Accumulating Education and Experience in a Global Economy: Foreign Direct Investment, National S&T Strategies, and Indigenous Innovation in Asian Development

William Lazonick
Center for Industrial Competitiveness
University of Massachusetts Lowell

william_lazonick@uml.edu

March 2009

This paper draws on chapter five in my forthcoming book, Sustainable Prosperity in the New Economy?: Business Organization and High-Tech Employment in the United States, Upjohn Institute for Employment Research, 2009. An earlier and much abridged version of this paper appeared as "Globalization of the ICT Labor Force," in Robin Mansell, Christanthi Avgerou, Danny Quah, and Roger Silverstone, eds., The Oxford Handbook of Information and Communication Technologies, Oxford University Press: 75-99. I would like to thank Bob Bell, Isa Cann, He Gao, Mustafa Erdem Sakinc, Öner Tulum, and Yue Zhang for research assistance.

Development Dynamics in a Global Economy

Since the 1960s the development strategies of national governments and indigenous businesses in Asian nations have interacted with the investment strategies of US-based high-tech companies as well as US immigration policy to generate a global labor supply of educated and experienced high-tech labor. This process has entailed flows of US capital to Asian labor as well as flows of Asian labor to US capital. As a result, new possibilities to pursue high-tech careers, and thereby develop productive capabilities, have opened up to vast numbers of individuals in Asian nations. Many found the relevant educational programs and work experience in their home countries. But many gained access to education and experience by following global career paths that included study and work abroad, especially in the United States.

For a nation in the process of development, these global career paths have posed a danger of "brain drain": the career path could come to an end in the United States (or another advanced economy) rather than in the country where the individual had been born and bred. At that same time, for nations such as South Korea, Taiwan, China, and India that at certain stages of their development have experienced brain drain, the education and experience that their nationals acquired abroad created valuable "human capital" that could potentially be lured back home. A major challenge for these Asian nations has been the creation of domestic employment opportunities through a combination of strategic government initiatives, foreign direct investment (FDI), and the growth of indigenous businesses, that would enable the career paths of global nationals to be followed back home, thus transforming a potential "brain drain" into an actual "brain gain".

This paper analyzes the interaction the key elements of the development dynamic that, based on investments in education "ahead of demand", has enabled a number of Asian nations, including China, Hong Kong, India, Malaysia, Singapore, South Korea, and Taiwan, to experience rapid economic growth over the past quarter century or so. In the next section I discuss the investments in education that these nations made. Then I show how, in the absence of sufficient domestic employment opportunities for college-educated natives, these nations experienced a "brain drain". I then document how foreign direct investment in the microelectronics industry from the 1960s created high-tech employment opportunities in these nations that began to staunch the brain drain. Next I present a case study of how, in South Korea, the creation of national research institutes and the emergence in indigenous companies as world-class competitors in the late 1980s reversed the brain drain as expatriate Koreans who had accumulated education and experience abroad found it attractive to return home. Next I recount how Malaysia's development strategy, officially launched with the opening of the Bayan Lepas Free Trade Zone (BLFTZ) in Penang in 1972, resulted in sustained growth for indigenous, and increasingly more educated, high-tech labor over the ensuing decades, but, lacking the emergence of major indigenous companies, was unable to generate the growth experience of nations such as South Korea and Taiwan. I then turn to the case of India, a nation with perhaps the most unequal education system in the world, but one in which the growth of the IT services sector since the early 1990s has provided employment for college-educated people who would have otherwise either gone abroad or have joined the ranks of the educated unemployed. The final national case study is that of China, a vast country that through the interaction of a national development strategy, the growth of indigenous high-tech enterprises, and massive foreign direct investment, is reshaping the global economy. I conclude by comparing and contrasting the interaction of national strategy, FDI, and indigenous innovation in the growth of these Asian nations, and highlight the basic problem that this growth poses to economic development in the United States.

Education and Growth in Asia

Between 1970 and 2000, real GDP per capita increased 7.5 times in South Korea, 5.4 times in Taiwan, 4.7 in Singapore, and 3.7 in Hong Kong. In the process these four nations became known as the "Tiger economies". During this period Japan, starting from a much higher base than the four Tigers, saw its real GDP per capita rise 2.2 times while that of the United States rose 1.9 times. Over these three decades Japan's GDP per capita increased from 35 percent to 75 percent of that of the United States, Korea's from 13 percent to 51 percent, Taiwan's from 20 percent to 59 percent, Singapore's from 30 percent to 79 percent, and Hong Kong's from 38 percent to 76 percent (Maddison 2007). The increases in wages that these higher levels of GDP per capita both permitted and reflected did not undermine the competitive advantage of Japan or the Tiger economies. On the contrary, by further mobilizing the skills and efforts of the indigenous labor force as well as increasing the extent of domestic product markets that enjoyed a degree of protection, rising wages were integral to the dynamics of economic growth.

These cases of rapid growth entailed active and purposeful government initiatives to build communications and educational infrastructures, and develop domestic high-tech knowledge bases. National and local governments also provided subsidies to business enterprises, both foreign and domestically owned, to make use of these infrastructures and knowledge bases to generate products that could ultimately be competitive at home and abroad.[1] These government and business investments in high-tech capabilities created large numbers of indigenous high-tech employment opportunities. Insofar as these investments generated higher productivity than previously, they contributed to the economic growth of the nation.

In general, a portion of these productivity gains accrued as higher returns to labor, thus eliminating to some extent the low-wage advantage that the nation may have had. Given the presence of other lower wage nations in the process of developing their productive capabilities, economic growth that results in higher wages creates an imperative to "upgrade" employment opportunities by moving into higher value-added activities. As part of a dynamic national investment strategy, the emergence of ever more remunerative high-tech employment opportunities may be both cause and effect of sustained economic growth.

The most fundamental, and expensive, expenditure of a government that seeks to support economic development is investment in a system of primary, secondary, and tertiary education. In the case of Japan, investments in education that began in the late 19th century laid the foundations for the nation's economic transformation from the 1950s. With laws dating back to 1886 that made primary education universally free and compulsory, by 1909 98 percent of all Japanese school-age children went to primary school (Koike and Inoki 1990, 227-228). Japan also developed a system of

[1] See for example Amsden 1989; Wade 1990; Branscomb and Choi 1996; Hobday 1995; Kim 1997b; Jomo et al. 1999; Lu 2000; Mathews and Cho 2000; Ernst 2002; Amsden and Chu 2003; Saxenian 2006; Breznitz 2007; Lazonick 2007.

higher education from the late nineteenth century that sent its graduates into industry (Yonekawa 1984). Additionally, from the late 19th century, Japanese companies engaged in the practice of sending university-educated employees abroad for extended periods of time to learn about Western technology (Fukasaku 1992; Matsumoto 1999). Of utmost importance to Japan's post-World War II development was the fact that for decades Japanese industrial enterprises had made university-educated engineers integral to their managerial organizations (Morikawa 2001, 62-63).

These investments in education meant that in 1960 only 2.4 percent of Japan's population, aged 15 and over, had no schooling while on average Japan's population had 7.8 years of schooling (the US figures were 2.0 percent with no schooling and 8.5 years of schooling on average). By contrast, in 1960 the no-schooling proportions were South Korea, 42.8 percent; Taiwan, 37.3 percent; Singapore, 46.2 percent; and Hong Kong, 29.7 percent; while the average years of schooling of these populations were South Korea, 4.3; Taiwan, 3.9; Singapore, 4.3, and Hong Kong, 5.2 (Barro and Lee 2000). A major challenge that faced the would-be Tigers, and other Asian nations such as Malaysia, Indonesia, the Philippines, and Thailand, was to transform their national educational systems into foundations for industrial development.

South Korea dramatically transformed its educational system after 1960. The average years of schooling of South Korea's 15-plus population rose from 7.9 years in 1980 to 10.8 in 2000, surpassing Japan's 2000 figure of 9.5 and not far behind the US figure of 12.0. By last half of 1990s South Korea had the highest number of Ph.D.s per capita of any country in the world (Kim and Leslie 1998, 154).

India, a nation with 680 million people aged 15 or over in 2000 compared with Korea's 37 million, has not experienced such as dramatic transformation of its mass education system. In 1960 the Indian 15-plus population included 72.2 percent with no schooling, and had on average 1.7 years of schooling. By 2000 India's no-schooling figure remained high at 43.9 percent, while the average years figure was only 5.1. With one-sixth of the world's population, in the first half of the 2000s India had over one-third of the world's illiterates (EFA Global Monitoring Report 2006, 276, 278, 284-287).

Yet, at the same time, India has become a leading source of supply of engineers and programmers to the global ICT labor force. The stage was set by government investments made in the 1950s and 1960s, of which the decision to create a number (originally four) Institutes of Technology, modeled on the Massachusetts Institute of Technology, stands out (Sebaly 1972; Bassett 2005).[2] The first Indian Institute of Technology (IIT) was founded at Kharagpur, West Bengal in 1952 (Shenkman 1954, 28; Bassett 2005). A 1959 Act of Parliament established IIT Kanpur, which became the leading technological institute in India. From 1962 to 1972 IIT Kanpur received assistance from the Kanpur Indo-American Programme (KIAP), through which a consortium of nine US universities assisted in setting up research laboratories and academic curricula.

In the late 1960s India was only second to the United States in the number of students in universities, even though on a per capita basis the number of university students in India was extremely low (Ilchman 1969, 783). Notwithstanding the important

---

[2] http://www.iitkgp.ernet.in/institute/history.php.

contribution of the IITs to the creation of an elite corps of engineering graduates, Indians graduates were more numerous in the natural sciences. For 1975-1990 India's 1,907,944 bachelor's degrees in natural sciences represented over 97 percent of the US total, and, by the late 1980s, India was granting more such degrees annually than the United States. India's output of undergraduate engineers was less prodigious, but significant nonetheless, rising from 35 percent to 45 percent of the annual number of US engineering graduates from 1975 to 1990 (National Science Foundation 1993, Appendix, Table A-3).

China, by contrast, focused much more on producing engineers than natural scientists. The total Chinese output of undergraduate engineers for 1982-1990 (the period for which Chinese data are available) exceeded the totals for 1975-1990 of Japan by 29 percent, United States by 35 percent, and the combined numbers of Taiwan, Korea, and India by 72 percent. From 1975 to 1990, South Korea quadrupled while Taiwan and India both doubled their annual outputs of engineering bachelor's degrees. Between 1990 and 2000 India increased its total enrollments in engineering from 258,284 to 576,649,[3] while China increased its undergraduate engineering degrees awarded from 114,620 to 212,905, and South Korea from 28,071 to 56,508. Perhaps more significantly, in the first four years of the 2000s, China more than doubled its undergraduate engineering degrees, awarding 442,463 in 2004. Over the same period South Korea increased its undergraduate engineering degrees to 70,034 (National Science Board 2004, Appendix Table 2-34; National Science Board 2008, Appendix Table 2-38).

Table 1 shows the number of science and engineering doctorates awarded per 100,000 population age 25-34 years for the most recent year available in five leading Asian countries and the United States. While, by this measure, the United States outstrips the five Asian nations in the physical and biological sciences, it lags behind South Korea, Japan, and Taiwan. At a much lower level of doctorates per capita, China and India are about even in the sciences but China is far ahead of India in engineering. China, moreover, is catching up. In 2001 the ratio of engineering doctorates in China was only 1.8 per 100,000 population aged 25-34 years, while in the United States this ratio was 13.9 (National Science Board 2004, Appendix Table 2.36).

Table 1. Doctoral degrees awarded per 100,000 population, age 25-34, most recent available year, selected Asian countries and the United States

Country	Year	All S&E fields	Physical/ biological sciences	Engineering
China	2004	10.1	3.1	5.5
India	2003	4.6	3.3	0.6
Japan	2005	41.3	8.3	21.1
South Korea	2004	44.0	9.8	25.4
Taiwan	2005	37.0	7.2	20.2
United States	2006	66.2	25.1	14.6

Sources: National Science Board 2008, Appendix Table 2-40; Population statistics from US Census Bureau, International Data Base, available at http://www.census.gov/ipc/www/idb/summaries.html

[3] Statistical Abstract India, 2002 and 2003 at http://mospi.nic.in/mospi_cso_rept_pubn.htm.

Brain Drain

The US figures, however, include large proportions of people, especially from Asia, who were not US citizens or permanent residents. Already in the period 1964-1970 there were on average 25,656 foreign engineering students on non-immigrant visas studying in the United States, of whom 18.6 percent were from China and Taiwan, 16.2 percent from India, and 2.5 percent from South Korea. In 2003-2004, of the 279,076 foreign graduate students in the United States, 66.0 percent were from Asia, with 22.6 percent of the total from India and another 18.2 percent from China, followed by 8.9 percent from South Korea and 5.4 percent from Taiwan (Institute of International Education 2005). In 2005 foreign citizens on temporary visas earned 43.6 percent of the engineering master's degrees awarded in the United States, compared with 33.9 percent in 1995 and 38.2 percent in 2000, while they also earned 58.6 percent of the engineering doctoral degrees, compared with 42.1 percent in 1995 and 46.0 percent in 2000. In 2005, in mathematics and statistics, foreign citizens on temporary visas earned 38.6 percent of the master's degrees and 50.0 percent of the doctoral degrees, while in computer sciences these figures were 42.0 percent and 52.7 percent respectively (National Science Board 2008, Appendix Tables 2-30 and 2-32). In 2007, among graduate students in the United States on temporary visas, Indians and Chinese represented 44.0 percent and 20.3 percent respectively in engineering, 10.5 percent and 41.5 percent in mathematics, and 55.2 percent and 15.0 percent in computer sciences (National Science Board 2008, Appendix Table 2-24).

In 2002-2005, of all non-US citizens who received US engineering doctorates, 46 percent had "definite plans to stay" in the United States after graduation, compared with 51 percent in 1998-2001. The proportion of Chinese with these intentions was 56 percent and Indians 63 percent, compared with 62 and 70 percent respectively in 1998-2001 (National Science Board 2008, Appendix Table 2-33). The greater ease with which graduates on temporary visas were able to secure "green cards" from the late 1990s may also have been a factor in keeping these numbers high (see Vaughan 2003). Insofar as foreign university graduates stayed in the United States to pursue careers, they became part of their home country's brain drain.

An investment in high-tech education can only make an immediate contribution to the growth of a developing nation if there are employment opportunities in the domestic economy that can make productive use of the labor that has been educated. Employment experience in turn augments the productive capabilities of the domestic labor force, especially in industries that make use of sophisticated technologies. The problem of high-tech brain drain occurs when a developing nation invests in the education of scientists and engineers (S&E), but the most attractive employment opportunities for these university graduates are abroad rather than at home.

The S&E brain drain was a major problem in the 1960s and 1970s for the developing Asian economies (see Adams 1968; Van der Kroef 1968; Fortney 1970; Pernia 1976). In the late 1960s Asia surpassed Europe as the main source of scientists and engineers coming to the United States from abroad (Schmeck 1973). The United States stood accused of taking the best that the newly industrializing countries had to offer, thus building US high-tech capabilities at the expense of economies that could ill afford it.

Encouraging the Asian brain drain was the US Immigration and Naturalization Law of 1965 that abolished the national quota system in favor of preference to people whose skills could be "especially advantageous" to the United States (Fortney 1970, 217). Of the 41,652 professional, technical, and kindred workers who immigrated to the United States in 1967, engineers, at almost 21 percent of the total, represented the largest single group. In 1966 the 4,921 new immigrant engineers were equivalent to 9.5 percent of the new graduates of US engineering institutions (Fortney 1970, 219). As Judith Fortney (1970, 218) summed up the change: "The old law discriminated severely against all residents of 'coloured' countries, especially those of Asia. Immigrants from Asia in the professional, technical, and kindred worker category more than doubled between 1965 and 1966 (2,078 to 5,628) and again between 1966 and 1967 (5,628 to 12,282)."

