōrifu, 1982), p. 360, table 420.

[6] See *Education in Japan: A Graphic Presentation* (Tokyo: Ministry of Education, 1982), p. 27, table 10, for striking visual depiction of this tracking by sex in Japan.

[7] Calculated by combining U.S. disciplines included in the broad Japanese divisions of *rika* (science) and *kōgaku* (engineering). Data from U.S. Department of Commerce, Bureau of the Census, *Statistical Abstract of the United States (1982–1983)* (Washington, D.C.: Government Printing Office, 1984), p. 167, table 278. See below for a discussion of the differences between "engineering" subject matter in Japan and the United States.

first-year engineering students were women, up from 6.6 percent in 1972.[8] In Japan the proportion is so small that it is typically dropped from statistical listings.

The same sexual differentiation affects graduate proportions. In 1980, 87.1 percent of Japanese graduate students were male.[9] More important, graduate education is required for more careers in the United States than in Japan. Hence the relative share of engineering in all graduate education is lower in the United States even though the absolute number of students is larger than in Japan. In 1980, there were 299,095 U.S. master's degrees awarded in the United States. In the same year, Japan had only 35,781 students in master's programs. The United States actually awarded more master's degrees in engineering (16,846) than Japan had students (14,864) in such programs![10]

American observers are only nominally correct in noting that Japan has graduated more students with "engineering training" than the United States since the late 1960s. Computer science, architecture, environmental planning, and so on are taught only in engineering faculties (*kōgakubu*) in Japan. If U.S. and Japanese engineering programs are adjusted to a common set of subjects, the U.S.-Japan gap almost entirely disappears even in 1976, and for subsequent years U.S. output exceeds that of Japan by an increasing margin.[11]

The single-minded attention given to engineering as an indicator of the technological manpower available to industry ignores continued U.S. superiority in physical, mathematical, and biological sciences. A claim such as that by Gregory that only "at times" has the U.S. level equaled that of Japanese universities is patently false. In 1980, the United States produced 118,000 "physical science" (Japanese definition) graduates (first degree), whereas Japan produced 12,000. Moreover, the U.S. edge appears to be increasing, albeit slowly.[12] To focus only on engineers implies that chemists

[8] Keven D. Shell, "Career Planning Characteristics of Engineering Students," *Engineering Education* 73 (December 1983): 165–70.

[9] Sōrifu Tōkei Kyoku, p. 633, table 423.

[10] U.S. data from National Science Board, p. 271, table 3-28. Japanese data from Sōrifu Tōkei Kyoku, Nihon tōkei nenkan (Tokyo: Nihan Tōkei Kyōkai, 1983) p. 633, table 423. Roughly one-quarter of U.S. graduate students in engineering are foreign. Even if adjustment is made for those who leave after completing their education, there is still a U.S. *numerical* superiority. For data on foreign students in the United States, see National Science Board, p. 227, table 1-38.

[11] The most consistent data on Japan is found in Maekawa Tsutomu, "Kōtō kyōiku ni kansuru tōkei shiryō," *Daigaku kenkyū nooto* 58 (November 1983): 54–55, table 15. This article discusses the many problems with Japanese data, albeit in a strictly Japanese context. For data on the United States, I have used National Science Foundation, *National Patterns of Science and Technology Resources* (Washington, D.C.: NSF, 1984), p. 86, table 82. As is typical of NSF sources, this publication does not discuss or even recognize questions of data consistency or definition. There is no indication of whether the totals given include graduates in "engineering technology." A priori it can be expected that figures for the highly decentralized United States are more likely to be understated than for highly centralized Japan.

[12] Gregory, p. 72. Sources as in previous note. "Physical science" (*rika*) faculties in Japan include mathematics and the biological sciences other than medicine.

and physicists, for example, have no role in the well-being of such industries as semiconductors and fiber optics.

Neither the current labor market nor National Science Foundation (NSF) projections of future demand show a general shortage of engineers. Only two major fields (out of 30 some included under the general rubric of engineering) show current and probable future shortages: aeronautical/aerospace and electrical/computer engineering.[13] In other fields there is concern over a possible surplus! These fields are, moreover, those most intimately associated with military demand. The cancellation of one or more major armaments systems could easily change the demand structure substantially.[14] Indeed, the dependence of U.S. engineering on military work is *the* major reason for decreased enrollments in the 1970s. Unemployment among engineers due to military spending reductions in the early 1970s turned students to other disciplines.[15] Any thoughtless enrollment expansion in the United States invites a repetition of this cycle.

It has been claimed that this apparently greater output of engineers has led to a situation in which "by 1980 Japanese industry employed 35 engineers per 10,000 population against only 25 in the US, reflecting a higher aggregate technological level in Japan."[16] This claim is highly suspect on two grounds. First, there is no real Japanese equivalent for "engineer" in American usage. The usual equivalent, *gijutsusha,* is also applied to technicians and even blue-collar workers. For example, a 1983 report on computer workers included keypunchers under the heading *gijutsusha.*[17] Similarly, the annual surveys of private industry wages done by the National Personnel Authority (Jinji'in) define *gijutsusha* to include those engaged in "management, planning, or repair," provided they have a "technical or scientific" (*rikōgaku*) background—educational level unspecified.[18] In Ministry of Education data, the term *gijutsusha* is applied to those taking technical jobs without regard to their undergraduate studies. Thus, in 1982, 47.8 percent of those graduating from schools of agriculture and 7.8 percent of those who studied home economics (*kaseigaku*) were listed as becoming *gijutsusha.*[19]

There is apparently no Japanese data source on industrial employment that counts graduates of 4-year university programs in engineering.[20]

[13] National Science Foundation, *National Patterns of Science and Technology Resources,* p. 4.

[14] National Science Foundation, *Projected Response of the Science, Engineering and Technical Labor Market to Defense and Non-Defense Needs: 1982–1987* (Washington, D.C.: NSF, 1984), p. 18.

[15] Fred Landis, "The Economics of Engineering Manpower," *Engineering Education* 73 (December 1983): 157–62.

[16] Gregory (n. 2 above), p. 71.