Over 30,000 college graduates went abroad from Taiwan between 1956 and 1972, with only 2,586 returning (Ho 1975, 40). Nearly 60 percent of those who left Taiwan had science or engineering educations, and they tended to be the best students, thus exacerbating that nation's loss. In the 1950s and 1960s South Korea also had a serious brain drain. In the period 1953-1972 10,412 students, of whom 5,376 were in science and engineering, requested permission from the Korean Ministry of Education to study in the United States, with over 90 percent not returning after graduation (Yoon 1992, 6). Between 1974 and 1988 the number of immigrant scientists and engineers as a proportion of all scientists and engineers in the United States increased from 5.8 percent to 10.5 percent, with the five leading sources being India, UK, Taiwan, Poland, and China (Arnst 1991; North 1995, 6).

The US Immigration Act of 1990 increased the annual number of employment-based visas that could be issued (including family members) from 54,000 to 140,000. The "employment-based preferences" (EBP) class represented 11.6 percent of the immigrants admitted during 1996-2000 and 15.7 percent during the period 2001-2004, notwithstanding a large, but temporary decline in EBP admissions in 2003. From 1996 through 2004 454,000 Indians received green cards, with 190,000 of these admissions being EBP. Indians received 8.4 percent of the EBP visas in 1996, 21.8 percent in 2001, and an average of 24.7 percent in 2002-2004, before falling to 19.3 percent in 2005 and 10.8 percent in 2006, and 12.3 percent in 2007 (US Immigration and Naturalization Service 1997-2001; US Department of Homeland Security 2002-2007). Before 1998, when India led with 12.3 percent of EBP visas, China had been the largest recipient with 13.9 percent in 1996 and 15.4 percent in 1997. In 2002-2004 China received 10.6 percent of these visas, falling to 8.4 percent in 2005, 6.0 percent in 2006, and 6.8 percent in 2007.

H-1B and L-1 non-immigrant work visas have also been of great importance in enabling the flow of educated Asians to the United States for high-tech employment. Indians have been the top nation in terms of numbers of H-1B visas issued since 1993 when they surpassed Filipinos (US Department of State 1997-2006). In 2000-2003 Indians received 57.0 percent of the 547,000 initial H-1B visas and 48.0 percent of the 457,000 continuing visas issued (US Department of Homeland Security 2002-2004). Chinese were a distant second with 9.5 percent of the initial and 7.7 percent of the continuing visas. Over the decade from 1997 to 2009, Indians received 43.5 percent of all H-1B visas issued, followed by the British and Chinese each with 5.5 percent.

Indians have also been the leading recipients of L-1 visas since 2000, when they surpassed both the Japanese and British (US Department of State 1997-2006). Traditionally it has been multinational companies (MNCs) based in *advanced* nations that have dominated the L-1 visa category. The proportion of L-1 visas that went to Indians climbed dramatically from 4.5 percent in 1997 to 38.1 percent in 2005 and 43.8 percent in 2006 (US Department of State, 1997-2006). The next closest in 2006 were British with 8.7 percent, Japanese with 7.0 percent, and Germans with 4.2 percent. Indians, therefore, have become the leading source of both immigrant and non-immigrant entrants to the United States in search of work as well as education.

H-1B visas are predominantly high-tech visas. In FY2000-2003, 98 percent of visas were issued to people with at least bachelor's degrees. In FY2003, 50 percent had bachelor's degrees, 31 percent master's degrees, 12 percent doctorates, and 6 percent professional degrees. At 39 percent of the total, the largest occupational category among visa holders was "computer-related", followed by "architecture, engineering, and surveying" (12 percent), "education" (11 percent), and "medicine and health" (11 percent) (US Department of Homeland Security 2002-2004).

Under the Immigration Act of 1990, which amended earlier legislation, an H-1B visa is issued for an initial period of three years, with the possibility of reapplying for extension for another three years. H-1B visa holders can apply for permanent resident (that is, immigrant) status, and employers of H-1B visa holders often sponsor the non-immigrant for permanent resident status. Under the American Competitiveness for the 21st Century Act of 1998, H-1B visa holders can obtain one-year extensions while waiting to become permanent residents, prompting some to contend that H-1B is a "pre-immigrant" rather than "non-immigrant" program. In 2001 more than 228,000 non-immigrant visa holders became permanent residents (Vaughan 2003). Alternatively, former H-1B visa holders who have been out of the United States for at least one year can obtain take a job with a new H-1B visa, valid for three years, again with the possibility of a further three-year extension (Yale-Loehr 2003a).

Created in 1970, the L-1 visa category enables a MNC, whether US or non-US, to bring foreign employees from abroad to work for the company or an affiliate in the United States. The sponsoring firm must have employed an "intracompany transferee" continuously for one year in the previous three years "in a managerial or executive position or in a position where she gained specialized knowledge" (Yale-Loehr 2003b). Executives and managers enter on an L-1A visa, and can work in the United States for up to seven years, while employees with specialized knowledge enter on an L-1B visa and can work for up to five years.

There is no limit to the number of L-1 visas that can be issued. Such was also the case with H-1 visas prior to the Immigration Act of 1990.[4] During the 1980s H-1 visas began to be widely used. The number of H-1 visas issued doubled from around 10,000 in 1969 to 20,000 in 1979, and then climbed to almost 49,000 in 1989 (Lowell 2000, 3). In October 1990, prior to the passage of the 1990 Act, Electronics Weekly reported:

---

[4] The H-1 visa for foreigners of "distinguished merit and ability" became known as the H-1B visas when a special category of H-1A visas was created for registered nurses under the Immigration Nursing Relief Act of 1989 (Mailman and Yale-Loehr 2003).

> US electronics companies are worried about proposed changes in US immigration laws that will limit the number of foreign staff they can hire. US electronics companies rely heavily on electronics engineers and other skilled staff from abroad….A proposed law passed by the House of Representatives proposes a limit of 25,000 H-1B visas per year. Currently, there is no quota on H-1B visas and as many as 45,000 are granted each year.[5]

The British magazine, Computing, warned: "Jobs for thousands of UK programmers/ analysts threatened by immigration bill limiting work visas". The article quoted Charles Sporck, CEO of National Semiconductor, as saying that in some parts of his company "at least a third of the staff are from overseas," and also cited a Microsoft representative as saying his company relied heavily on foreign programmers (Foremski 1990).

In the ultimate passage of the Immigration Act of 1990, however, business interests prevailed. The Bill that was enacted set the annual cap of initial H-1B visas at 65,000, about 16,000 *more* than the number issued in 1989, rather than the 25,000 cap that labor interests had been advocating. The change was influenced by lobbying efforts from the business community, including immigration lawyers (see, for example, Szabo 1989). In November 1990, on the eve of the signing of the new Immigration Act by President George Bush, Harris N. Miller, coordinator of the Business Immigration Coalition, representing 250 companies and business associations formed to lobby for the new bill, told a New York Times reporter: "We're very concerned about shortages of skilled people, particularly in the sciences and engineering, computer science and mathematics" (DePalma 1990). In 1991, with the Immigration Act in place, Miller remarked: "We were successful because we refashioned the debate from the jobs displacement issue, where we always lost, to the competitive issue" (Lee 1991).

In 1995 Miller became president of the Information Technology Association of America (ITAA). As a leading trade association for the ICT industries that was in the forefront of lobbying efforts that helped to secure the American Competitiveness and Workforce Improvement Act of 1998. This legislation raised the annual H-1B cap to 115,000 initial visas in fiscal years 1999 and 2000.[6] The American Competitiveness for the 21st Century Act of 2000 raised the annual cap to 195,000 initial visas in FY2001-2003. As of October 1, 2003 the annual cap of 65,000 was restored, but with an extra 20,000 visas available to foreign-born professionals who have an advanced degree from a US institution of higher education.[7]

In 2007 and 2008, Congress debated an increase in the H-1B cap. Any changes in the H-1B cap, however, would now have to be enacted as part of Comprehensive Immigration Reform, legislation that includes a process for legalizing the status of illegal immigrants, almost all of whom are poorly educated and low paid. In effect,

---

5 "New visa limit could restrict companies' employment of foreign staff," Electronics Weekly, October 24, 1990, 8.

6 The relevant fiscal year runs from October 1 to September 30.

7 "USCIS reaches H-1B cap," US Citizenship and Immigration Services Press Release, August 12, 2005. Of the 65,000 visas that can be issued annually, 6,800 are set aside for Chile and Singapore under the terms of US trade agreements with those countries. If any of these 6,800 visas are unused, they are added to the next year's visa cap.

high-tech business interests found their efforts to have the H-1B cap raised stalled by the failure in Congress to secure the votes for reform of illegal immigration laws.

Advocating the H-1B increase was Compete America, an association that among its 16 company members includes Analog Devices, Cisco Systems, Google, Hewlett-Packard, Intel, International Rectifier, Microsoft, Motorola, National Semiconductor, Oracle, QUALCOMM, and Texas Instruments.[8] In Congressional hearings in 2007, Bill Gates of Microsoft argued:

> Unfortunately, America's immigration policies are driving away the world's best and brightest precisely when we need them most. The terrible shortfall in our visa supply for the highly skilled stems not from security concerns, but from visa policies that have not been updated in over a decade and a half. We live in a different economy now. Simply put: It makes no sense to tell well-trained, highly skilled individuals – many of whom are educated at our top colleges and universities – that the United States does not welcome or value them. For too many foreign students and professionals, however, our immigration policies send precisely this message (quoted in Elstrom 2007).

An argument against raising the H-1B cap came from information released by two US Senators, Charles Grassley of Iowa and Richard Durbin of Illinois, that showed that in 2006 Indian IT services companies represented four of the top five, and ten of the top twenty, users of H-1B visas.[9] The top four India-based companies – Infosys Technologies, Wipro, Tata Consultancy Services (TCS), and Satyam Computer Services – held a combined total of 14,836 H-1B visas. In 2007 H-1B visas were more widely distributed, but Infosys still led the list of successful applicants with 4,559 petitions approved, while Wipro was second with 2,567, Satyam third with 1,396, and TCS sixth with 797 – a four-company total of 9,319. These companies were also large-scale users of L-1 visas, with TCS leading with 4,887 visas in 2006. Cognizant Technology Solutions, a New Jersey-based spinoff of Dun & Bradstreet that employs about three-quarters of its workforce in India, was in 2006 the second largest user of L-1 visas and sixth largest user of H-1B visas.[10] Indeed, almost all of the US-based ICT firms that employ large numbers of non-immigrants on H-1B and L-1 visas in the United States have significant numbers of employees in India as well.

FDI in Stems the Asian Brain Drain

Over the last four decades of the 20th century, therefore, the career paths of vast numbers of well-educated people from around the world, and especially Asia, took them to the United States for specialized education and specialty occupations. The challenge that faced the developing nations that experienced this brain drain was to create employment opportunities that could bring these people, with their enhanced capabilities, back home, or alternatively, to create employment opportunities at home so that educated individuals would not need to go abroad to develop their capabilities and establish a high-tech career.

---

[8] http://www.competeamerica.org/whoweare/coalition/index.html.

[9] http://grassley.senate.gov/public/index.cfm?FuseAction=Issues.View&Issue_id=162d578c-0862-4135-a0ed-da0f73a9fee2

[10] "Two Indian BPO firms in world's 'hot growth' companies list," Press Trust of India, May 28, 2007.

Historically, a key source of these employment opportunities in Asian nations occurred from the 1960s when US microelectronics companies offshored semiconductor assembly operations. Subsequent to the invention of the transistor at Bell Labs in 1947 and with the support of Cold War military spending, an array of US companies including Western Electric, Raytheon, GE, RCA, Westinghouse, IBM, Texas Instruments, Motorola, and, from 1957, Fairchild Semiconductor, made the United States the center of the global semiconductor industry (Tilton 1971). From the late 1950s, however, US companies began to feel competitive pressure in the production of transistors from the Japanese, who had successfully transferred the technology from the United States (Flamm 1985, 70). By the early 1960s US semiconductor manufacturers began to consider the option of doing labor-intensive assembly work in low-wage offshore locations.

In a memoir published in 2001, Charles Sporck (2001, 95), who had been head of manufacturing at Fairchild Semiconductor from 1961 to 1967 before becoming CEO of National Semiconductor, recalled how in the early 1960s Fairchild had pioneered in offshoring the assembly of transistors to Asia:

> Fairchild's establishment of a Hong Kong facility in 1963 was the first Southeast Asian manufacturing venture of any American semiconductor company. The plant provided an immediate cost advantage in both direct labor and overhead, and overnight it challenged the wisdom of most investments in assembly automation by TI, Motorola and others. In fact, we started a trend toward assembly plants in Southeast Asia that was adopted by many other companies as time went by.

In 1971 a United Nations research report could state: "Every established United States semiconductor firm appears to be engaged in some offshore assembly without exception" (Chang 1971, 17). The report listed 33 offshore facilities established during 1963-1971 by 22 different US semiconductor companies, of which eight, with 16 offshore plants among them, were based in Silicon Valley (Chang 1971, 19-20). From 1972 Malaysia became a favored location for semiconductor assembly, with Hewlett-Packard and Intel being among the first to open plants in the new Free Trade Zone in Penang. In 1974 Malaysia hosted 11 US-owned semiconductor facilities, South Korea nine, Hong Kong eight, Taiwan three, and the rest of Asia six, while there were 15 US facilities in Latin American countries, primarily Mexico (Davis and Hatano 1985, 129).

By 1970 almost all of the assembly work in semiconductors that still remained in the United States was automated. But rapid changes in technology that rendered automated processes obsolete combined with the availability of hard working, low-wage labor to favor the use of labor-intensive methods in a number of developing countries. By the first half of the 1980s US-based merchant producers did 80 percent of their semiconductor assembly offshore, while much of the assembly operations that remained in the United States were for military purposes (Davis and Hatano 1985, 129).

US tariff policy facilitated the offshoring movement. Sections 806.30 and 807 of the Tariff Schedule of the United States permitted goods that had been exported from the United States for foreign assembly to be imported with duty charged only on the value-added abroad. In 1967 dollars, "806/807" imports of semiconductors to the

United States increased from $130 million in 1969 (accounting for 95 percent of all semiconductor imports into the United States) to $2,267 million in 1979 (79 percent) to $3,368 in 1983 (69 percent) (Flamm 1985, 74).

As late as 1974 Mexico was the most important single national location for 806/807 semiconductor exports, but from 1975 its share eroded sharply (Flamm 1985, 76). In 1970 the average hourly wage in semiconductor assembly in Singapore, Hong Kong, and Korea was less than one-tenth that in the United States, and about half that in Mexico (Chang 1971, 27; Sharpston 1975, 105). The relatively high value and low weight of semiconductor products meant that the proximity of Mexico to the United States did not offer an appreciable transportation advantage over an Asian location (Moxon 1974, 35-36; Flamm 1985; Davis and Hatano 1985, 129). Within Asia during the 1970s and early 1980s there was a marked shift of 806/807 activity from Hong Kong to Malaysia and the Philippines, while South Korea and Singapore sustained substantial market shares. In 1985 there were 63 US semiconductor plants in East Asia, employing just under 100,000 people (Scott 1987, 145, 147; Henderson 1989, 54, 59).

Although the impetus to offshore chip assembly was the search for low-wage labor, the lowest-wage Asian locations such as Indonesia and Thailand did not dominate. Other considerations, most notably political stability and the productivity of labor, entered into plant location. In 1967, for example, James Stokes, the head of Signetics Korea, offshored from Silicon Valley, was quoted as saying:

> If we had been looking only for cheap wages, we could have gone to Africa. After only a couple of weeks of training, these girls are ready to work on a machine completely new to Korea. This is much faster than we anticipated. Another thing I like about Koreans is that they're very hard workers. They're used to hard work and they don't mind working long hours." [11]

In 1970 George Needham, director of Motorola's assembly plant on the outskirts of Seoul told plant visitors that a Korean female worker could be taught to assemble semiconductors in two weeks less than her American counterpart. "The girls here are more motivated," Needham was quoted as saying. "Life is tough in this country. These people really need this work." He claimed that production costs in South Korea were one-tenth of those in a similar Motorola plant in Phoenix, Arizona, the headquarters of the company's semiconductor operations (Shabecoff 1970, 57).

In the 1960s and 1970s, however, South Korea and many other Asian nations had more to offer MNCs than just low-wage, hard-working female labor for assembly operations. Of great significance for the persistence of these offshored investments even as wage levels rose was the fact that when in the 1960s and 1970s foreign semiconductor companies employed relatively low-wage (female) labor to perform low-skill production jobs, they could find relatively low-wage (male) labor to perform *high-skill* engineering and managerial jobs. By the mid-1980s all of these Asian economies were on the way to transforming themselves from relatively low-wage to relatively high-wage economies. The availability of an indigenous supply of high-skill labor was critical for upgrading productive capabilities so that the ICT industries

[11] "Low wages in Korea attracting foreign investors," New York Times, January 20, 1967

of these nations, and the offshored facilities, could remain competitive in a higher wage environment.

The importance of this high-skill labor, even in the early 1960s, is evident in Charles Sporck's follow-up to his statement, quoted above, about Fairchild's 1963 entry into Hong Kong in search of low-wage assembly workers (Sporck 2001, 95):

> Although we went to Hong Kong for direct labor savings, we found that we could hire engineers and other overhead people at dramatically lower costs as well. In many cases, they had been educated and trained in the United States and they were highly capable technicians and supervisors. Their availability and their overall caliber made the decision to go offshore immediately successful.

The fact that qualified indigenous engineers were available to the US semiconductor companies when they offshored their assembly operations in the 1960s and 1970s is of great importance for understanding what in the early 1990s the World Bank (1993) would call, with considerable mystification, the "East Asian miracle." The type of economic transformations that occurred in Asia depended on the availability of both a highly educated, high-tech labor force and employment opportunities that would enable the members of this labor force to contribute to the growth process. The transformations in productive capabilities that occurred in South Korea, Taiwan, Hong Kong, Singapore, and Malaysia from the 1970s and in the world's two most populous nations, India and China, since the 1980s were the results of the interaction of the investment strategies of developmental states, innovative enterprises, and educated individuals in the pursuit of high-tech careers.

South Korea's Reversal of the Brain Drain

In its 1993 report on the development of Asia's human resources in science and technology, the National Science Foundation (1993, 1) stated: "Asian countries with high technology economies will compete with the United States for the Asian-born graduates of US universities. Though Asian scientists and engineers will continue to contribute to the US labor force, more will probably return to Asia." South Korea in particular was very aggressive from the late 1960s in the implementation of various policies designed to reverse the brain drain. In his study of the process, undertaken in the early 1990s, Bang-Soon Yoon (1992, 5) argued that "[t]he Korean model of RBD [reverse brain drain] is without precedent in the world and has been highly successful….Brain drain is no longer considered a social problem by [Korean] policy-makers."

How was such a reversal achieved? By the 1990s the successful development of South Korea and Taiwan in the ICT industries had created employment opportunities that entailed sufficiently high salaries and sufficiently challenging jobs to lure back large numbers of nationals – in the well-documented case of Taiwan an annual average of over 6,000 people from 1993 to 1996 (Saxenian and Hsu 2001, 905-906) -- who had acquired high-tech education and experience abroad. As a dynamic historical process, the reversal of the brain drain was an effect as well as a cause of successful industrial development. It could not have occurred but for the investment strategies of developmental states and innovative enterprises that from the 1960s and 1970s had upgraded the quality of higher education and employment opportunity available to indigenous high-tech labor.

From the outset, MNCs that had come to South Korea and Taiwan in search of low-wage labor for labor-intensive assembly operations in the 1960s and 1970s created a demand for university-educated labor. Over time, as these companies invested in higher value-added activities the high-end employment opportunities increased. Encouraged by this transfer of technology through FDI, national governments made investments in research institutes and graduate programs to build an indigenous knowledge base. These institutes and programs, which themselves generated attractive domestic high-tech employment opportunities, in turn supported the emergence of indigenous Korean and Taiwanese companies as world-class competitors. In many cases, highly educated and very experienced Koreans or Taiwanese who had been pursuing successful careers in the United States played key roles in building indigenous research institutes and companies (for the case of Taiwan, see Saxenian 2006, chs. 4 and 5). The vast majority of the employees of these indigenous companies was, however, home-grown.

Among the pioneering US MNCs in South Korea, Motorola made the most significant contribution to reversing the brain drain. Motorola trained a group of 50 Korean engineers to start up Motorola Korea (MK) in 1967 with a total employment of 300 people. By 1972 MK was Korea's largest electronics company, both in terms of sales and exports (Bloom 1992, 38). Two years later MK had 5,000 employees, including two-thirds of the original 50 Korean engineers (Behrman and Wallender 1976, 267, 299). As Jack Behrman and Harvey Wallender (1976, 270) put it in their detailed case study of the transfer of technology within Motorola to MK, the Korean subsidiary "is run virtually by Korean engineer-managers, since all manufacturing units are under Koreans and the only American is the general manager, who has a financial background….The Korean managers have almost all been 'promoted from within' as the company expanded, and nearly all are in their early thirties and have been given such responsibility because of their education and abilities."[12]

Automation reduced MK's headcount to 3,800 in 1988, with about 2,100 employees in its semiconductor operations. In December 1988, in the midst of labor demands for better pay and work conditions that marked Korea's transition from its "newly industrializing" stage, MK closed its plant after a group of workers, carrying cans of gasoline, had occupied a computer room, and threatened to set themselves on fire.[13] A non-union company around the world, Motorola had agreed to recognize the union but had balked at some of the union demands. The plant was reopened within a week.[14]

In May 1989, a Business Week article asked, "Is the era of cheap Asian labor over?", and answered that "rising wages and union strife are sending some companies packing" (Yang and Nakarmi 1989). As an example:

> When Tandy Corp. set up an electronics manufacturing facility in South Korea in 1972, the lure of low-cost, docile Korean labor was an obvious attraction.

[12] Behrman and Wallender (1976, 300-302) provide details on the internal career paths followed by managers of the manufacturing units between 1967 and 1974,

[13] "Workers occupy computer room of Motorola factory," Reuters News, December 29, 1988.

[14] "Union flare-up cools at Korean Motorola site," Electronic Buyers' News, January 9, 1989, 2.

> But this past March, Tandy closed its factory in the face of an angry anti-American labor confrontation, leaving 1,400 workers without jobs. In addition to the strife, Korea's labor costs have exploded, and it no longer made economic sense to make low-end computer components there (Yang and Nakarmi 1989).

Among the US chip companies, National Semiconductor, in the midst of rationalizing its global capacity, closed down its Korean facility, laying off 250 employees (Clark 1990).[15] Motorola, however, never considered leaving Korea, in part because it was building a major presence there in wireless communications. As of the end of 1993, MK employed 2,500 people, and had shipped $3.2 billion in electronics products since it had opened in 1967.[16]

In 1996 MK began construction of a state-of-the-art manufacturing complex for wireless products and semiconductor packaging at Paju, 40 kilometers north of Seoul.[17] Then in 1998, in the wake of the Asian financial crisis, Motorola pledged to invest $300 million in Korea over the next three years. The first stage of this new investment package was a software design center at its Paju chip plant that began operations with 50 Korean software programmers.[18]

Motorola's continuing commitment to Korea was highlighted in a 1998 Far Eastern Economic Review article entitled, "Remaking Korea Inc." (Lee 1998):

> So significant is its contribution deemed to the economy that the domestic media recently elevated it to chaebol status, calling it "Motorola Korea Group." Motorola was one of the first foreign firms to bring in state-of-the-art technology that eventually sparked a semiconductor explosion in South Korea, greatly benefiting the chaebols. Motorola Korea's deals for subcontracting, local sourcing and direct technical support helped lay the foundations for the domestic computer-chip industry. The firm also was the first to introduce the paging system and cellular phones to South Korea in the mid-1980s. Most importantly, Motorola became a rich fount of human capital for domestic upstarts. "From the beginning, we hired locals and trained them," says Rhyn Cheigh, a Motorola vice-chairman in Seoul. "A few years later, when Korean companies started to set up their own semiconductor operations, they scouted many of our employees. Some of the key people today at Samsung, LG, Hyundai and Anam are from Motorola."

In 1999, as part of its global strategy to outsource manufacturing, Motorola sold the Paju plant, with 880 employees, along with another Motorola facility in Taiwan, to Advanced Semiconductor Engineering (ASE), a Taiwanese company. Despite the sale, Motorola remained committed to Korea; by that time, semiconductors represented only 30 percent of Motorola's business in Korea, and MK had a long-term supply agreement with ASE in any case (Flannery 1999).[19]

---

[15] "National Semiconductor closes plant in S. Korea," Electronic World News, May 15, 1989.

[16] "Key contributor to Korea's semiconductor industry exported $3.2 billion of semiconductors, communications equipment," Business Korea, February 1, 1994: 53.

[17] "Motorola Korea breaks ground for chip telecom plant," Korea Economic Weekly, June 14, 1996.

[18] "Motorola Korea opens software R&D center," The Korea Herald, July 23, 1998.

[19] "Motorola vows continued commitment to Korea," Korea Times, April 19, 1999; "ASE Group to beef up Korean operation," Korea Economic Weekly, November 1, 1999.

In 2004 Motorola spun off its entire semiconductor product division as Freescale Semiconductor. As an independent company, Freescale had plants in Hong Kong and Malaysia but no Korean operation. In May 2005, however, Freescale announced that, attracted by Korea's expertise in mobile technology, it would open an R&D center in Seoul, with six engineers. Freescale was not the only US semiconductor company navigating back to South Korea in search of high-skill labor for high-end work. National Semiconductor, absent from Korea since 1989 when it closed its assembly facility in the midst of labor unrest, came back to Korea in 2005 to launch both a design center and an R&D center (Wohn 2005).

By the 2000s South Korea has the research capability to serve the high end of the high-tech market. Not only had the brain drain been reversed; with MNCs now locating in Korea to access highly skilled ICT labor, to could no longer be taken for granted that the center of the world of high-end work is the United States or even Japan. Beginning in the last half of the 1960s, as we have seen, MNCs in search of low-wage labor played a critical role in beginning the reversal process by offering opportunities to Korean engineers and managers to accumulate ICT experience while staying at home. In the process they transferred considerable technology to, and developed considerable capability in, Korea.

The investments that permitted the economic transformation of Korea did not come, however, from MNCs alone. Building on the capabilities that FDI brought to Korea, as well as on the capabilities of Koreans who had been studying and working abroad, the Korean government and indigenous businesses made the investments in ICT that made Korea a leading "career path" location. Of particular importance, more in terms of quality than quantity, was the repatriation of Korean scientists and engineers who had worked abroad.

In 1968 some 2,000 Korean scientists and engineers lived abroad (Kim and Leslie 1998, 168). The very existence of these expatriates presented an opportunity for South Korea to build indigenous high-tech capabilities if only the brain drain could be reversed. From the last half of the 1960s, the Korean government saw the creation of an industrial research complex as a way to lure back some of those expatriate Koreans so that they could contribute to the development of Korea's knowledge base (Bloom 1992, 54; Yoon 1992). Specifically, the desire by Korea's policy-makers to transform the nation's brain drain into its brain gain served as both opportunity and impetus in the establishment of two seminal knowledge-creating institutions, the Korea Institute of Science and Technology (KIST) and the Korea Advanced Institute of Science and Technology (KAIST).

KIST came into being in 1966 after USAID funded a team of US scientists to visit South Korea in May 1965 to offer advice on the formation of a national institute for scientific research. Headed by Donald Hornig, scientific advisor to President Lyndon Johnson, the team included James Fisk, president of Bell Labs, and Bertram Thomas, president of the Battelle Memorial Institute (Bloom 1992, 54; Kim and Leslie 1998, 159-161). These discussions led KIST to opt for the Battelle contract research model, which entailed ongoing interaction with industry, rather than the Bell scientific research model. The US government provided substantial initial funding, including a $3.1 million contract to Battelle to provide technical advice.

In 1967 the government ensured KIST's autonomy in research and management and its financial stability through special legislation, The Assistance Act of the Korea Institute of Science and Technology (Yoon 1992, 16-17). The same year saw the creation of the Ministry of Science and Technology (MOST) (Bloom 1992, 54). A 1975 MOST document entitled "Policy and Strategy for Science and Technology" described KIST as "the window through which the transfer of foreign technology to domestic industry can be made….It guides and counsels industries in selecting appropriate technologies for import and in modifying, improving, and adapting imported technology for application and dissemination. KIST is the bridge between domestic industry and advanced technologies of foreign countries" (quoted in Kim and Leslie 1998, 161).

In conducting a search for its first scientists and engineers, KIST's ideal profile was an undergraduate degree from Seoul National University, plus a graduate degree and five years of work experience abroad. In its first year, 1969, KIST had 494 employees, of whom 18 were repatriated scientists and engineers (14 with doctorates) (Yoon 1992, 13-14). To attract key personnel from abroad, KIST paid high salaries and offered perquisites such as relocation expenses, free housing, and education expenses for children. Such compensation packages subsequently became the norm in government repatriation initiatives (Yoon 1992, 14-16). By 1975, out of a total of 984 employees, KIST had 137 repatriates, 69 of whom were permanent (Yoon 1992, 13).

During the 1970s there was a proliferation of government research institutes in Korea, some of them spinoffs of specialist departments of KIST (Lee et al. 1991). The Korea Institute of Electronics Technology (KIET) emerged in 1976 to conduct research into semiconductor design, processes, and systems. At the head of each of KIET's three research divisions was a Korean with research experience in the US semiconductor industry (Bloom 1992, 56; Mathews and Cho 2000, 118).[20] In a joint venture with the Silicon Valley chipmaker, VLSI Technology, KIET put in place Korea's first VLSI pilot wafer-fabrication plant in 1978, and by 1979 had launched a fully operational 16K DRAM fab (Mathews and Cho 2000, 118).

Overall from 1968 through 1980 MOST-sponsored repatriation programs brought 130 overseas Koreans on a permanent basis and 182 on a temporary basis to public R&D institutes back home (Yoon 1992, 10). The repatriates brought knowledge, experience, connections, and leadership to South Korea. Given the rapid growth in demand for scientists, engineers, and technicians in Korea from the late 1970s, however, the vast majority of those employed by the public research institutes had to be home-grown.

The number of researchers in Korea grew from 14,749 in 1978 (0.40 researchers per 1,000 population), to 18,434 in 1980 (0.48) and 28,448 in 1982 (0.72), with the government share in R&D expenditures constituting 49 percent of the total in 1978, rising to 52 percent in 1980, and then falling to 41 percent in 1982 as business enterprises began to invest heavily in their own R&D (Arnold 1988, 439).[21] Government investments in indigenous R&D capability demanded complementary

[20] In 1985 KIET merged with the Korea Electrotechnology and Telecommunications Research Institute to become the Electronics and Telecommunications Research Institute (ETRI).

[21] Over this four-year period, total Korean R&D expenditures tripled while GNP more than doubled, with R&D expenditure as a proportion of GNP rising from 0.67 to 0.95 (Arnold 1988).

investments in indigenous academic institutions to generate a homegrown supply of high-tech labor. Analogous to KIST, the keystone educational investment was the founding in February 1971 of the Korea Advanced Institute of Science (KAIS), the nation's first specialized graduate school of science and engineering. KAIS admitted its first master's students in 1973, its first doctoral students in 1975, and its first undergraduate students in 1986.[22] Along the way, KAIS became KAIST when, at the end of 1980, KIST and KAIS were merged. The name of the academic institution remained KAIST when the two organizations demerged in 1989 as KAIST moved its campus 100 miles south of Seoul to become the centerpiece of Taedok Science Town (Kim and Leslie 1998, 178-180).