[17] Konpyuuta Rōdō Kenkyū Kai, *Konpyuuta rōdō hakusho* (Tokyo: Ningen To Gi jutsu Sha, 1983), p. 17.

[18] Jinji'in Kyūyo Kyoku, *Minkan kyūyo no jittai* (Tokyo: Jinji'in, 1984), pp. 11–12.

[19] Shibata Shingo, *Genba kara no shokugyō an'nai* (Tokyo: Yūhikaku, 1983), pp. 16–17.

[20] Based on discussions with researchers at the National Institute for Educational Research (Kokuritsu Kyōiku Kenkyūjo) in Tokyo.

Even surveys of researchers do not impose a university education requirement, a reflection of the lingering importance of graduates from prewar technical colleges, institutes, and vocational schools. Japanese numbers are further pushed up by reporting those "primarily employed" in research and development (R & D), while the United States reports "full-time equivalents." The 1984 *Kagaku gijutsu hakusho* (White paper on science and technology) specifically warns against comparing U.S. and Japanese data pertaining to numbers of researchers.[21] Even with this inherent understatement, NSF figures put the number of engineers *and* scientists in the United States at 62.7 per 10,000 labor force versus 55.6 for Japan in 1981.[22]

Second, even if U.S. and Japanese data could be adjusted to common definitions, there is no body of economic theory to relate relative numbers of engineers to national economic performance. Japanese growth rates (gross domestic product) were roughly four times those of the United States in the 1960s, although the United States had a three-to-one advantage in scientists and engineers. The Soviet Union has long produced more "engineers" than the United States and Japan absolutely and on a per capita basis without matching, let alone exceeding, either nation economically or technically.

In American and British writing, Japanese engineers are perceived as a high-status group with easy entry into the highest level of government and management. A NSF report goes so far as to claim that "managerial positions in both government and industry are heavily populated by people with engineering degrees" and, furthermore, "about 50% of all directors have engineering qualifications." The same report also claims that only half of those with engineering degrees go into engineering as such; the rest enter management or government service.[23]

These claims are at odds with both logic and Japanese writing on the subject. If half of all engineering graduates actually went into government or management, it would be impossible for the private sector to have the number of engineers (as such) claimed for it by these same sources! In 1981, Ministry of Education statistics reported only 5.6 percent of new graduates with engineering education being employed in the public sector. Only 4.5 percent were listed as going into managerial or clerical positions; most (85.2 percent) were employed in technical jobs.[24]

[21] Kagaku Gi jutsu Chō, *Kagaku gi jutsu hakusho* (Tokyo: Kagaku Gi jutsu Chō, 1984), p. 34.

[22] National Science Foundation, *National Patterns of Science and Technology Resources* (n. 11 above), p. 37, table 18. Except for the surveys of management background cited below, there is no information for Japan on scientists and engineers in activities other than R & D.

[23] National Science Foundation, *Science and Engineering Education for the 1980s and Beyond* (n. 2 above), p. 58; Gregory (n. 2 above), p. 71. The NSF report is based on a British government source, *Engineering Our Future* (London: Her Majesty's Stationery Office, 1980). Gregory did not respond to two letters asking for his sources.

[24] Monbushō, Gakkō kihon chōsa hokusho (Tōkyō: Monbushō, 1981), pp. 322, 328.

Fifty percent (or more) going into management or government may have been true in the 1890s.[25] It is definitely not true for the 1980s. Only the Construction Ministry (Kensetsushō), roughly equivalent to the U.S. Corps of Engineers, is known currently for a significant percentage of engineers in its ranks. In 1984, the educational background of senior officials at the Ministry of International Trade and Industry (MITI) was 18 in law, 2 in economics, 1 in engineering, and 1 in science.[26] Those who focus on Japanese "industrial policy" portray MITI as the agency responsible for guiding postwar Japanese economic development.[27]

Sociological studies of Japanese management do not indicate that engineering is a particularly favored route to high corporate status. A comprehensive survey by Mannari Hiroshi and James Abegglen of the Japan business elite as of 1970 (the peak of Japan's "miraculous" growth) found that only 23 percent of chief executives had an engineering *or science* background. The U.S. figure was more than double: 53 percent. Business and economics majors were more important in Japan (44 percent) than in the United States (32 percent) as were those with law backgrounds (24 percent in Japan, 9 percent in the United States). After examining comparable data for other Western countries, the authors concluded, "The proportion of men [chief executives] who studied engineering and science is the lowest in Japan."[28] Similar results for Japan in the 1960s have been obtained by Mannari and other Japanese scholars.[29] The image of engineers presented in Japanese journalism and career guidance works does not indicate that engineers enjoy particularly high status or are on a fast track to managerial rank. A 1981 career guidance book for would-be mechanical engineers, for example, describes them as having a "handicap" in competing with candidates from the clerical side of business.[30]

Quasi-sociological studies on the origins of Japanese businessmen in magazines such as *Daiyamondo* (Diamond) pay little attention to the field, focusing instead on the advantages of graduation from particular universities.[31] This approach may be anachronistic but does indicate that

[25] See Iwauchi Ryūichi, "Institutionalizing the Technical Manpower Formation in Meiji Japan," *Developing Economies* 15, no. 4 (December 1977): 427.

[26] Japan Trade and Industry Publicity, *MITI Handbook* (Tokyo: Japan Trade and Industry Publicity, 1984), pp. 175–87. Earlier years show essentially the same pattern.

[27] The most thorough study available in English is Chalmers Johnson, *MITI and the Japanese Miracle: The Growth of Industrial Policy* (Stanford, Calif.: Stanford University Press, 1982).

[28] Mannari Hiroshsi, *The Japanese Business Leaders* (Tokyo: University of Tokyo Press, 1974), p. 227.

[29] See Mannari, p. 185, for his 1960 data. See also the survey by Aonuma cited in Kono Toyohiro, *Strategy and Structure of Japanese Enterprises* (London: Macmillan, 1984), p. 34. This found that in 1962, of 1,500 top managers, only 23 percent had "engineering" backgrounds, where that term is taken to include those with prewar technical high school and even vocational school educations.

[30] Yoshikawa Hideo and Teraoka Toshiteru, *Enjinia shinrō senryaku* (Tokyo: Nihon Kōgyō Shinbun Sha, 1981), p. 207.

[31] I surveyed the last 5 years of this magazine because it and publications by its parent firm are commonly used by Japanese sociologists studying the relation between education and corporate

there is no widespread Japanese perception that a particular field gives one an advantage in obtaining managerial rank. If a specific discipline is cited as leading to high executive status, this is invariably the study of law, preferably at the University of Tokyo.

Comprehensive surveys of occupational prestige conducted in 1975 found civil engineers in nineteenth and mechanical engineers in twentieth place. This put engineers just above airline stewardesses but well below the law-based professions of judge (first) and higher civil servant (sixth).[32] Similarly, competition ratios for various university programs do not indicate engineering as an exceptionally popular field. In 1980, business administration (10.1:1) and law (8.1:1) were more popular (by this measure) than engineering (4.4:1) or engineering/science (5.1:1).[33] Sitting for bar examinations is far more popular than the pursuit of any engineering credential.[34]

Neither starting pay nor lifetime earnings give any indication that engineering graduates enjoy special status in Japan. Although premiums of 10 percent or more were paid to newly graduated engineers in prewar Japan, that has not been the case in postwar Japan.[35] Annual surveys of starting and career salaries in the private sector show at most a 1 or 2 percent premium, and only for starting salaries (see table 1).[36] It is in the United States where engineers enjoy extraordinary income and status.

Since at least the early 1960s, engineering graduates in the United States have enjoyed a substantial premium over humanities and social science graduates. In 1983, this premium exceeded 50 percent and has been widening.[37] Indeed, starting salaries for bachelor's graduates in engineering have equaled or exceeded those for experienced Ph.D.'s in the

advancement. It is also quite popular. One article out of a dozen or more in the period 1980–85 described engineers as being in a "strong position" for advancement. By "strong" this article explained that 12.2 percent of newly promoted executives in 1981 had come from the engineering, development, or production side of firms. "Shinnin jūyaku hakusho," *Shūkan daiyamondo* (July 11, 1981), p. 63.

[32] Tominaga Ken'ichi, ed., *Nihon no kaisō kōzō* (Tokyo: Tokyo Daigaku Shuppan Kai, 1979), p. 446.

[33] Calculated from Sōrifu Tōkei Kyoku (n. 5 above), p. 631, table 421. Note that for most undergraduates in Japan, the study of "law" does *not* mean preparation to become a lawyer. It is more a preparation in the commercial code and political science than in law as taught in the United States.

[34] For the popularity of the Japanese bar exam, see John Owen Haley, "The Myth of the Reluctant Litigant," *Journal of Japanese Studies* 4, no. 2 (Summer 1978): 386.

[35] "Engineers' Syndrome," *Rikuruuto* 18, no. 3 (March 1985): 21. See also Earl H. Kinmonth, *The Self-made Man in Meiji Japanese Thought* (Berkeley and Los Angeles: University of California Press, 1981), chap. 8, for the overall graduate job market in prewar Japan.

[36] I have used Jinji'in Kyūyo Kyoku ([see n. 18 above], pp. 24–26) for generalizations about Japanese salaries. This is an annual survey conducted to establish parity for civil servants vis-à-vis employees in the private sector. References to engineers derived from this source are to university-educated *gijutsusha* working for firms with more than 500 total employees. Persons included in this category are largely, but not exclusively, those who have studied "engineering."

[37] Landis (n. 15 above), p. 160; National Science Board (n. 2 above), p. 265, table 3-18.

TABLE 1
JAPAN: RELATIVE COMPENSATION IN 1984

Occupation	Relative Compensation
"Engineers" (*gi jutsu shūnin*)	100
Associate professors (*jokyōju*)	126
Assistant professors (*kōshi*)	106
Teachers (high school)	107
Electricians	81
Carpenters	82
Heavy equipment operators	90
Machine operators	79

SOURCE.—*Minkan kyuyo no jittai* (Tokyo: Jinji'in, 1984), pp. 24–26.
NOTE.—The data given here reflect formal monetary compensation by the individual's primary employer. No information is available on total income, which may include overtime, earnings from side jobs, and nonmonetary compensation in the form of perks and fringe benefits.

humanities and social sciences.[38] To add insult to injury, this widening gap has been caused by a steady decline in real terms of salaries for nonengineers, whereas those for engineers have held steady or increased.[39] High starting salaries are matched by high average earnings. A 1981 survey showed that average salaries for employed (as contrasted with private practice) engineers exceeded even those of (employed) medical practitioners (see table 2).

Viewed in the light of Japanese data, one of the most striking features of the United States is the low pay for teachers at all levels, especially in elementary and secondary education. Whereas salaries for U.S. engineers have been stable or increasing in constant dollars, those for public elementary and secondary teachers have been declining.[40] This difference helps to explain why students who major in education have the second-lowest test scores among U.S. college students. Those scores have declined over time, whereas those of engineering students have remained constant and high.[41] No comparable movements are to be noted either in applicant quality or relative wages in Japan.

[38] In 1984, the starting salary for U.S. bachelor's-level graduates was $26,100. Engineering Manpower Commission, *Engineers Salaries: Special Industry Report 1984* (Washington, D.C.: American Association of Engineering Societies, 1984), p. 22. As an associate professor with a Ph.D. and 10 years' experience in teaching, I received $26,300 in the same year!

[39] Landis (n. 15 above), p. 160.

[40] National Center for Educational Statistics, *The Condition of Education* (Washington, D.C.: NCES, 1984), p. 51, chart 1.19.

[41] For recent test scores, see NSF, *Science and Engineering Education: Data and Information* (Washington, D.C.: NSF, 1982), p. 126.

TABLE 2
UNITED STATES: RELATIVE EARNINGS

Occupation	Relative Earnings
Engineers	100
Physicians (employed)	87
Teachers (college, university)	82
Teachers (elementary)	60
Teachers (secondary)	65
Technicians	64
Managers	75
Clerical workers	43
Craft workers	65
Operatives	45

SOURCE.—Nancy F. Rytina, "Earnings of Men and Women: A Look at Specific Occupations," *Monthly Labor Review* 105, no. 4 (April 1982): 26–29.