KAIS was the brainchild of a 30-year-old Korean physicist, KunMo Chung, working in the United States (Kim and Leslie 1998). After completing his undergraduate degree in physics and taking graduate courses in public administration at Seoul National University, Chung secured funding from USAID to do a Ph.D. in theoretical physics at Michigan State University. He subsequently held positions at MIT and Princeton before becoming head of a plasma physics lab at Brooklyn Polytechnic. "Along the way," according to Dong-Won Kim and Stuart Leslie (1998, 164), "Chung never lost his interest in public policy."

> He attended graduate courses in public administration at Harvard during his stint at MIT and wrote as a class assignment a paper on the issue of brain drain in the developing world that would become his blueprint for a new Korean graduate school. In early 1969 Chung approached John A. Hannah, his former mentor at Michigan State, who had recently been appointed head of USAID. Would he be interested in supporting a new graduate school for science and engineering in South Korea that, Chung expected, could help stem the brain drain to the United States and promote economic self-sufficiency?

Responding to Hannah's request for a detailed proposal, by October 1969 Chung had produced a document entitled, "The Establishment of a New Graduate School of Applied Science and Technology in Korea". Hannah handed off the proposal to USAID's Korean division, which forwarded it the Korean Economic Planning Board (EPB) (Kim and Leslie 1998, 165). EPB in turn piqued the interest of MOST, which in April invited Chung to Korea to present his plan to key political leaders. With President Chung-Hee Park's support, by July 1970 KAIS had won legislative approval.

As with KIST, USAID provided financial assistance and advice. To bring KAIS to fruition, the US presidential science advisor, Lee DuBridge, appointed a five-man committee of engineering educators, with Frederick Terman as chair. Among the other committee members were two of Terman's protégés and Chung (Kim and Leslie 1998, 167). At the time the provost of Stanford University, Terman was previously dean of Stanford Engineering, and the academic visionary behind the emergence of Silicon Valley (Leslie and Kargon 1996). In writing his original proposal for KAIS, Chung had been influenced by a recent report by Terman on the reform of engineering education in New York State (Kim and Leslie 1998, 165-169). In effect, therefore, from conception to founding, KAIS reflected Terman's ideas, including the mission,

[22] See the KAIST website: http://www.kaist.edu/as_intro/as_nt_facts/as_ft_gnr/as_ft_gnr.html. The undergraduates went to Korea Institute of Technology, which merged with KAIST in 1989.

as the Terman report put it, "to serve the needs of Korea's developing industry without delay and compromise, and a "steeples of excellence" strategy of "instruction in only a limited number of high priority fields [to achieve] a truly outstanding program in each of these fields" (quoted in Kim and Leslie 1998, 168).

The government provided all KAIST students with tuition, room and board, a stipend, and a conversion of the normal compulsory three years of military service into three years of work in a government research facility subsequent to receiving their master's degrees (Kim and Leslie 1998, 169). From its inception through 1996, KAIST awarded a total of 3,108 bachelor's degrees, 9,566 master's degrees, and 2,647 doctoral degrees. Of the master's recipients 43 percent went to industry, 17 percent to government research institutes, and an estimated 34 percent to advanced training. Of the doctoral recipients, 45 percent went to industry, 27 percent to government research institutes, and 26 percent to academic positions (Kim and Leslie 1998, 174).

By the 1990s there were plenty of good employment opportunities for these graduates in Korea, given the presence of not only MNCs such as Motorola Korea or government research institutes such as KIST, but also, and indeed, primarily, Korean *chaebol* such as Samsung, Hyundai, and LG (Lucky-Goldstar) that through indigenous innovation had transformed knowledge transferred from abroad into world-leading products in a number of high-technology sectors. In no Korean industry was this transformation as dramatic as in semiconductors. In 1980 semiconductors represented 2.5 percent of Korea's production and 2.5 percent of exports; in 1990 7.3 percent of production and 7.0 percent of exports (Byun 1994, 709).

In semiconductors, no Korean company was as successful as Samsung. With $20.5 billion in revenues and 7.5 percent of the market, in 2007 Samsung was the world's number two supplier of semiconductors, behind Intel with revenues of $33.8 billion, and ahead of Toshiba and Texas Instruments, each with revenues of $11.8 billion.[23] Samsung was the world leader in the flash memory market, and shared the world lead in the DRAM market with South Korea's Hynix Semiconductor, formerly Hyundai Electronics.

Linsu Kim (1997a) has provided a lucid account of how Samsung transformed its Electronics division into a world leader in semiconductors. The learning process, Kim (1997a, 88) stresses, was collective and cumulative:

> Learning how to solve problems is usually built up over many practice trials on related problems. Thus, it requires considerable time and effort directed at solving simple problems early on before moving on to solving the more complex problems. Such effort intensifies interaction among the organization's members and facilitates knowledge creation and conversions at the organizational level.

Samsung entered the semiconductor industry in 1975 when it bought Korea Semiconductor Company (KSC), a just-launched semiconductor firm that had run into financial trouble. The founder of KSC, Ki-Dong Kang, a Korean-American Ph.D.

[23] "Worldwide semiconductor revenue increased 4 percent in 2007," Gartner press release, March 31, 2008, at http://www.gartner.com/it/page.jsp?id=635207

who had worked in semiconductor design at Motorola, now provided Samsung with his knowledge. Samsung also took over the assets of an abortive transistor joint venture between Goldstar and National Semiconductor (Mathews and Cho 2000, 116). Thus, in 1975 Samsung acquired the capability to fabricate wafers and produce LSI chips for consumer electronics products just as the Korean government promulgated a six-year plan to promote the semiconductor industry (Kim 1997a, 88).

In 1982 Samsung started its Semiconductor R&D Laboratory to reverse engineer semiconductors from Japan and the United States. At the same time Samsung organized a task force to formulate a strategy for entering into the production of VLSI chips. After six months of information gathering and analysis, the team spent a month on a fact-finding trip to the United States where it especially sought advice from Korean-Americans with semiconductor expertise. The major semiconductor companies in the United States had already rebuffed Samsung's requests to license 64K DRAM technology, so the task force identified smaller companies strapped for cash that would make the technology available. One such company was Micron Technology, founded by former Texas Instruments engineers in 1978, which in 1982 had just generated its first revenues from its new fabrication facility in Idaho (Spaeth 1984). As part of the deal, Samsung sent its engineers to Micron for training. Subsequently, in 1985 Samsung was also able to buy an advanced high-speed MOS process for $2.1 million from Zytrex, a 1983 Silicon Valley startup that had just gone bankrupt (Chira 1985; Pollack 1985b).

In 1983 Samsung announced a massive investment to design and produce 64K VLSI chips. As the biggest chaebol in Korea, Samsung was able to fund the investments in semiconductors from earnings from other divisions. It was also able to avail itself of government subsidies. The product development process involved two parallel groups, one in Silicon Valley that employed 300 American engineers led by five Korean-Americans with Ph.D.s and design experience at major US chip companies, and the other in Korea, led by two Korean-American scientists who had developed 64K DRAMs at US companies as well as by Korean engineers who had run Samsung's LSI operations and who had received VLSI training at Samsung's US technology suppliers. Samsung's Silicon Valley unit also trained the company's Korean engineers as part of the process of transferring technology from the United States to Korea (Byun 1994, 711; Kim 1997a, 89-93).

When Samsung released its 64K DRAM in 1984, it lagged the United States chipmakers by 40 months and the Japanese by 18 months. Samsung repeated this product development process for its 256K chip released in 1985, and further reduced the technology gap with the United States and Japan – as indeed it continued to do with the 1M DRAM in 1987, the 4M in 1989, and the 16M in 1992, at which point it had caught up (Byun 1994, 713).

Between 1980 and 1994 the company's sales soared from 2.5 billion Won to 115.2 billion Won. In the process Samsung Electronics increased its R&D as a proportion of sales from 2.1 percent in 1980 to 6.2 percent in 1994. In 1980 the company employed 690 R&D staff, who in that year produced only 18 local patent applications and four local patent awards, and no foreign patent applications or awards. In 1994 8,919 R&D staff could claim credit for 2,802 local applications and 1,413 local awards, along with 1,478 foreign applications and 752 foreign awards. The generation of one local patent award for Samsung Electronics required 116.8 R&D

staff in 1985, 10.4 in 1990, and 6.3 in 1994, while the generation of one foreign patent award required 992.5 R&D staff in 1985, 52.2 in 1990, and 11.9 in 1994 (Kim 1997a, 95).

As a result of the employment opportunities that Samsung as well as other leading chaebol such as Hyundai and Lucky-Goldstar had created, by the late 1980s the brain drain had been reversed. Indeed in 1989 a Wall Street Journal article entitled "Costly Exports", announced: "Reverse 'Brain Drain' helps Asia but Robs U.S. of Scarce Talent – Korea in Particular Benefits as Scientists Return to Take Top Jobs" (Yoder 1989). The Koreans now took a very different view of the estimated 6,000 scientists and engineers in the United States than they would have two decades before. The Wall Street Journal article went on:

> Koreans in the U.S. "have become a precious resource for us," says Chin Hai Sool, a director general at Korea's Ministry of Science and Technology. The big players in Korea's booming semiconductor industry -- Samsung, Goldstar Co. and Hyundai Electronic Industries Co. -- are all headed by recent defectors from Intel Corp., Honeywell Inc. and Digital Equipment Corp.

In sharp contrast to the Korean perspective was that coming from those concerned with the implications of the reverse brain drain for the supply of scientists and engineers in the United States. From the long-time leader of a prominent Washington-based professional association came the complaint of labor shortage:

> "We've been counting on foreign graduates to stay here and fill our needs because we haven't been filling our own needs for a long time," says Betty Vetter, executive director of the Commission on Professionals in Science and Technology, in Washington. "There's nobody to replace these people."

And from a high-tech corporate executive and future US vice-presidential candidate (as H. Ross Perot's Reform Party running-mate in the 1996 elections) came the complaint of lost competitiveness:

> The returnees are having a visible effect on the competitiveness of Korea and other Asian lands. "We're giving these countries an enormous subsidy," says Pat Choate, vice president of policy analysis at TRW Inc. "It's perhaps the largest technology transfer program in the history of the world."
>
> TRW's Mr. Choate suggests that foreigners should be required to sign an agreement to work in the U.S. for three to five years after graduation. "Extraordinary measures are necessary," he says.

By the early 1990s Korea had developed to a stage at which it could quickly tap this "precious resource". Of 13,878 foreign S&E doctorate recipients with temporary visas from US universities in 1990-91, almost 56 percent were from China (2,779), Korea (1,912), Taiwan (1,824), or India (1,235). In 1995 47 percent of the 1990-91 recipients were working in the United States, including 88 percent of the Chinese, 79 percent of the Indians, 42 percent of the Taiwanese, but only 11 percent of the Koreans – a proportion that was even lower than the 13 percent of the 227 Japanese doctoral recipients (Johnson and Regets 1998). By the early 1990s, a study of "reverse brain drain" could conclude that "[t]he Korean model of RBD is without precedent in the world and has been highly successful….Brain drain is no longer considered a social problem by [Korean] policy-makers" (Yoon 1992, 5).

Malaysia's FDI-Driven Development

Not all of the Asian nations that have built up significant ICT capabilities since the 1960s have been able to engage in indigenous innovation in the manner of Korea (for the case of indigenous innovation in Taiwan, see Mathews 1997; Saxenian 2006, chs. 4 and 5; Breznitz 2007, ch. 3). Malaysia in particular has over the past three decades become a world center for electronics manufacturing based on FDI. During 2003-2007, the Malaysian economy grew at about 5.5 percent per annum, with electronics dominating its manufacturing base and exports.[24] Malaysia has prospered on the basis of FDI over a sustained period of time because MNCs have been successfully upgrading their productive capabilities there, thus making it possible to pay employees higher wages and still remain globally competitive.

Since the 1960s the rule among US MNCs has been to employ nationals rather than expatriates in host countries. Data from the early 1980s on employment in the Bayan Lepas Free Trade Zone (BLFTZ) confirms the overwhelming reliance of MNCs on indigenous labor at all levels of the local organization, even in newly industrializing countries. In 1982 27 electronics/electrical factories employed a total of 24,446 people, of whom 5,389 (22 percent) were male and 6,625 (27 percent) were non-factory workers. Only 34 of these employees -- 0.14 percent of the total, 0.63 percent of males, and 0.51 percent of non-factory workers -- were expatriates. For BLFTZ as a whole there were 226 expatriates out of 52,073 employees, representing 0.43 percent of the total, 1.16 percent of males, and 1.55 percent of non-factory workers (Salih and Young 1987, 184). Given the small absolute number of expatriates – just 1.26 per electronics/electrical factory in 1982 -- the indigenization of the labor force at the MNCs obviously extended high up the organizational hierarchy. A survey done in the mid-1990s found that National Semiconductor's only expatriate in Penang was the managing director. Texas Instruments, with 2,800 employees in Malaysia, and Motorola, with 4,000, each had only three expatriate managers. The survey also revealed that in the Malaysian electronics industry US MNCs were more indigenized than European and Japanese MNCs (Ismail 1999, 27-28).

Intel's history in Malaysia from the early 1970s to the present illustrates the upgrading of indigenous capabilities by a US MNC in the semiconductor industry. Intel was one of the first semiconductor manufacturers to offshore to BLFTZ when Malaysia launched it in 1972, and as a company itself only founded in 1968, the Penang facility was Intel's first offshore plant. In 1974 Intel employed about 1,000 people in Penang,[25] and about 2,000 a decade later. Over the next ten years Intel's Penang production tripled, but its labor force remained around 2,000 because of automation of labor-intensive assembly processes. In 1980 engineers had represented only one out of 40 Intel employees in Penang, but in 1994, one in six (Zachary 1994; Ismail 1999, 27). Over time Malaysia became Intel's main source of expertise on assembly operations. It was reported, for example, that in the mid-1980s, when Intel was setting up its assembly line in its automated chip factory in Chandler, Arizona, it

---

[24] See http://indexmundi.com/malaysia/gdp_real_growth_rate.html; more generally see Best 2001, ch. 6.

[25] "Intel closes two plants in California for week due to slowing business," Wall Street Journal, September 4, 1974.

had to bring in its Malaysian experts from Penang as consultants (Dreyfack and Port 1986). In 1990, when Intel set up a design optimization lab at the Penang facility, it sent ten engineers to Silicon Valley for training. At that time, Intel announced that it would continue to invest in automation in Penang with the goal of attaining zero-defect production (Dennis 1990).

In July 1992 Intel decided to shift its entire microcontroller design, manufacturing, and marketing operations out of the Chandler facility to its Penang plant, a move that Lai Pin Yong, Intel Malaysia's managing director, called a milestone for the local electronics industry. "This is the first time in Malaysia," Yong said, "that a multinational is giving its offshore plant total responsibility of an important product." As a result, Intel Malaysia expected to add another 50 engineers to the 300 that it already employed.[26] Plans for the Design Centre had been laid a few years earlier; in preparation, a team of 30 Malaysians had received training in the United States and Japan for two to three years. When the Intel Penang Design Centre opened in November 1992, it was said to be the first of its kind in Southeast Asia (Leow 1992; see also Ismail 1999, 32-33).