The U.S. pattern at the university level is also quite different from that prevailing in Japan. To prevent the alleged flight of professors to private industry, many universities pay more to engineering than to other faculty.[42] In the University of California (UC) system, this premium ranges up to more than 30 percent for associate professors.[43] All engineering faculty enjoy a premium even if they are not in the two areas (aeronautical/aerospace and electrical/computer engineering) that are generally claimed to be prone to flight. Consulting and other types of moonlighting are virtually unregulated, even encouraged, during the regular academic year. This increases the differential between engineering and nonengineering faculty, since the latter have few chances for lucrative side employment.

Japanese universities (in the public sector) pay all faculty of the same rank and length of service the same amount. Specialization in medieval poetry brings the same compensation as specialization in solid-state physics.[44] Pay schemes such as those in the UC system increasingly undermine the notion of the university as an agency dedicated to the pursuit of knowledge rather than profit.

[42] For one example of this claim, see National Science Foundation, *Science and Engineering Education for the 1980s and Beyond* (n. 2 above), p. 9. This and other reports essentially ignore the reverse flow from industry to academia.

[43] "Academic Salary Scales," mimeographed (Berkeley: University of California, 1985), pp. 1, 6.

[44] Medical practitioners are the only category that receives extra compensation according to specialization. For recent data on academic salaries in the public sector (where most of the best Japanese universities are found), see Nishida Yoshiteru, "Kokuritsu daigaku kyōin no chingin suijun," *Chingin to shakai haōshō*, no. 892 (June 1984), pp. 24–28; and *Education in Japan* (n. 6 above), p. 83, table 38. Note that this latter source gives *monthly* pay. In recent years, public-sector employees have received 16.92 months pay per year due to the so-called bonus system.

Two Engineering Programs

The extreme pay differentials (by Japanese standards) offered to U.S. engineering graduates suggest the possibility that the latter are better educated than their nominal Japanese counterparts. To test whether this is indeed the case, I have chosen to examine engineering programs at two schools with which I have been affiliated: the University of California, Davis (UCD), and Kobe University. Deans of both engineering schools believe their programs "typical" with no noted curriculum quirks.[45]

Both schools are similar in that their history as comprehensive universities begins only after World War II: both have much longer histories as single-course (faculty) schools. Universities such as UCD and Kobe are more representative of the mainstream in their respective countries than are older and more famous schools such as MIT and Tokyo University. Within engineering, I have focused on electrical engineering (EE) because I began my undergraduate career at the University of Wisconsin—Madison in electrical engineering in 1964. This field is also of interest because electronics is a major area of competition between the United States and Japan.

Minimum preparation for admission to engineering schools within the UC system is phrased in terms of high school courses (required years in parentheses): history (1), English (4), mathematics (2), laboratory science (1), foreign language (2), and mathematics, science, or foreign language (1+).[46] In the UCD case there are no further requirements for admission to engineering, although the following high school courses are recommended: algebra (2), plane geometry (1), trigonometry (½), analytic geometry (½), chemistry (1), and physics (1). In Japan this would be an appropriate list for those seeking admission to a good high school.

Would-be students must also submit scores from either the College Entrance Examination Board (CEEB) or American College Testing (ACT) programs. These tests scores are ignored for California residents with a high school grade point average (GPA) greater than 3.30 (A = 4.0). Those below this level need SAT scores ranging from 400 (for a 3.30 GPA) to 1,600 (for a 2.78 GPA). Since the GPA calculations undervalue advanced mathematics and take no account of quality variations among high schools, the effect would appear to be to reward high achievers in mediocre programs.

[45] Descriptions of the two programs are derived from *Graduate and Undergraduate Bulletin 1984–1985* (Davis: University of California, Davis, 1984); and *Kobe daigaku kōgakubu benran* (Kobe: Kobe Daigaku Kōgakubu, 1984).

[46] California has two separate state systems with different budgets, administrations, and entrance requirements. The system described here includes Berkeley (UCB), Los Angeles (UCLA), and so forth.

Admission to Japanese national universities, where most of the prestigious engineering programs are, is based solely on entrance examinations. For all practical purposes, high school grades are ignored. No specific high school course requirements are stated, although in practice successful preparation for the examinations leads to an emphasis on science, mathematics, and foreign language.

For all but the most unpopular schools, there are two tiers of examinations. The first, called the Common First Tier-Test of Academic Ability (Kyōtsu dai'ichi gakuryoku shiken), has been heavily influenced by the American SAT and differs primarily in the weight given to foreign language (essentially English). Recent versions of this have involved 9 hours of tests in five subjects spread over 2 days. Despite this apparent rigor, passing the first-tier exam does little more than qualify one to take the second-tier examination for really desirable schools. At Kobe University, admission to engineering required taking second-tier tests in the following subjects (number of units in parentheses): algebra/trigonometry (1), analytic geometry (1), differential/integral calculus (1), statistics/probability (1), physics (1), chemistry (1), English (3), and French or German (1).[47]

Each subject involves a small number of questions, usually no more than three or four. These are difficult and often require a special test mentality above and beyond knowledge of the nominal subject matter. Although examination coaching is a growing business in the United States, this is far more developed in Japan, with organizations specializing in preparing students for the examinations of particular faculties (departments) within particular schools.[48]

The passing grade for second-tier examinations is adjusted from year to year to produce a fixed quota of new students. For Kobe, this was 490 in engineering. Such quotas are seldom changed. Expansion in enrollments in Japan is primarily by creating new faculties, not by expanding enrollments at a given university.[49] Just as public-sector universities in Japan do not follow every market whim in faculty salaries, they do not follow the shifting fancies of students in the fashion of American universities.[50]

The English-language sections of these examinations are singularly difficult. Typical questions involve the translation of archaic English proverbs and the ability to unscramble two similar stories that have been jumbled

[47] All statements about Kobe University examinations are derived from *'85 daigaku nyūshi shiriizu: Kobe daigaku* (Tokyo: Kyōgaku Sha, 1984). This is one of a series of popular cram manuals known to would-be college entrants as "the red books" because of their red (orange) covers. Information on the second-tier requirements is found on pp. 21–22.

[48] For very vivid descriptions of these schools, see Shimahara Nobuo, *Adaptation and Education in Japan* (New York: Praeger, 1979).

[49] T. J. Pempel, *Patterns of Japanese Policy Making: Experiences from Higher Education* (Boulder, Colo.: Westview, 1978), describes the background of enrollment expansion in postwar Japan.

[50] Japanese public-sector universities are currently being pressured by the Ministry of Education to relax their quotas *temporarily* to accept Japan's second baby boom.

sentence by sentence. The relevance of archaic English proverbs to modern engineering is far from clear. The only rationalization that might be applied is to note that the proverbs, typically of the Samuel Smiles or *Poor Richard's Almanac* variety, stress hard work.

Relevant or not, such questions have been asked on Japanese university entrance examinations since these were first instituted in the late nineteenth century.[51] Their continued use helps to explain why Japanese students put so much effort into English study with so little result, at least in terms of speaking and writing. The second-tier examinations represent the traditional method of selection in Japan, that which was shared by all institutions prior to the development of the Common First-Tier Test and that which remains the selection method for private schools. These examinations are designed not to measure potential ability but rather to limit those passing to the number of openings.[52] Examinations are written by the various faculties (colleges in American parlance) and reflect their choice of subjects.[53] The mathematics and science questions are less obtuse and archaic than those in the English section but no less difficult. I would judge the level of knowledge required to be about the same as I had at the end of my second year as a student in electrical engineering at the University of Wisconsin in the mid-1960s.

The overall distribution of credits required for graduation in electrical engineering is shown in table 3. The most striking difference between the two programs is the weight of foreign language study: 10 percent versus 0 percent. Moreover, in practice, the weight is greater at Kobe. If no suitable Japanese textbook exists, a foreign one will be used. Equipment and computer software manuals are often in English; their use results in further language study. Language study clubs are active, and the employment of foreigners as tutors is common.

In the United States even high-prestige programs such as MIT have no foreign language requirement for admission or graduation. If anything, UCD is slightly ahead of MIT in this respect. The University of California system has once again instituted a token high school foreign language requirement. Unfortunately, this is defined in terms of high school credit, not competency or achievement.[54]

[51] The reception of Samuel Smiles and other Anglo-American "self-help" writers in Japan is discussed throughout Kinmonth, *The Self-made Man in Meiji Japanese Thought* (n. 35 above).

[52] Private universities also use them as a fund-raising device by charging stiff fees for the privilege of taking the examination.

[53] Actual application is to a specific *gakubu* (faculty) within a given university. Changing faculties is very difficult and usually requires repeating the examination process. The Japanese *gakubu* is broader than the American department but usually smaller in scope than a college within a university.

[54] For recent comments on the difficulty of introducing foreign languages into engineering education in the United States, see George Burgliarello, "International Concerns in Engineering Education," *Engineering Education* 72 (January 1982): 266–68. For depressing documentation of the level of language studies in the United States and business indifference to foreign language capability,

TABLE 3
CREDITS REQUIRED FOR GRADUATION

	Kobe		UCD	
	Credit	%	Credit	%
Senior thesis	10	7	0	0
Specialty	74	54	106	59
Foreign language	14	10	0	0
Humanities/social science	16*	12	24	13
Mathematics/physical science	24*	17	50	28
Total	138	100	180	100

* Minimum. Students may take substantially more credits. Kobe University operates on a semester system; UCD on a quarter schedule. Physical education requirements have been deducted from the totals for both schools.

Praise for the Japanese record on foreign language study must be tempered by the qualification that such study is entirely opportunistic and essentially equivalent to the study of English. The record on other languages is no better and perhaps inferior to that of the United States. Comprehensive universities in the national sector offer only English, French, Spanish, German, Russian, and Chinese. Some U.S. high schools do better than this. Student interest is concentrated on English. Only German has a small constituency in law and medicine. Surveys show that 55 percent of all engineers in Japan have no spoken competence in any foreign language. Of those with some claimed capability, this is predominantly in English.[55] Korean is virtually ignored despite proximity, heavy Japanese investment in that country, and increasingly stiff competition from Korean firms.

The Kobe student who works in Western languages can typically draw on good local collections. The rare UCD student with a reading knowledge of Japanese can find some major periodicals; his counterpart at UCB (Berkeley) will find virtually none in the engineering library and only a few more if he goes to a storage facility where unused materials are located. With no senior thesis requirement, it is possible for a UCD student to graduate without acquiring any experience in research that involves surveying the state of the art through technical and academic journals in English, let alone in a foreign language. A Japanese senior thesis is almost certain to involve foreign language sources, primarily English, but often German or Russian as well.

see President's Commission on Foreign Language and International Studies, *Background Papers and Studies* (Washington, D.C.: Government Printing Office, 1979).

[55] Shūshoku Jōhō Sentaa, *Gi jutsusha wa nani o kangaete iru ka* Tokyo: Shūshoku Jōhō Sentaa, 1983), p. 13. Presumably all university graduates have at least some reading knowledge.

In the electrical engineering program, the required mathematics courses are similar: differential and integral calculus through complex analysis. Statistics and probability receive somewhat more weight in the Kobe case. This does not, however, reflect any special Japanese concern with quality control. It is a local peculiarity.[56] The most important difference in the two programs is that much of the calculus and differential equation material is repetitious in the Kobe case but remedial at UCD. The Kobe student needs calculus and differential equations just for admission. Because of the lax standards that prevail in U.S. high schools, especially those in California, the UCD student is usually studying calculus and more advanced mathematics for the first time.[57]

In nominal terms the Kobe and UCD programs require approximately the same proportion of humanities and social science courses (excluding foreign languages). As is common in Japanese universities, Kobe has a separate faculty and campus for teaching general education courses. These courses are concentrated in the first 1.5 years.