In 2003, with US$2.3 billion invested in Malaysia since 1972, Intel Malaysia employed about 1,000 Malaysians in R&D and had secured 21 US patents. In August 2003 Intel added to its Malaysian R&D capabilities by opening a design and development center with a focus on manufacturing processes and packaging technology for Intel's various products. On a visit to Penang in August 2003 to open the new center, Intel CEO Craig Barrett reportedly commended "the Malaysian Government and business leaders for their work in stimulating IT research and innovation through university research grants and efforts to strengthen education programmes", while warning that "a critical factor to the impact of Intel's investment hinged on the continued availability of talent to sustain design and development efforts locally."[27]

In December 2005, with almost 10,000 employees, about 10 percent of its global labor force, at five sites in Malaysia, including the original Penang location, Intel announced plans to invest $230 million in a 2,000-person assembly and test site, along with a design and development center, in Kulim (Ismail 2005; Yee 2005). On the occasion of this investment, Craig Barrett, now Intel's chairman, stated: "Intel is working with the Education Ministry to help grow Malaysia's globally competitive ICT workforce. Through the Intel Teach to the Future programme, we have trained more than 30,000 Malaysian teachers to use technology to improve student learning." Barrett continued: "Effectively integrating technology into the classrooms opens up new and exciting learning opportunities, giving young people the knowledge and skills to compete in an increasingly complex world" (quoted in Ismail 2005).

Evolution of IT Services in India

In the wake of a Memorandum of Agreement on high-technology transfers from the US to India, signed after years of negotiation in May 1985, the Indian Department of Electronics announced its intention to build "technology parks" that would permit foreign companies to be wholly owned for the purpose of developing and exporting

[26] "Intel to move microcontroller operations to Penang plant," Electronic Times, July 30, 1992.
[27] "Intel to expand capacity with RM152m investment," Business Times, August 27, 2003.

large-scale software systems (Tenorio 1985). In June 1985 Texas Instruments (TI) began exploratory talks with the Indian government about establishing a software development center in Bangalore. Two key conditions for TI were 100 percent ownership of the facility and permission to establish a connection to its own company's global communications network (Mitchell 1986). The Indian government acceded to both demands.

In the mid-1980s TI was a global company with an Asian presence in Japan, Taiwan, Singapore, and Malaysia. It was, however, like other US semiconductor companies, facing a major competitive challenge from the Japanese in commodity memory chips. TI's future lay in custom chips, particularly ASICs and VLSI (Mitchell 1986). These products called for substantial software programming, using computer-aided design. As TI India recounts on its website:

> The initial activity of TI India was the development and support of proprietary Electronic Design Automation (EDA) software systems used for Integrated Circuit (IC) design by TI's semiconductor design centers worldwide. This activity included the development of applications for creating, simulating, testing and verifying both logical and physical IC manufacturing processes.[28]

Robert Rozeboom, vice president of TI's semiconductor group design automation department, told a reporter in August 1985 that TI had "started to look at India seriously in 1984 as a potential site for software development for our computer-aided design. Software development is critical to our semiconductor operations. India has such a strong educational system in the sciences and it has such a large number of graduates who are underemployed, it became an obvious choice for us."[29] The US-India technology transfer agreement created an opening for TI to locate a software development center in India. It was a small investment for TI: $5 million out of total 1986 capital expenditures of $446 million.

TI India employed 16 engineers and programmers when it began operations in 1986. This number increased to 85 in 1990, 275 in 1995, 500 in 2000, 1300 in 2005, and 1,800 in 2007, which was almost 6 percent of TI's worldwide labor force. All of these employees in India were engaged in R&D.[30] And all were Indians. A report in 2002 stated that among the 750 engineers and programmers who TI employed in Bangalore, there were no expatriates.[31]

In 1997 an article in Electronic Engineering Times called TI India "a dream company for local engineers" (Bindra 1997).

> It is developing native leadership talent, and has established excellent local university programs. Besides creating EDA software, TI India develops cell libraries, design methodologies and support software for the parent company's ASIC and digital signal processor product families. Currently, TI India is

---

[28] http://www.ti.com/asia/docs/india/about_tii.html

[29] "Texas Inst. looks to grab fast-growing Asia market," United Press International, August 19, 1985, 50.

[30] "Texas Instruments to focus on R&D in India," Indo-Asian News Service, April 3, 2007.

[31] "Business as usual for US firms in India," Reuters News, June 3, 2002. It was also reported that HP had fewer than ten foreigners among its 3,000 employees in India, and none in top management positions.

> working on 16-Mbit and 8-Mbit flash designs. The division has the ability to keep pace with technical advances in processes, said Srini Rajam, TI India's managing director. As a result, TI India has emerged as a strategic product-development center for TI's semiconductor business.

A report issued in 2003, when TI India topped "India's first ever list of Top 25 Great Places to Work", read:

> TI India, a subsidiary of TI Inc, employs 832 people in a single site in India. It has eight women at senior management level. Staff turnover is at seven percent. The company has 170 employees who have completed five years with the company. It has 18 employees who are over 44 years of age.[32]

About 75 percent of TI India's employees were working on digital signal processing (DSP) chips, used in cell phones, modems, MP3 players, digital still cameras, and Voice over Internet Protocol phones.[33] In DSP, the mainstay of TI's overall semiconductor business, TI India had become, according to a company press release, "the research base for its parent company." By the end of 2003 TI India had garnered 225 US patents (Rai 2003).

In 2006 TI's website contained a solicitation to Indians working in the US that proclaimed that "the time has never been better to come back to India."[34] The pitch:

- If you are a 4+ year experienced engineer here's your opportunity to work on challenging projects and actually turn your ideas into groundbreaking innovations.
- Working at TI India will boost your career and improve your lifestyle – and you'll be giving back to your country.
- Opportunities and compensation in India have never been better. This is your chance to take on a leadership role and live your life in a place called home.

Almost two decades after it had been the first MNC to locate in Bangalore, TI was not alone in viewing India as a prime location for software programming and R&D (see Mitra 2007). By 1992 it was reported that 30 other MNCs, including Motorola and IBM, had set up software programming facilities in Bangalore (O'Reilly 1992). IBM, which had left India in 1978 over issues of foreign ownership, returned in 1992 after India's 1991 liberalization reforms (Tarrant 1991; Tripathi 1992; Chatterjee 1994). HP set up a subsidiary in India in 1989, but waited until 2002 to launch its first Indian research lab.[35] In April 2004 AMD announced that a $5 million investment in a microprocessor design center that would employ 120 chip designers and development engineers by the end of 2005 (Sharma 2004). In the first half of 2005 both Intel and Microsoft set up advanced research centers in Bangalore (Dudley 2004; Subramanyam 2005). That summer Intel set up a platform definition center in Bangalore "to define locally relevant computing solutions based on Intel technology."[36] In September Microsoft announced that over the next six months the

---

[32] "Geek haven: Texas Instruments," Business World, September 1, 2003, 28.
[33] "India to increase staff strength," Business Line, March 11, 2002.
[34] http://www.ti.com/recruit/docs/india/info.shtml.
[35] "Hewlett-Packard launches research lab in India," Agence France-Press, February 22, 2002.
[36] "Intel opens platform definition centre in Bangalore, Asia Pulse, August 1, 2005.

staff at its software facilities in Hyderabad and Bangalore would increase from 1,500 to 3,000 (Ribeiro 2005). In October, as part of a $1.1 billion expansion in India over three years, Cisco broke ground on a $50 million, million-square-foot, R&D campus in Bangalore that would double to 3,000 the number of people on Cisco payrolls in India.[37] A month later, Cisco's rival, Juniper Networks, announced a new $8.5 million development center in Bangalore that would increase its employment in India from 325 to 675.[38] In December Intel said that it would spend $1 billion in India over the coming years, including $800 million on education and community programs and the remainder primarily for the expansion of its R&D center in Bangalore.[39]

By the mid-2000s, however, the growth of indigenous information-technology enterprises made Indians far less reliant on MNCs for high-tech employment than in the past. For the year ending March 31, 2008 the five leading Indian information technology (IT) companies – Tata Consultancy Services (TCS), Wipro, Infosys, Satyam, and HCL Technologies – generated a total of $18.7 billion in revenues and employed a total of 368,000 people worldwide, up from a combined $2.4 billion in revenues and 46,000 employees in 2001.[40]

TCS is the largest of these five IT companies with $5.7 billion in revenues in fiscal 2007 (year ending March 31, 2008). Based in Mumbai as part of Tata Group, India's largest industrial conglomerate, TCS began supplying offshore IT services in 1968. Besides engaging in software development in India, during the 1980s TCS became a leading "bodyshop", sending engineers and programmers to do projects abroad. In 1989, when TCS employed 1,450 people, an article on bodyshopping in Australia observed: "Tata Consultancy does not operate as a conventional bodyshop. It employs graduates in India, trains them for a year, and if they meet the required standards, sends them overseas on year-long contracts" (Head 1989). TCS increased its employment level from 2,000 people in 1991 to 16,800 in 2001. In the 2000s employment at TCS soared, reaching 111,407 in March 2008, with a net addition of 35,672 employees in the previous year and with plans to add 30,000-50,000 people over the next year.[41] Over 90 percent of TCS employees were Indian nationals (TCS Annual report 2007-2008, 32-33). The company generated 56 percent of its global revenues in North America, 29 percent in Europe, and 9 percent in India.

Following behind TCS are Wipro and Infosys, both based in Bangalore, with revenues for the year ending March 31, 2008 of $4.9 billion and $4.2 billion respectively. H. M Hasham Premji founded Wipro (an abbreviation of Western Indian Vegetable Products) in 1946 as a vendor of cooking oil. He died in 1966, but his son Azim, just short of receiving his undergraduate degree electrical engineering at Stanford University, returned to India to run the business. Wipro entered the computer business in the late 1970s after IBM had left the country rather than submit to government regulations that required 60 percent Indian ownership of foreign affiliates. Subsequently Wipro expanded into IT services and software. In 1992 the company

[37] "Cisco pledges $50 million more for Bangalore campus," CMP TechWeb, October 21, 2005.
[38] "Juniper sets eye on Indian telecom market," Business Standard, November 24, 2005.
[39] "Intel announces $1 billion investment plan for India," Computer Reseller News, December 15, 2005.
[40] The end of the fiscal year is March 31 for Infosys, Satyam, TCS, and Wipro, and June 30 for HCL. Note that given the accounting fraud scandal at Satyam that came to light in January 2009, the Satyam revenue and employment figures included in these five-company totals may be overstated.
[41] "Tata Consultancy: To hire 30,000-50,000 staff this FY," Dow Jones International News, April 21.

had 1,640 employees of whom at least 1,000 had a bachelor of science degree.[42] Ten years later Wipro employed more then 14,000 people, and in March 2008 82,122.

Infosys Technologies was founded as a software development company in 1981 by N. R. Narayana Murthy, the company's CEO until 2002, and six other software engineers, including Nandan M. Nilekani, the current CEO. Murthy had an undergraduate engineering degree from the University of Mysore and a master's degree in electrical engineering from IIT Kanpur, while Nilekani had an undergraduate degree in electrical engineering from IIT Mumbai. During its first decade the company gained a reputation for high-quality offshore design and development for companies such as GE, DEC, Reebok, and Nestlé. In 1992 Infosys employed more than 300 software engineers.[43] The company grew to 5,389 employees in 2001, and then surged to 52,715 employees in March 2006, 72,241 in March 2007 and 91,187 to March 2008. To achieve the net additions of 19,526 employees in 2006-2007 and 18,946 employees in 2007-2008, Infosys hired 30,946 and 33,177 people respectively. Almost 75 percent of these hires were beginning their careers. The average age of "Infoscions", about 93 percent of whom the company described as "software professionals", was 26 years (Infosys Annual Report 2007-2008, 5, 132, 135).

Indigenous Innovation in China

While India's emergence as a force in the world of ICT has been focused mainly on IT services, China's development path has been much more diverse. In entering a full range of industries with different levels of skill, China has had the advantage over India of a much more extensive system of mass education, as shown in Table 2. Note that in both 1980 and 2000 India had a much higher proportion of the population who had completed post-secondary education, although in each of the nations the group that attained this level of education represented an elite. At the university level, as we have seen, an important difference between China and India in the 1980s was that China emphasized undergraduate degrees in engineering while India emphasized undergraduate degrees in science. In terms of the supply of college-educated personnel, therefore, China was much better positioned than India in the 1990s to absorb technology from the advanced nations and adapt it to indigenous industrial uses.

Table 2 Highest levels of educational attainment of the populations, 25 years old and over, China and India, 1980 and 2000

	China		India	
Highest level of educational attainment (% who completed level in parentheses)	1980	2000	1980	2000
No schooling	44.9	20.9	72.5	44.5
1st level (primary education)	32.3 (12.2)	40.7 (15.3)	11. 3 (4.2)	33.2 (12.4)
2nd level (secondary education)	21.7 (5.6)	35.7 (14.1)	13.7 (5.1)	17.4 (6.5)
Post-secondary (higher education)	1.0 (0.9)	2.7 (2.3)	2.5 (1.7)	4.8 (3.3)
Average years of school	3.6	5.7	2.7	4.8

Source: Barro and Lee (2000).

[42] "India's electronics industry," The Economist, May 4, 1991.
[43] "More US software jobs going to foreign workers," Boston Globe, July 5,1993

In the 1980s and 1990s, to unleash these productive capabilities to support industrial development, China quite deliberately transformed the relation between its science and technology (S&T) infrastructure and high-tech enterprises that competed for growing commercial markets. China had developed considerable S&T capability under the central planning system prior to the economic reforms in the late 1970s (Suttmeier 1975; Sigurdson 1980; Conroy 1992; Gu 1999). Until the 1980s, however, the evolution of the S&T infrastructure was driven exclusively by government demand, much of it for military purposes. A prime task of the reform process was to transfer national S&T resources to businesses that could innovate in producing for commercial markets.

The transformed S&T infrastructure consisted of national programs, ranging from basic research to industrial R&D, and public research institutes that interacted with industrial enterprises to develop technologies for domestic and, increasingly, international product markets. It included National Key Laboratories for basic research, National Engineering Centers for applied research, and Corporate R&D Centers and Experimental Zones for New Technology Industries for the commercialization of technology (Gu 1999). What turned this S&T infrastructure into a "national system of innovation" in the 1980s and 1990s was the emergence of highly autonomous business enterprises that were successful in the commercialization of technology. The most notable successes occurred in ICT. The institutionalization of organizational relations among government institutes and business enterprises not only permitted China to develop new productive capabilities but also ensured that these capabilities would be utilized to meet new demands for industrial application.

The importance of ICT to China's development in the late 20th and early 21st centuries is clear in the trade data. During the 1990s and into the 2000s China became both a major exporter and major importer of electronic office machines, information technology products, and telecommunications products, as world trade in electronics became increasingly based on a vertically specialized international division of labor (Amighini 2004). In 1992 China had about 2 percent of world trade in office machines, less than 1 percent in IT products, and 2 percent in telecom products. In these different ICT groupings, China lagged far behind nations such as the United States, Japan, Germany, Singapore, and Hong Kong. By 2003, however, China had become the world's leading exporter in all of these groupings, with 18 percent of office machines, 18 percent in IT products, 11 percent in telecom products (Amighini 2004, 207-208). In semiconductors, China increased its share from 1 percent in 1992 to 5 percent in 2003; it still remains highly dependent on semiconductor imports, but, as we shall see in the case study of Intel below, the assembly and testing of computer chips in China has been rapidly on the rise.

ICT figures especially prominently in China's trade relations with the United States. US exports of advanced technology products (ATP) to China increased from $5.5 billion (representing 2.4 percent of all US ATP exports) in 2000 to $20.3 billion in 2007 (7.4 percent) before declining to $18.7 billion in 2008 (6.8 percent) (see Table 3a). Meanwhile US ATP imports from China rose from $10.7 billion in 2000 (5.5 percent of all US ATP imports) to $91.4 billion (27.6 percent) in 2008 (see Table 3b). In 2003 US ATP imports from China surpassed those from Japan, and in 2008 these imports from China were almost three and a half times those from Japan. In 2007 US ATP exports to China exceeded those to Japan by 2.6 percent after being 8.7 percent lower the year before, and in 2008 the value of US ATP exports to each of the two nations were almost identical.