At UCD, a general education program is now being redeveloped after a lapse during which students could select from a menu of courses almost any combination that added to the proper number of credits. Whether this newly formalized general education program proves to be more than the previous smorgasbord system under a new name remains to be seen. General education courses are taught by regular faculty from all departments, with the result that no faculty members are totally involved with the success of the program. Students may take these at their convenience. The model program provided in the UCD College of Engineering *Bulletin* shows these courses scattered over the 4-year program. Clearly, mathematics, science, and specialty courses have priority over general education.

Although at most American universities, general education gets only grudging acceptance from engineering schools,[58] some Japanese writers have given the opposite impression to their readers.[59] This very incorrect

[56] I initially assumed that there was such a relation. Faculty at Kobe quickly corrected me. This was a reminder to me that every "logical connection" of one phenomenon with another is not necessarily based on any organic relation.

[57] The pathetic state of U.S. high school students' mathematics knowledge has been widely documented. For a recent source that indicates little or no improvement, see Curtis C. McKnight, Kenneth J. Travers, and John A. Dossey, "Twelfth-Grade Mathematics in U.S. High Schools," *Mathematics Teacher* 78, no. 4 (April 1985): 292–300. The sample questions given in this article were, in my judgment, *easier* than the questions typical of high school entrance (ninth-grade level) examinations in Japan!

[58] For American views hostile to general education, see "Education," *IEEE Spectrum* 21, no. 6 (June 1984): 128–32; Robert Cole, *Work, Mobility, and Participation* (Berkeley and Los Angeles: University of California Press, 1979), p. 43, n. 9; and Leland Miles, "Liberal Arts in an Age of Technology," *American Education* 20, no. 6 (June 1984): 2–6.

[59] Seki Masao (at Hiroshima University) has written frequently in this vein. See Seki Masao, "Kōgyō daigaku no kadai o kangaeru," *Daigaku ronshū* 13 (1984): 77–102. This article is a Japanese analogue to the American writing that uses a selective picture of Japan to push a particular personal preference.

view comes from looking at the recommendations of curriculum committees and the practices of a few somewhat eccentric schools. The Japanese have been very attentive to the proposals of U.S. curriculum committees. The general education recommendations of the Walker Report (1968) are perhaps more respected in Japan than in the United States.

Considering that in both societies a large number of engineers do move to management positions, the Japanese graduate is probably *somewhat* better equipped for this than his American counterpart. The Japanese engineer has had some exposure to at least two other cultures through language study. His American counterpart has had none. Similarly, the American student has been isolated in high-pressure, technical subjects from his or her first days in college and often feels an inability to "communicate."[60] The low-pressure, general education programs in Japan leave more time for developing "people skills" and for exploring intellectually either through individual reading or group activities, even if formal instruction is typically deadly dull and performance standards minimal.[61] Because Japanese companies pay little attention to grades, the concern of U.S. students that poor performance in a humanities course may drag down their GPA is unknown in Japan.

The nominal titles of specialized courses are nearly identical at Kobe and UCD. Without a course-by-course comparison and extensive monitoring of the actual instruction, it is impossible to say whether similar titles convey similar content. Kobe courses seem to be somewhat more theoretical in orientation that UCD offerings, with somewhat less laboratory work involved. Kobe engineering faculty who have studied and taught in the United States suggested to me that the Japanese approach is more concerned with fundamental science and theory than is the case in the United States.

In this respect, the university continues a pattern evident in high school. Examination pressure leaves Japanese high school students with less free time than in the United States.[62] Tinkering with cars, computers, or ham radios, though not unknown, is less frequent than in the United States. For older engineers, educated before the sharp rise in Japanese incomes, such experimentation was also economically unlikely. Club activities for university students only partially make up for this lack of "hands-on experience." Moreover, there is no Japanese equivalent (at the university

[60] On the desire of U.S. engineers to enter management, see "Do EE Careers Suffer from Poor Management?" *IEEE Spectrum* 21, no. 6 (June 1984): 50–54. On the problems that U.S. engineers have as managers, see M. K. Badaway, *Developing Managerial Skills in Engineers and Scientists* (New York: Van Nostrand, 1982).

[61] For a description of instruction in Japanese general education programs, see Bruce A. Kimball, "Japanese Liberal Education: A Case Study in Its National Context," *Teachers College Record* 83, no. 2 (Winter 1981): 245–61.

[62] See Lawrence P. Grayson, "Japanese Technological Education," *Engineering Education* 74, no. 4 (January 1984): 212, for data on how U.S. and Japanese high school students use their "free" time.

level) for the American "internship" or "work-learn" programs in which students work either full or part time, receiving credit for their activity. The short (6-week) summer vacation in Japan is not conducive to serious corporate work before graduation, and there is no tradition of such employment.

Japanese companies do not expect engineering graduates to possess substantial mechanical skills on graduation. Technician skills (soldering, wiring breadboards, etc.) are taught in corporate boot camps that are also, and more importantly, part of making raw recruits into good (corporate) soldiers.[63] American observers may see this as remedial action to correct for a weak university education.[64] This is not, however, the perception of *large* Japanese firms. Since the early 1960s, there has been no pressure from corporations to make Japanese engineering education more explicitly practical.[65] Moreover, in recent years, the nonvocational, nonspecialized (relative to the United States) bent in Japanese education has come to be seen as a strength.[66]

In volatile markets, firms can only guess at future needs when they hire. Given a strong (though not absolute) commitment to retaining employees even during sharp economic downturns, flexibility is more important than immediately applicable mechanical skills. Studies of Japanese engineers show that within 2–3 years of hiring, more than 40 percent will be following a technical specialty substantially different from that which they studied in college.[67] This is coupled to a strong corporate sense that narrow specialization would work against success in such promising areas as "mechatronics" (the melding of electronics and mechanical devices), fine ceramics, fiber optics, and so on.