Table 3a: Shares of US Advanced Technology Product exports, 2000-2008, to the 10 nations that had the highest shares in 2008

	2000	2002	2004	2006	2008
Total US ATP exports $m.	225,415	180,629	201,454	252,569	275,818
	% of US ATP exports to top 10 nations in 2008				
	2000	2002	2004	2006	2008
Canada	11.4	9.6	10.1	9.3	10.0
Mexico	6.7	7.0	8.2	7.4	7.1
Japan	9.8	9.3	9.0	7.7	6.8
China	2.4	4.6	4.7	7.0	6.8
Germany	5.5	5.2	4.6	5.1	6.2
United Kingdom	7.4	5.9	6.0	5.0	4.6
Singapore	3.9	4.5	5.0	4.8	4.5
Netherlands	4.2	4.0	4.5	4.0	4.4
Brazil	2.6	2.2	2.2	2.8	4.0
France	4.1	4.7	4.6	4.0	3.9

Source: US Census Bureau, at http://www.census.gov/foreign-trade/statistics/country/index.html

Table 3b: Shares of US Advanced Technology Product imports, 2000-2008, from the 10 nations that had the highest shares in 2008

	2000	2002	2004	2006	2008
Total US ATP imports $m.	195,660	196,100	238,478	290,848	313,137
	% of US ATP imports from top 10 nations in 2008				
	2000	2002	2004	2006	2008
China	5.5	10.2	19.2	25.0	27.6
Mexico	6.6	8.3	9.3	10.6	12.2
Japan	17.8	12.1	10.0	8.9	8.1
Malaysia	6.5	7.7	7.6	8.6	6.1
Ireland	3.4	6.7	5.6	4.9	5.3
Canada	10.4	7.0	5.8	5.1	5.0
South Korea	7.0	7.1	7.5	4.7	4.9
Taiwan	7.6	6.8	5.4	4.8	4.2
France	4.8	4.9	3.7	3.4	3.6
Germany	4.5	4.1	4.0	3.9	3.5

Source: US Census Bureau, at http://www.census.gov/foreign-trade/statistics/country/index.html

US ATP imports from China are highly concentrated in ICT, while US ATP exports to China are spread across a wider range of industrial sectors (see Table 4). In 2008 88.0 percent of US ATP imports from China were classified in the information and communications grouping, with another 9.5 percent in the opto-electronics and electronics groupings combined. Of US ATP exports to China in 2008, electronics made up 35.4 percent, aerospace 28.2 percent, information and communications 19.6 percent, life science 7.5 percent, and flexible manufacturing 5.7 percent.

Table 4. US Advanced Technology Products trade with China, 2006-2008,by ATP category

	2006		2007		2008	
	Exports	Imports	Exports	Imports	Exports	Imports
US ATP trade with China, $b	17,633	72,727	20,349	88,006	18,733	91,393
	% distribution of US trade with China					
Biotechnology	0.19	0.05	0.31	0.06	0.49	0.06
Life Science	5.30	0.89	5.53	0.84	7.50	1.17
Opto-Electronics	1.51	6.60	1.62	6.05	1.38	7.24
Information & Communications	17.90	88.47	16.51	88.57	19.57	87.95
Electronics	34.10	2.72	32.30	3.21	35.40	2.24
Flexible Manufacturing	6.14	0.61	7.09	0.55	5.72	0.60
Advanced Materials	0.67	0.14	1.16	0.16	1.52	0.16
Aerospace	34.11	0.40	35.38	0.35	28.23	0.44
Weapons	0.01	0.11	0.01	0.14	0.01	0.13
Nuclear Technology	0.09	0.00	0.09	0.07	0.18	0.00

As in the analyses of the development of Korea, Malaysia, and India that I have outlined previously in this paper, a key to understanding China's progress in ICT is the dynamic interaction among investments by the Chinese government, indigenous enterprise, and MNCs in the development of productive capabilities. A pioneer in carrying out this type of research for the case of China was the late Qiwen Lu, with whom I collaborated closely (see Foreword to Lu 2000; Lu and Lazonick 2001; Lazonick 2004). In his book, China's Leap into the Information Age, Lu (2000) did in-depth case studies of the evolution of four leading indigenous computer companies: Stone, Legend, Founder, and Great Wall. Lu documented the transfer of technological capabilities developed within the S&T infrastructure to indigenous business enterprises, and the transformation of these capabilities by these enterprises, often in collaboration with MNCs, into innovative products.

In May 2005 one of these companies, Lenovo – known as Legend Group Limited until a year earlier – acquired IBM's PC operations for $1.75 billion with the right to use the IBM name on its products for five years.[44] IBM retained an 18.9 percent stake in Lenovo (reduced to 4.7 percent by July 2008) that it viewed as beneficial to its own expansion plans in China. For its part, Lenovo located its headquarters in the United States along with most of the design and development work (Poletti 2004).

In 2004, prior to the deal with IBM, Lenovo had already been China's largest PC producer with a 25.1 percent market share, followed by Founder with 9.9 percent, Tsinghua Tongfang with 7.8 percent, Dell with 7.2 percent, and IBM with 5.1 percent.[45] With $3.0 billion in revenues and 11,400 employees in fiscal 2004, Lenovo took control of a loss-making division of IBM that, nevertheless, had $9 billion in revenues and 10,000 employees, about 40 percent of whom were working in China. With the IBM acquisition, Lenovo became, after Dell and HP, the third-largest PC maker in the world with a 7.2 percent global market share. It also increased its share of the Chinese PC market to over 33 percent.[46] In 2007 Lenovo was fourth in global

[44] For a study of the evolution of Lenovo that is complementary to the earlier study by Lu (2000, ch. 3), see Xie and White 2004. Unless otherwise indicated, the following account of the evolution of Legend into Lenovo draws on Lu 2000, ch. 3.
[45] "Lenovo ranked top Chinese computer maker in 2004," Associated Press Newswires, March 9, 2005.
[46] "Lenovo sees more market share growth," Industry Updates, June 1, 2006.

PC shipments with a 7.5 percent, having been surpassed by the Taiwanese firm Acer, as a result of its acquisition of the US company Gateway (Deffree 2008). During fiscal 2008 Lenovo had revenues of $16.4 billion and before-tax profits of $513 million, and as of March 31, 2008 employed 23,100 people worldwide.

Legend was founded in 1984 in the Zhongguancun region of the Beijing Haidian District by the Institute of Computing Technology of the Chinese Academy of Sciences (CAS) for the purpose of commercializing the Institute's knowledge. Originally named "New Technology Development Company of the Research Institute of Computing Technology of CAS" – or ICT Co. – the company's eleven founders were initially Institute employees, with the Institute providing ICT Co. with a loan of RMB200,000 as well as office space and research facilities. The creation of the company within a major government research institute led to the depiction of Legend as the product of "one academy, two systems".

In setting up ICT Co., it was agreed that it would have "full autonomy in managerial decision-making, financial budgeting, and employee recruitment", even while having full access to the Institute's S&T resources and the use of the Institute's brand name in marketing its products (Lu 2000, 65). Initially, the new company had to scramble for income, even selling roller skates at one point, and it secured its first substantial revenues from a CAS service contract for the installation and operation of 500 imported computers. The product that launched the company on a growth path was a Chinese word-processing add-on card that could be used with existing IBM PCs and clones and that bore the "Legend" brand name. ICT Co. hired the key state scientist who had developed this technology within CAS. The add-on card was ICT Co.'s most important product during its early years, but the company also produced a wide array of computer-related items.

In April 1988 ICT Co. entered into a joint venture in Hong Kong, setting up Legend (Hong Kong) Co. for the purpose of marketing motherboards and add-on cards worldwide. In October of that year ICT Co. reorganized itself as Legend Computer Group Co., with Legend (Hong Kong) and Beijing Legend Computer Group Co. as its constituent subgroups. Legend remained a state-owned enterprise. Notwithstanding its origins within CAS and its ongoing reliance on the Institute for technological resources, however, Legend maintained managerial autonomy over strategic decision-making. That autonomy was reflected in the fixed annual payment of RMB1.2 million that ICT Co. and then Legend paid to the Institute. In 1985 this sum was 40 percent of ICT Co.'s revenues, but by 1988 it was less than 1 percent and by 1991 less than .02 percent. Meanwhile by 1986 ICT Co. had paid back its RMB200,000 loan to the Institute. In 1995 the relation between Legend and the Institute was brought full circle when CAS authorized Legend to take over the running of the Institute as the company's internal research organization.

Besides control over its revenue flow and access to state science and technology resources, an essential determinant of Legend's success was the integration of, to quote Lu (2000, 71), "R&D, manufacturing, marketing, and services into a coherent business structure". Within this integrated structure, before-and-after sales services, available in all the major cities of China, played a central role in both accessing customers and learning from them (Xie and White 2004, 410-411). In the early years, when potential customers had to be taught how to use computers, the company placed highly trained technical personnel in the field to help make sales and had 3,000 to

4,000 technicians available for after-sales instruction. Through the formation of Legend Chinese Word-Processing System Users' Association, the company turned its users into advocates of its products and provided feedback for product development. From 1985 the company also held two major technology fairs per year with more than 5,000 people attending annually. As the president of Legend recalled in a speech in 1995:

> What were our major competitive advantages? Other Chinese word-processing add-on cards were mostly developed by research institutes. These institutes did not have the kind of marketing capability that we had. I remember at a product contest in early 1986, there were at least several Chinese word-processing add-on cards, the quality and performance of which were as good as ours. Why did they lose? It was because they did not have the organizational capabilities to derive ideas from the market and act accordingly. We had an advantage in this regard. (Quoted in Lu 2000, 73)

ICT Co. entered into the personal computer business by becoming the sole distributor in China for AST, on whose machines it installed its Chinese word-processing system. ICT Co. and then Legend prospered immensely as AST became the leading PC brand in China. This relation took advantage of, and helped to build further, Legend's distribution channels, which in turn facilitated the development and marketing of scores of other computer-related products.

It was from this base, and with a view to eventually becoming a leading international vendor of PCs under it own brand name, that in 1988 the company launched a joint venture in Hong Kong with a company called China Technology that had ample financial resources and international legal expertise. By subsequently acquiring an 80 percent share of a small Hong Kong manufacturing plant, Legend (Hong Kong) built up its international business in PC motherboards. The original owner-entrepreneur of the Hong Kong plant retained the other 20 percent ownership stake and stayed on after the acquisition as the plant's general manager. When the output of the plant proved to be low quality, however, Legend bought the remaining 20 percent, dispensed with the services of this general manager, and brought in production managers and engineers from Beijing to improve quality.

In 1990 Legend introduced its own brand-name computer in China. According to Xie and White (2004, 411-413), while MNCs were trying to sell PCs with last-generation processors to the Chinese, Legend offered their customers the latest processors. Legend also designed the features of its PCs, and developed software in response to customer feedback. Legend Hong Kong had already tried to market its PCs internationally, but was unsuccessful mainly because Legend was not a global brand. In China, however, the brand was well known, and the company had a nationwide sales and service network to support its products. Legend's sales of its PCs in the domestic market increased from 2,000 in 1990 to 100,000 five years later. With this growth, Legend increased its commitment to R&D, establishing centers not only in Beijing, Shenzhen, and Hong Kong but also in Silicon Valley. In the Chinese PC market, Legend became the high quality, low cost producer.

In 1994 Legend went public on the Hong Kong Stock Exchange as Legend Holdings, Ltd. Twenty-five percent of the shares were issued to the public, while Beijing

Legend retained almost 39 percent. Four private Hong Kong individuals who had been associated with China Technology held another 32 percent between them (two of them holding 12 percent each). Beijing Legend's president became the chairman of Legend Holdings Ltd., and Beijing Legend supplied three of the five of Legend Holdings executive directors. The IPO raised HK$200 million, much of which was used to permit Legend to expand its manufacturing capacity. In addition, Legend did a secondary rights offering of shares (which left the ownership structure essentially unchanged) to raise HK$108 million specifically to build the Legend Science and Technology Park in Huiyang, China, near Shenzhen, less than 50 miles from Hong Kong. The company also took a controlling interest in a Hong Kong semiconductor company.

In the conclusion of his chapter on Legend, Lu stressed the fact that whereas most previous studies of the China-Hong Kong industrial relationship focused on Hong Kong's access to cheap Chinese labor in Guangdong (for example, Vogel 1989), the case of Legend was one of much greater complementarity of capabilities; China brought technology and managerial capability to Hong Kong as much if not more than vice versa. Lu also emphasized that (as of the time of writing in 1998), notwithstanding the listing of the company on the Hong Kong Stock Exchange and the minority shares held by private individuals in Hong Kong, majority ownership of Legend remained in collective hands – a vague combination of CAS, ICT, and Legend employees – and this ownership translated into Beijing remaining the locus of strategic control.

In 1997 Legend passed IBM and Compaq to become, China's leading PC brand (Xie and White 2004, 409). The company then began to diversify into set-top boxes, via a joint venture with Microsoft in 1999, as well as into Internet services, via a joint venture with Pacific Century CyberWorks, a major Hong Kong telecommunications company, in 2000. The company also did contract manufacturing, which accounted for 7 percent of revenues in 2002, 5 percent in 2003, and 4 percent in 2004. Even with this diversification, Legend remained overwhelmingly focused on its PC business, which represented about 90 percent of sales in the 2000s before it divested itself of its non-core businesses, including contract manufacturing, in 2004. Legend inaugurated the Lenovo brand name in 2003 specifically for international markets, and then made the brand name the company name in anticipation of its absorption of the IBM PC business.

The case of Legend/Lenovo exemplifies the ways in which over time the complementarity between indigenous enterprises and MNCs has become ever more important to China's development. The rapidly expanding US trade with China in advanced technology to which I have previously referred reflects in part imports from and exports to the United States by US MNCs such as Cisco, Dell, HP, IBM, Intel, Microsoft, Motorola, Oracle, and Sun Microsystems that have offshored to China. Some of these companies, for example Dell in computers, have competed for Chinese markets with indigenous companies such as Lenovo and Founder. US ICT companies have also set up shop in free trade zones, such as the Pudong district in Shanghai, from which they have produced for export, employing highly qualified but still relatively low-cost Chinese ICT labor. US ICT companies have also been prominent in joint ventures with Chinese companies, often as a means of developing relations with Chinese businesses and governments that will yield new investment opportunities and product markets in the future. Increasingly in areas such as chip manufacture and packaged software in which US ICT companies still have distinct competitive advantages, these companies are investing in new facilities in China in order to supply inputs to Chinese ICT companies that are growing rapidly by serving the burgeoning Chinese domestic markets.

Intel is a prime example of a world leader in ICT that began to make significant investments in China in the last half of the 1990s and that has accelerated its direct investment in China in the 2000s. Intel's first major business deal with China came in late 1984 when it sold the Chinese government 1,000 microcomputers with the Intel 8088 processor.[47] Less than a year later, Intel opened up a two-person marketing office in Beijing, run by William Huo, a 25-year-old Taiwan-born American with a Princeton degree in electrical engineering and computer science. Sales agreements still had to be approved at Intel's Far East headquarters in Hong Kong. Under the auspices of China's State Education Commission, Huo's job was to set up microprocessor development labs at 100 Chinese universities where engineers would be taught how to program Intel processors (Sabin 1986).

When in June 1986, Li Tieying, the Minister of Electronics Industry, came to Palo Alto as the first Chinese official to attend a trade meeting of the US semiconductor industry, he complained that, despite many visits by US executives to China, there had thus far been no foreign investments in chip manufacturing. The major problem, he was told, was China's unwillingness to protect intellectual property.[48] In addition, COCOM – Coordinating Committee for Multilateral Export Controls – embargoed the exports of military-related technology, including advanced semiconductors, to Communist regimes (see e.g., Bozman 1990; Parker 1994a and 1994b).

In September 1988, however, Motorola launched the first semiconductor facility in China as a wholly-owned venture. At the time, Intel was among a number of chip companies said to be contemplating similar investments. It appeared that Intel would make its first move into Chinese production in 1991 when it reportedly entered into a joint venture with the state-owned China Electronics Corporation (CEC), the nation's largest electronics enterprise group, and the Hongkong Corporation to produce microprocessors for the Chinese market.[49]

In September of the following year the Intel head office instructed Intel Technology Malaysia to enter into negotiations with the Chinese authorities about opening a semiconductor plant in China.[50] In March 1994 Intel signed a contract with CEC whereby CEC would promote Intel's products as the standard PC architecture in China, while Huajing Electronics, a CEC subsidiary and China's largest semiconductor producer, would assemble and test Intel 386SX microprocessors and Intel microcontrollers (Johns 1994; Kehoe 1994).

In September 1994 Intel supported this initiative by launching a wholly-owned subsidiary, Intel Architecture Development Ltd. (IADL) in Shanghai. With 25 Chinese engineers initially, IADL would develop software that would make PCs, and

[47] "Intel begins shipment under Chinese contract," Wall Street Journal, December 12, 1984.
[48] "Electronics Weekly concludes its look at US semiconductors in '86," Electronics Weekly, January 28, 1987.
[49] "State councillor meets US businessman," Xinhua News Agency, March 8, 1991.
[50] "Malaysian unit to look at Intel moves into China," Electronic Times, September 3, 1992.

Intel chips, more applicable to Chinese needs (Riley 1994).[51] A month later IADL signed a Memorandum of Understanding with Jitong Communications, a key ICT vendor attached to the Ministry of Electronics, to exhibit and sell Intel products.[52]

Enabling Intel's more aggressive stance toward selling its more advanced products in China was the end of the Cold War and the disbanding in March 1994 of COCOM. Included among the products embargoed by COCOM had been Intel's Pentium chip. In December 1994 Intel held seminars in Beijing, Shanghai, Guangzhou, Chengdu and Xian to reveal, in the words of the Reuters reporter, "the Pentium's sensitive operational guts to Chinese software developers" (Parker 1994).

On his trip to Shanghai to launch IADL, Andrew Grove, Intel's CEO, announced that the company was exploring the possibility of opening up a wholly-owned chip factory in China (Pei 1994), and indeed by the following June plans for such a plant had been hatched.[53] One report on the project noted that "Intel is planning to pull-out its expatriates as soon as possible in view of installing Chinese in key executive positions. Hence, management training is expected to become a priority for the America company."[54]

Run by Intel Technology (China) Co. Ltd. and located in Shanghai's Pudong Development Zone, the facility went into operation at the beginning of 1998, assembling and testing flash memory chips for export. The plant quickly became the largest exporter among MNCs in Pudong, and by 2000 had 800 employees. Construction was underway to increase Intel's Shanghai factory space from 120,000 to 500,000 square meters.[55] By the time the expansion came on line, Intel had spent about $500 million on it.[56] In 2004 Intel had three assembly and test facilities in Shanghai with 2,000 people on their payrolls out of a total of 2,400 Intel China employees across the country (Heim 2004).

In 1997 Intel had moved its regional sales functions from Hong Kong to Beijing to better position itself to tap into China's growing market opportunities (LaPedus 1997). The following year, also in Beijing, the company set up Intel China Research Center (ICRC), its first research facility in the Asia-Pacific. According to Intel's website, the mission of ICRC is to "empower the future of the digital world through research and platform innovations, and drive strategic technology collaborations with Chinese government, academia and industry."[57]

One such collaboration, begun in 1999, was with Legend Holdings to expand the use of the Internet in China. Legend was the first Chinese PC maker to which Intel supplied chips; the two companies had been working together closely since the mid-1990s, with Intel pushing Legend to increase the power of its PCs. Indeed, in 1998 Legend ceremoniously presented its millionth PC to Intel CEO, Andrew Grove (O'Neill 1998). Now the two companies would work together to upgrade the speed of

---

[51] "Intel to help set up PC standards," Shanghai Star, September 9, 1994.
[52] "A golden deal for Intel," Electronic Times, November 3, 1994.
[53] "China – Intel plans assembly plant in Shanghai," Newsbytes, June 7, 1995.
[54] "China: Initial investment of $30,000,000 to build microchip plant is to be followed by significant additional outlays, Intel (USA)," ESP-Report on Engineering Construction & Operations in the Developing World, July 1, 1995.
[55] "Intel expands IC chop production in China," Asia Pulse, September 8, 2000.
[56] "Intel to reinvest US$302,000,000 to China," AsiaPort Daily News, September 26, 2001.
[57] http://www.intel.com/cd/corporate/icrc/apac/eng/167066.htm

computer terminals as well as the capacity and applications of servers in China's broadband network. [58] They took the collaboration further when in 2003 they opened the Intel-Lenovo Technology Advancement Center in Beijing for home networking and security applications.[59] Nevertheless, less than a year later Lenovo announced that it would use microprocessors from AMD, Intel's long-time rival, in two of its new consumer PCs.[60] At the time Lenovo said that it was not considering using AMD chips for commercial PCs and servers. In 2006, however, Lenovo did just that as it used AMD microprocessors in PCs designed for businesses (Evers 2006).

In 2000 Intel placed IADL (now called Intel Architecture Labs), ICRC, and other Intel support centers under the umbrella of Intel China Labs (Hou 2000).[61] By the mid-2000s, Intel was involved in a wide variety of government, academic, and industrial collaborations, many of them focused on wireless technology. In June 2005 the company created the $200-million Intel Capital China Technology Fund to invest in Chinese technology companies in areas related to Intel's strategic interests.[62] In September 2005 Intel launched Asia-Pacific Research & Development Ltd. in Shanghai's Zizhu Science Park, with prospective employment of 1,000 people by the end of 2006, as "part of the company's ongoing effort to embrace the growing pool of technical talents in China, to enhance local R&D capabilities, and to deliver time-to-market, customized platforms and solutions for markets across Asia Pacific and the world."[63] In January 2006, Intel China established an "Innovation Alliance", initially with 22 Chinese high-tech companies including 10 computer manufacturers and 12 software vendors and content providers. Open to all Chinese ICT companies, Intel would use the Innovation Alliance to offer member enterprises technical support and consulting services related to market surveys, product design, and application software.[64]

In 2001 Intel had 90 percent of the Chinese microprocessor market (Young and Lin 2006). In 2002 the Chinese market became Intel's second largest, trailing only the United States (Young 2003). During the 2000s China has been the company's fastest growing market, notwithstanding the fact that it has lost significant market share to AMD. In 2004 Intel's China market share had fallen to 74 percent, down 16 points from 2001, while AMD's increased from 5 percent to 18 percent over the same period (Young and Lin 2006). In 2007 AMD was still eating into Intel's share of the China market, and in fact had itself become the leader in microprocessors with over a 50 percent share.[65]

In an interview in Beijing in 2004, Craig Barrett, Intel CEO, pronounced that people in China "are capable of doing any engineering job, any software job, and managerial job that people in the US are capable of doing" (quoted in Heim 2004). In 2005 Intel employed over 5,000 people in China, about 5 percent of its global labor force and a

---

[58] "Legend, Intel to boost China Internet use," Reuters News, March 8, 1999.
[59] "Intel, China's Legend Group set up technology center in Beijing," Xinhua Financial Network News, August 28, 2003.
[60] "China's Lenovo to use AMD chips in two new PCs," Asia in Focus, June 11, 2004.
[61] "Intel to set up R&D umbrella program," Asiainfo Daily China News, November 6, 2000.
[62] "Intel establishes $200 million China venture fund," Business Wire, June 13, 2005
[63] "Intel expands research and development in China," M2 Presswire. September 15, 2005.
[64] "Intel (China) Ltd forges Innovation Alliance with 22 Chinese enterprises," China Industry Daily News, January 13, 2006.
[65] "AMD eats into Intel's market share in China," chinadaily.com.cn, September 6, 2007, at http://www.chinadaily.com.cn/china/2007-09/06/content_6086152.htm

doubling of the Chinese employment level from 2004 (Wallace 2005). Most of these people worked in Intel's four assembly and test factories, three in Shanghai and a fourth in Chengdu, in the southwestern province of Sichuan, which began operations in December 2005. In March 2005, Intel announced that it would build a second plant in Chengdu to come on line in 2007.[66]

As in Malaysia, virtually all of the people who Intel employs in China are home grown. An article published in 2006 in the *Wall Street Journal* provides an excellent description of how, in Chengdu, a low-cost location but one with little history of high-tech manufacturing, Intel recruited and trained, in collaboration with local universities, a labor force for its first chip plant, and was in the process of doing the same for the second one (Ramstad and Juying 2006). The article also noted that with the completion of the second Chengdu plant, "the company has said it will build its next factory in yet another place where no other chip manufacturing exists: Vietnam."[67]

Global Labor Flows and National Economic Development

I began by asking why, with so many educated people coming from Asia to the United States for further study and work experience, so many jobs are going from the United States to the places from which these people are coming to employ people just like them. The answer is that the flows of people from East to West and jobs from West to East are complementary movements in the globalization of the high-tech labor force as a dynamically evolving process. At an early stage of development, people go from East to West for graduate education and work experience through which they can build careers in a way not possible at home. Meanwhile jobs go from West to East in search of low-wage but nevertheless productive labor. Over time, through MNC investment in higher value-added activities, the quality of the indigenous labor force improves. As living standards rise in the East, some of its expatriates, now more educated and experienced from their time in the West, are lured back home. Indeed some of them will make the return trip to the East as employees of the companies for which they had worked in the West. If and when indigenous companies emerge in the East as global players, the need to go abroad for education and experience is further reduced, while many of the most educated and experienced expatriates working in the West come back home to assume leadership posts.

Focusing mainly on Asian entrepreneurs who have spent time starting or managing companies in Silicon Valley, AnnaLee Saxenian (2006, 18-21) has characterized these flows as "brain circulation", an apt characterization for the global career paths that increasing numbers of East Asians are pursuing. As these "brains" circulate, their capabilities accumulate. What I have outlined in this paper are the historical forces, beyond the desire of talented individuals to pursue challenging and rewarding careers, that created the global ICT labor force and that have enabled nations such as South Korea, Taiwan, India, and China to reap the returns on national investments in education by bringing large numbers of educated and experienced people back home.

---

[66] "Intel to build 2nd chip test and package plant in southwest China," AFX International Focus, March 23, 2005.

[67] See also Hopfner (2007). Intel's $1 billion plant in Ho Chi Minh City, with a capacity for 600 million chip sets per year, is slated to begin production in September 2009, with 500 engineers, increasing to 1,000 by the end of 2009. After a three year ramp-up, Intel expects to employ 4,000 at the Vietnam plant

More important quantitatively, the growth dynamic that has been set in motion in these nations has generated domestic employment opportunities that are sufficiently challenging and rewarding so that it is increasingly unnecessary for ambitious college graduates to go abroad to pursue careers.

These historical forces cannot be understood as "market forces". Rather, as I have illustrated, their essence resides in a triad of investment strategies of MNCs engaged in FDI, national governments that construct indigenous science and technology infrastructures, and indigenous companies that build on the investment strategies of foreign companies and domestic governments to become world-class competitors in their own right. This triad takes as its historical starting point the existence of a national education system that created a highly educated labor supply in advance of domestic employment demand. In the absence of jobs at home, market forces, aided by changes in US immigration policy, directed this labor abroad, with brain drain as the result. By means of the investment triad, nations such as South Korea and Taiwan in effect confronted these market forces, and helped to generate a dynamic of indigenous job creation that reversed the brain drain, and transformed expatriate scientists and engineers from a wasted investment into a valuable resource. China and India are now doing the same.

The particular cases that I have examined reveal distinctive development paths, depending on the relation over time of investment by foreign and indigenous enterprises. In the cases of Motorola in Korea, Intel in Malaysia, and Texas Instruments in India, US-based MNCs invested early, and then upgraded and expanded their investments over substantial periods of time. In addition, in each case great emphasis was placed on the almost exclusive employment of indigenous engineers and managers, and in the early years created some of the first attractive opportunities for nationals to pursue high-tech careers at home.

In the case of South Korea, indigenous investments by government and business rather than FDI have since the late 1980s driven the development of domestic high-tech capabilities. Samsung in particular has emerged as a world leader in ICT. In the 2000s these indigenous investments are creating new opportunities for high-end investment by MNCs in South Korea, including new investments by a company such as Motorola that has been doing business there for over 40 years. In contrast, in the absence of leading indigenous ICT companies, Malaysia's growth still remains highly dependent on the upgrading strategies of MNCs such as Intel, with scant impetus to indigenous innovation.

For US high-tech MNCs, the inducement to invest in India was never low-wage, low-skill labor. What first attracted Texas Instruments to India in the mid-1980s was the availability of highly educated engineers and programmers who also happened to have relatively low wages. Over time TI expanded and upgraded its Indian operations, employing larger numbers of educated labor to design increasingly complex products. Two decades after TI came to Bangalore, India is experiencing a growth dynamic in which, with both skill levels and wages rising, indigenous companies such as TCS, Wipro, and Infosys are taking the lead, and in which MNCs continue to be attracted to India more for the high quality of its ICT labor supply than for its low cost.

A similar process of indigenous innovation has been taking place in China, but with the difference that indigenous Chinese companies such as Lenovo and Founder, the leading Chinese electronic publishing company (see Lu 2000, ch.4; Lu and Lazonick 2001), have emerged to serve the growing Chinese consumer and business markets, and have drawn upon the capital goods expertise of MNCs such as Intel, TI, Motorola, and HP to develop higher quality, lower cost products. Lenovo and Founder are prime examples of indigenous companies that have become leading competitors not only in China but also internationally. In the communications technology sector, Huawei Technologies and ZTE, are doing the same (Feng and Zhang 2008). While there are large numbers of Chinese ICT employees who have acquired higher education and work experience in the United States, the vast majority have been receiving that education and experience in China.

Given the growth dynamic that has taken hold in these nations, sheer size ensures that Indians and Chinese will dominate the expansion of the global ICT labor supply. Combined, the population of India and China is 33 times that of South Korea and Taiwan. India and China have rapidly growing home markets that both provide domestic demand for the products of indigenous companies and give their governments leverage with MNCs in gaining access to advanced technology as a condition for FDI. While India and China offer indigenous scientists and engineers rapidly expanding employment opportunities at home, vast numbers of their educated populations are studying and working abroad. Aided by the liberalization of US immigration policy, the global career path is much more of a “mass” phenomenon for Indian and Chinese scientists and engineers than it was for the Koreans and Taiwanese. History tells us that, following global career paths, more and more Indian and Chinese high-tech labor will migrate back to the places from whence they came. The globalization of the high-tech labor force and the sustained development of India and China have gone, and will continue to go, hand in hand.

What are the implications of the globalization of the ICT labor force for employment opportunities in a high-wage country such as the United States? “Offshoring” has been a major political issue in the United States in the 2000s (see Hira and Hira 2005), precisely because of the globalization of the ICT labor force, whose evolution I have just analyzed. Responding to a reporter who in late 2003 asked what, in view of the outsourcing phenomenon, job prospects in Silicon Valley would look like in three years, the ever-quotable Craig Barrett stated: “Companies can still form in Silicon Valley and be competitive around the world, It’s just that they are not going to create jobs in Silicon Valley” (Merritt 2004). In 2004 Barrett was quoted (in Heim 2004) as saying:

> As CEO of Intel, my allegiance is to the shareholders of Intel and to the success of the company. We go after the most cost-effective resources around the world, no matter where they are. [However,] as an American citizen, I would have to be worried about whether jobs that are created are created outside the U.S. . . . As a citizen, I see all these resources and I think this puts my country in danger.