Japanese observers and Americans who have studied or experienced both Japanese and American factories have suggested that the answer to poor U.S. performance lies in part in the excessive status of U.S. engineers. Japanese industrial sociologists have noted that engineers in Japan are

[63] The use of military terminology here is deliberate. Many features of large corporations' personnel practices (the wearing of uniforms, morning assemblies, group calisthenics, etc.) appeared first in the late 1930s in Japan as part of the general militarism of the period. These developments are documented in Earl H. Kinmonth, "Militarism and the Middle Classes in Early (1931–1941) Shōwa Japan" (paper presented at the Tōhō Gakkai meeting, Tokyo, May 1985) (available on request). For a recent American description of corporate training practices in a large Japanese electronics firm, see Daun Bhasavanich, "An American in Tōkyō: Jumping to the Japanese Beat," *IEEE Spectrum* 22, no. 9 (September 1985): 72–81.

[64] This view is expressed in John A. Alic, Martha Caldwell, and Robert R. Miller, "The Role of Engineering Education in International Competitiveness," *Engineering Education* 72 (January 1982): 271.

[65] The small-business sector does occasionally call for a more vocational orientation. For the 1960s background, see Pempel (n. 49 above).

[66] This is a recurring theme in recent Japanese works on management.

[67] Iwauchi Ryūichi, *Gakureki shugi wa hōka shita ka* (Tokyo: Nihon Keizai Shinbun, 1980), pp. 112–13.

socially and economically closer to production workers. Indeed, Japanese engineers are physically closer to workers. Engineers assigned to factories have a desk on the shop floor next to the foreman, not an air-conditioned office in a separate building, as is often the case in the United States.[68] Even R & D engineers will not have a private office, or even a private phone.[69]

In many large Japanese companies, all employees, from operatives to president, wear the same uniform. Engineers punch time clocks and are paid by the same hybrid salary plus overtime scheme used for explicitly blue-collar workers.[70] In Japan, engineers and production workers belong to the same union, and the former have little of the (would-be) management versus worker attitude that can be found in the United States. There is no strong demarcation between (clean) design and (gritty) production, nor is there a sharp split between the activities of engineers and technicians. Japanese who observe American firms are struck by the concern with jurisdiction and specialization in the United States and by the failure of American firms to upgrade capable technicians or blue-collar workers to engineer.[71]

Companies consciously work to prevent the development of American-style status consciousness. It is common for engineers to clean their own work areas just as operatives clean the shop floor and elementary school children scrub their classrooms. As one American has observed, this kind of activity, which may go so far as having electrical engineers weed the lawn in front of their research center, "May not seem an efficient way to use trained professionals [but] it certainly helps to quench any sense of elitism among company workers."[72]

In contrast, the high pay and status of American engineers creates a major gulf between them and workers. This manifests itself in contempt. Robert Cole, for example, has noted that U.S. engineers think that they must "idiot-proof" equipment because workers lack the intelligence to have full control over the equipment that they operate.[73] Engineers in

[68] Okuda Kenji, "The Role of Engineers in Japanese Industry and Education," *Journal of Japanese Trade and Industry* 5 (1983): 23–26.

[69] Bhasavanich, p. 77.

[70] These generalizations are based on my own observations of two large engineering firms and conversations with their managers. Also see Bhasavanich. For a comprehensive treatment of Japanese salary schemes in large firms, see Robert J. Ballon, *Salaries in Japan: The System* (Tokyo: Institute of Comparative Culture, Sophia University, 1982). For the historical development of this system, see Kinmonth, "Militarism and the Middle Classes in Early (1931–1941) Shōwa Japan."

[71] Yamada Tomihisa, "Flip Side: Japanese Engineer Takes on US Work," *IEEE Spectrum* 22, no. 9 (September 1985): 78–79. Simillar observations are also found in Kawai Mikio, *Gi jutsu ōkoku Amerika no chōraku* (Tokyo: Nihon Keizai Shinbun Sha, 1981).

[72] Bhasavanich, p. 72.

[73] Cole (n. 58 above), p. 198.

the United States are hostile to unions and blame them for low U.S. productivity.[74]

The greater gulf between engineers and blue-collar workers in the United States is, in part, explained by more fundamental divisions in American society. Engineering in the United States has until very recently been a field primarily associated with midwestern, white males.[75] In 1981, only 2 percent of all employed U.S. engineers were women. Only 1 percent were black.[76] The general U.S. work force is, in contrast, more diverse and contains large blocks of workers who suffer from past (or current) discrimination. Although Japan has several significant minorities, their numbers are so small and the discrimination so total that they do not contribute to a split between blue- and white-collar workers.[77]

Japan, moreover, experienced the literal and figurative leveling of total defeat in World War II. The U.S. policy of indiscriminate bombing of civilian populations in the last years of the war did much to eliminate the physical trappings of status. Executive residences and slums alike were burned in the firebomb raids. The very fact of defeat discredited past managers and leaders. Their status was further undermined by purges and property confiscations. In a sense, the Supreme Commander of the Allied Powers (SCAP) proletarianized a segment of the Japanese elite.

All of these and other factors that can be proposed may pale beside an explanation suggested by looking at placement materials offered graduating students in the two countries. Student newspapers in the United States regularly carry large and striking advertisements by military and aerospace contractors that promise high salaries and exciting work to graduating engineering students. Nothing comparable is seen in Japan. Even firms with a large volume of military business will downplay this fact. A diversified electronics firm is more likely to feature an improved rice cooker than a missile guidance system.[78] This reflects, in part, an extreme difference between the United States and Japan in the proportion

[74] "*Spectrum*/Harris Poll: The Job," *IEEE Spectrum* 21, no. 6 (June 1984): 38–43. In this poll of electrical engineers, 81 percent cited unions as a cause of low productivity.

[75] See Kenneth O. Alexander, "Scientists, Engineers and the Organization of Work," *American Journal of Economics and Sociology* 40, no. 1 (January 1981): 51–66, for the ethnic image of the U.S. engineer. For startling visual confirmation of this tendency, see *Engineering Education* 72 (January 1982): 324–26.

[76] National Science Board (n. 2 above), p. 68.

[77] For the standard works on this subject, see George De Vos and Wagatsuma Hiroshi, *Japan's Invisible Race* (Berkeley: University of California Press, 1967); and Lee Changsoo and George De Vos, *Koreans in Japan* (Berkeley and Los Angeles: University of California Press, 1981). Japan's minorities are concentrated in the Kansai area. Foreigners who study and work in the Kantō (Tokyo) can be completely oblivious to the problem, especially since their Japanese hosts are unlikely to include a ghetto in the itinerary.

[78] Haneda Hiromasa at Kobe University, a specialist in control systems, provided me with a large selection of corporate brochures and pamphlets sent to his students. Examination of these and the student newspapers from the two schools is the basis for this paragraph.

of R & D accounted for by military spending. Roughly 25 percent of all R & D in the United States is devoted to the military.[79] In Japan, 0.6 percent of all R & D is for military purposes.[80]

Military contracts in the United States are often issued without competitive bidding. Profits are commonly guaranteed through "cost plus" contracts. Ordinary economic rationality and competitive forces do not apply.[81] If scientific and engineering employment in the United States roughly parallels R & D spending, this would mean that ordinary cost considerations do not operate in the employment of at least one out of four engineers (and scientists).[82] When employment in oligopolistic civilian sectors that share this attribute (aerospace, petroleum, etc.) are added, it may be that as many as one in three engineers in the United States is employed in industries that are not particularly conscious of personnel or production costs.

In this context, it is important to note that large differentials for engineers existed in Japan in the late 1930s and early 1940s when military contractors were major employers.[83] The compressed compensation range seen in contemporary Japan is very much a post–World War II phenomenon. Those who would describe current Japanese practice as an extension of Japanese traditions would be very hard put to support this thesis from the patterns to be seen in Japanese corporations in the 1930s or earlier.[84]

Are More Engineers the Answer?

The NSF publications and academics cited at the beginning of this paper assume that U.S. economic salvation lies in part in educating more engineers. Neither the Japanese nor the American historical record provides support for this expectation. Japan achieved its present economic success on a far smaller absolute and relative engineering base than did the United States. American productivity and relative technical prowess declined in the 1960s during a period when the proportion of engineers

[79] Calculated from the R & D versus GNP data given in National Science Foundation, *National Patterns of Science and Technology Resources* (n. 11 above), p. 37, tables 17, 19.

[80] Calculated from Kagaku Gi jutsu Chō (n. 21 above), pp. 336–37, table 1. The data are for fiscal year 1982.

[81] The literature on Pentagon irrationality is voluminous. For one recent, thoughtful article by an explicitly conservative critic, see Amitai Etzioni, "Do Defense Contractors Map Our Military Strategy," *Business and Society Review* 51 (Fall 1984): 29–34.

[82] I have tried to err on the conservative side. One congressional report claims, "Between 25 and 35 percent of the total employed scientists and engineers in the country are supported by defense work." Committee on Science and Technology (n. 3 above), p. 154.

[83] For the impact of military procurements on the college job market, see Kinmonth, *The Self-made Man in Meiji Japanese Thought* (n. 35 above), chap. 8, esp. pp. 307–8.

[84] The classic and still persuasive debunking of those who would describe postwar Japanese practice are "traditional" is found in Taira Koji, *Economic Development and the Labor Market in Japan* (New York: Columbia University Press, 1970).

in U.S. management, already much higher than that of Japan, was increasing.[85]

Although it is possible that a certain supply of engineers is necessary for economic growth, there is no guarantee that an increase will lead to still more growth. This is particularly true in the United States, where production engineering has had very low status. As a recent *Business Week* special observed, the United States does not seem to be suffering from any major shortage of engineering skill. Rather, "The basic problem is that US high tech companies are no longer consistently able to translate their technology into competitive products."[86]

If military spending is the chief cause of inflated engineering salaries, concern with graduate numbers or the content of engineering education seems irrelevant to U.S. problems. As long as salaries remain excessive, the gap between engineer and worker is unlikely to close. As long as the military, with its performance-at-any-cost mentality, remains a major employer of engineers, it is unlikely that they will develop the concern with efficient production that is so characteristic of Japanese engineers and firms. Given the trend to multinational business and the rise of Japan and other countries to technical rivalry with the United States, it would seem questionable whether more monolingual engineers with a narrow technical specialization built on a shameful high school education will in fact improve U.S. economic performance. This is an even more improbable outcome if any increment is taken for military R & D that makes at best a limited and delayed contribution to the civilian economy.

Nothing will be learned from Japan if agencies such as NSF push policy recommendations based on works such as the so-called Finniston Report. Apparently the original source for most of the claims questioned here, this report contains an explicit disclaimer that its information about foreign (non-British) cases comes from unverified impressions based on flying visits.[87] Although naive and in some cases sloppy use of statistical sources in NSF publications was identified as a problem as early as 1972, the treatment of Japan discussed here shows that little has been done to bring science or even common sense into the use of statistics in NSF publications.[88]

[85] For data on the change in the proportion of U.S. executives having engineering and scientific backgrounds, see Patricia Bonfield, *U.S. Business Leaders: A Study of Opinions and Characteristics* (Washington, D.C.: Conference Board, 1980), p. 39.

[86] "America's High-Tech Crisis," *Business Week* (March 11, 1985), p. 45.

[87] See *Engineering Our Future* (n. 23 above), pp. 209–14. No British experts on Japan appear to have been included in the commission that prepared this report. Although it does include a strong disclaimer, NSF writers seem to have totally ignored this. Other sources used were "conversations" with Japanese embassy officials. See *Science and Engineering Education* (n. 41 above), p. 61, esp. nn. 5–8, 20–24.

[88] William Kruskal, "Taking Data Seriously," in *Toward a Metric of Science: The Advent of Science Indicators*, ed. Yehuda Elkana et al. (New York: Wiley, 1978), discusses the problems with the 1972 edition of *Science Indicators* (n. 2 above).

The readiness of NSF researchers and some academics to repeat extreme, unfounded claims about Japan would be laughable in some situations but is dangerous in the present context. With the acceptance of such claims, Japan may well become something of a second Sputnik, a stimulus to engineering and science education but of a type that does not lead to an increase in American industrial productivity. The United States can ill afford still greater diversion of limited financial and intellectual resources into areas that have been responsible for weakening the U.S. industrial base.