Subsequently Barrett served as a member of the US National Academy of Sciences Committee on Prospering in the Global Economy in the 21st Century that delved into deficiencies in the development of science and engineering capabilities in the United States (CPGE 2005). Notwithstanding his obvious concern about these problems from a public policy perspective, on a radio talk show in February 2006, Barrett remarked: “Companies like Intel can do perfectly well in the global marketplace without hiring a single US employee.”[68]

Indeed, in the 2000s major US-based ICT companies such as HP, IBM, and Intel have indeed been expanding employment rapidly abroad while employing fewer workers in the United States. From 2001 to 2008 IBM increased its worldwide employment by almost 25 percent from 319,867 to more than 398,455, but its US employment fell by 21 percent from 152,195 to 120,227. In January 2009, with net income of $12.3 billion in 2008, laid off about 4,000 employees in the United States and Canada, and then, under a program called Project Match, offered them to possibility of being re-employed in places like China and India, at Chinese and Indian wages.[69]

Similarly, from 2002 to 2007 Hewlett-Packard’s worldwide employment expanded by 22 percent from 141,000 to 172,000, but its US employment fell by 21 percent from 67,350 to 53,519. In 2007 Intel’s worldwide employment of 85,187 was 2 percent higher than in 2001, but its US employment of 46,186 was 15 percent lower.[70] Some US-based companies that have increased US employment in the 2000s have expanded non-US employment at a faster rate. Microsoft doubled its US employment from 27,000 in 2000 to 55,000 in 2008, but the US share of worldwide employment fell from 69 percent to 60 percent. Cisco Systems increased its US employment from 25,000 in 2000 to 37,400 in 2008, but the US share of worldwide employment fell from 74 percent to 57 percent.[71]

These companies profit from offshoring but their top executives choose to use a large portion of those profits to buy back their own shares rather than augment the quality and quantity of jobs available in the United States (see Milberg 2008; Lazonick 2008a, 2008b, and 2009). From 2000 through 2007, Microsoft repurchased $81.7 billion of its own shares, equivalent to 80 percent of its net income over this period; IBM $56.4 billion (63 percent), Cisco Systems $43.1 billion (151 percent), Intel $41.8 billion (93 percent), and HP $33.7 billion (128 percent). In every one of these cases, expenditures on repurchases exceeded expenditures on R&D over the period 2000-2007. As I have argued in detail elsewhere (Lazonick 2009), the problem that faces educated and experienced high-tech workers in the United States is not global labor competition but rather the failure of the companies that they have to build to use the profits from globalization to reinvest in the United States.

[68] Craig Barrett, Interviewed by Tom Ashbrook, On Point, WBUR, February 11, 2006.
[69] “IBM offers to move laid off workers to India,” CMP TechWeb, February 2, 2009.
[70] These data are drawn from the companies’ global citizenship reports, available on their websites.
[71] These data are drawn from 10-K filings.

References:

Adams, Walter, 1968, ed., The Brain Drain, Macmillan.
Amighini, Alessia, 2004, “China in the International Fragmentation of Production: Evidence from the ICT Industry,” European Journal of Comparative Economics, 2, 2: 203-219.
Amsden, Alice, 1989, Asia’s Next Giant: South Korea and Late Industrialization, Oxford University Press.
Amsden, Alice, and Wan-wen Chu, 2003, Beyond Late Development: Taiwan’s Upgrading Policies, MIT Press.
Arnold, Walter, 1988, “Science and Technology Development in Taiwan and South Korea,” Asian Survey, 28, 4: 437-450.
Arnst, Catherine, 1991, “Poor nations seen aiding rich by brainpower export in billions,” Reuters News, April 7.
Aubin, Dena, 2006, “Cisco sells $6.5 billion in record US debt debut,” Reuters News, February 14.
Barro, Robert J., and Jong-Wha Lee, 2000, “International Data on Educational Attainment: Updates and Implications,” Harvard Center for International Development Working Paper No. 42, April: Appendix Data Files, available at http://www.cid.harvard.edu/ciddata/ciddata.html.
Bassett, Ross Knox, 2005, “Facing Two Ways: The Indian Institute of Technology Kanpur, American Technical Assistance, and the Indian Computing Community, 1961-1980,” paper presented at the Society of the History of Technology meetings, Minneapolis, November 5.
Behrman, Jack N., and Harvey W. Wallender, 1976, Transfers of Manufacturing Technology Within Multinational Enterprises, Ballinger.
Bindra, Ashok, 1997, “Silicon influx puts India on world electronics map,” Electronic Engineering Times, April 7.
Bloom, Martin, 1992, Technological Change in the Korean Electronics Industry, Development Centre OECD.
Bozman, Jean, 1990, “US’ plight: Factory flight,” Computerworld, March 19.
Branscomb, Lewis, and Young-Hwan Choi, eds., 1996, Korea at the Turning Point: Innovation-Based Strategies for Development, Praeger.
Breznitz, Dan, 2008, Innovation and the State: Political Choice and Strategies for Growth in Israel, Taiwan, and Ireland, Yale University Press.
Byun, Byung Moon, 1994, “Growth and Recent Development of the Korean Semiconductor Industry,” Asian Survey, 34, 8: 706-720.
Chang, Y.S., 1971, The Transfer of Technology: Economics of Offshore Assembly, The Case of the Semiconductor Industry, UNITAR Research Report no. 11, United Nations Institute for Training and Research.
Chatterjee, Julie, 1994, “Bangalore woos the technocrat,” Straits Times, January 21.
Chira, Susan, 1985, “Korea’s chipmakers race to catch up,” New York Times, July 15.
Clark, Don, 1990, “National Semi to trim 2,000 jobs in cutback,” San Francisco Chronicle, August 22.
Conroy, Richard, 1992, Technological Change in China, Development Center of the OECD.
Davis, Warren E., and Daryl G. Hatano, 1985, “The American Semiconductor Industry and the Ascendancy of East Asia,” California Management Review, 27, 1: 128-143.
Deffree, Suzanne, 2008, “Acer overcomes Lenovo as no. 3 PC OEM, nips at Dell’s heels for no. 2 spot,” Electronic News, March 6.

Dennis, William, 1990, "Intel to start MPU production in Malaysia," Electronic World News, April 9.
Dreyfack, Kenneth, and Otis Port, 1986, "Even American knowhow is headed abroad," Business Week, March 3.
Dudley, Brier, 2004, "Microsoft research lab is opening in India," Seattle Times, December 1.
Ernst, Dieter, 2002, "Global Production Networks and the Changing Geography of Innovation Systems: Implications for Developing Countries," Economics of Innovation and New Technology, 11, 6: 497-523.
Evers, Joris, 2006, "Lenovo expands use of AMD chips," ZDNet UK, August 8.
Feng, Kaidong, and Ming Zhang, 2008, "Governance and Technological Learning in a Transition Economy: The Case of the Chinese Telecommunications Equipment Sector," revision of a paper presented at the Conference on Innovation and Competition in the Global Communications Technology Industry, INSEAD, Fontainebleau, France August 23-24, 2007.
Flamm, Kenneth, 1985, "Internationalization in the Semiconductor Industry," in Joseph Grunwald and Kenneth Flamm, The Global Factory: Foreign Assembly in International Trade, Brookings.
Flannery, Russell, 1999, "Advanced Semiconductor to buy 2 Motorola plants," Asian Wall Street Journal, February 8: 3.
Foremski, Tom, 1990, "Jobs for thousands of UK programmers/analysts threatened by immigration bill limiting work visas," Computing, October 25.
Fortney, Judith, 1970, "International Migration of Professionals," Population Studies, 24, 2: 217-232.
Fukasaku, Tohiko, 1992, Technology and Industrial Development in Pre-War Japan: Mitsubishi Nagasaki Shipyard, 1884-1934, Routledge.
Gu, Shulin, 1999, China's Industrial Technology, Routledge.
Gutchess, Jocelyn, 1985a, "Employment Security *and* Productivity? It *Can* Be Done," National Productivity Review, 4, 3: 275-286.
Head, Beverley, 1989, "Bodyshopping boom eases Australia's skill shortage," Australian Financial Review, September 4.
Heim, Kristi, 2004, "U.S. high-tech giants invest in future competitor," San Jose Mercury News, March 15.
Henderson, Jeffrey, 1989, The Globalisation of High Technology Production, Routledge.
Hira, Ronil, and Anil Hira, 2005, Outsourcing America, American Management Association.
Ho, Samuel P. S., 1975, "Industrialization in Taiwan: Recent Trends and Problems," Pacifica, 48, 1: 27-41.
Hobday, Michael, 1995, Innovation in East Asia: The Challenge to Japan, Elgar Publishing.
Hopfner, Jonathan, 2007, "Intel readies Vietnam facility for fall 2009 launch," EETimes, August 9.
Hou, Mingjuan, 2000, "Intel boosts R&D in China," China Daily, October 26.
Ilchman, Warren F., 1969, "'People in Plenty': Educated Unemployment in India," Asian Survey, 9, 10:781-795.
Institute of International Education, 2005, Open Doors: Report on International Educational Exchange, 1948-2004, on CD-ROM.
Ismail, Izwan, 2005, "Intel steps up local investment," New Strait Times, December 12.
Ismail, Mohd Nazai, 1999, "Foreign Firms and National Technological Upgrading: The Electronics Industry in Malaysia," in Jomo K. S., Greg Fulker, and Rajah Rasiah, eds., Industrial Technology Development in Malaysia, Routledge: 21-37.

Johns, Brian, 1994, "Chip maker Intel signs China partnership agreement," Journal of Commerce, March 30.
Johnson, Jean, and Mark Regets, 1998, "International Mobility of Scientists and Engineers to the United States – Brain Drain or Brain Circulation?," Division of Sciences Resources Studies Issue Brief, MSF 98-316, Revised, November 10.
Jomo K. S., Greg Fulker, and Rajah Rasiah, eds., 1999, Industrial Technology Development in Malaysia, Routledge: 21-37.
Kehoe, Louise, 1994, "Intel in Chinese partnership," Financial Times, March 29.
Kim, Dong-Won, and Stuart W. Leslie, 1998, "Winning Markets or Winning Noble Prizes? KAIST and the Challenges of Late Industrialization," Osiris, 2nd ser., 13: 154-185.
Kim, Linsu, 1997a, "The Dynamics of Samsung's Technological Learning in Semiconductors," California Management Review, 39, 3: 86-100.
Kim, Linsu, 1997b, Imitation to Innovation: The Dynamics of Korea's Technological Learning, Harvard Business School Press.
Koike, Kazuo, and Takenori Inoki, eds., 1990, Skill Formation in Japan and Southeast Asia, University of Tokyo Press.
LaPedus, Mark, 1997, "China: Sleeping giant is stirring," Electronic Buyers News, January 13.
Larrowe, Charles P., 1961, "A Meteor on the Industrial Relations Horizon: The Foreman's Association of America," Labor History, 2, 3: 259-294.
Lazes, Peter, Leslie, Rumpeltes, Ann, Hoffner, Larry Pace, and Anthony Costanza, 1991, "Xerox and ACTWU: Using Labor-Management Teams to Remain Competitive," National Productivity Review, June 22.
Lazonick, William, 2004, "Indigenous Innovation and Economic Development: Lessons from *China's Leap into the Information Age*," Industry & Innovation, 11, 4: 273-298.
Lazonick, William, 2007, "Globalization of the ICT Labor Force," in Robin Mansell, Christanthi Avgerou, Danny Quah, and Roger Silverstone, eds., The Oxford Handbook of Information and Communication Technologies, Oxford University Press: 75-99.
Lazonick, William, 2008a, "Everyone Is Paying the Price for Share Buy-Backs." Financial Times, September 26.
Lazonick, William, 2008b, "The Quest for Shareholder Value: Stock Repurchases in the U.S. Economy." Louvain Economic Review, 74, 4: 479-540
Lazonick, William, 2009, Sustainable Prosperity in the New Economy?: Business Organization and High-Tech Employment in the United States, Upjohn Institute for Employment Research, forthcoming.
Lee, Charles S., 1998. "Remaking Korea Inc.," Far Eastern Economic Review, April 30.
Lee, Dal Hwan, Zong-Tae Bae, and Jinjoo Lee, 1991, "Performance and Adaptive Roles of the Government-Supported Research Institute in South Korea," World Development, 19, 10: 1421-1440.
Leow, Claire, 1992, "Intel Corp plans US$80m investment in Penang plant," Business Times Singapore, November: 13.
Leslie, Stuart W., and Robert H. Kargon, 1996, "Selling Silicon Valley: Frederick Terman's Model for Regional Advantage," Business History Review, 70, 4:435-472.
Lohr, Steve, 2004, "I.B.M. sought a China partnership, not just a sale," New York Times, December 13.
Lowell, B. Lindsay, 2000, "H-1B Temporary Workers: Estimating the Population," working paper, Institute for the Study of International Migration, Georgetown University, April 17.
Lu, Qiwen, 2000, China's Leap into the Information Age, Oxford University Press.

Lu, Qiwen, and William Lazonick, 2001, "The Organization of Innovation in a Transitional Economy: Business and Government in Chinese Electronic Publishing," Research Policy, 30, 1: 35-54.
Lynn, Kathleen, 1999, "For older workers, cash-balance pension plans can hurt," The Record (Hackensack NJ), May 20.
Maddison, Angus, 2007, "Historical Statistics, World Population, GDP, and per capita GDP, 1-2003 AD," accessed at http://www.eco.rug.nl/~Maddison/.
Mailman, Stanley, and Stephen Yale-Loehr, 2003, "Immigration Law; Foreign Nurses," New York Law Journal, December 22.
Mathews, John A., 1997, "A Silicon Valley of the East: Creating Taiwan' Semiconductor Industry," California Management Review, 39, 4: 26-54.
Mathews, John A., and Dong-Sung Cho, 2000, Tiger Technology: the Creation of Semiconductor Industry in East Asia, Cambridge University Press.
Matsumoto, Miwao, 1999, "Reconsidering Japanese Industrialization: Marine Turbine Transfer at Mitsubishi," Technology and Culture, 40, : 74-97.
Merritt, Rick, 2004, "Globalization of electronics: Political winds hit offshoring," Electronic Engineering Times, March 29.
Milberg, William, 2008, "Shifting Sources and Uses of Profits: Sustaining US Financialization with Global Value Chains," Economy and Society, 37, 3: 420-451.
Mitchell, Jim 1986, "TI grasping the future with both hands," Dallas Morning News, September 26.
Mitra, Raja M., 2007, "India's Emergence as a Global R&D Center," Swedish Institute for Growth Policy Studies, Working Paper R2007:012.
Morikawa, Hidemasa, 2001, History of Top Management in Japan: Managerial Enterprises and Family Enterprises, Oxford University Press.
Moxon, Richard, 1974, "Offshore Production in the Less Developed Countries: A Case Study of Multinationality in the Electronics Industry," New York University, Institute of Finance, Bulletin nos. 98-99.
National Science Board, 2004, Science and Engineering Indicators 2004, Two volumes, National Science Foundation.
National Science Board, 2008, Science and Engineering Indicators 2008, National Science Foundation.
National Science Foundation, 1993, Human Resources for Science and Technology: The Asian Region, Surveys of Science Resources Series, Special Report, NSF 93-303.
North, David S., 1995, Soothing the Establishment: The Impact of Foreign-Born Scientists and Engineers on America, University Press of America.
O'Neill, Mark, 1998, "Legend gives Intel chief millionth PC," South China Morning Post, May 7.
O'Reilly, Brian, 1992, "Your new global work force," Fortune, December 14.
Parker, Jeffrey, 1994a, "Intel's first China chip project challenges curbs," Reuters News, March 25.
Parker, Jeffrey, 1994b, "Intel pushes software in China," Reuters News, December 5.
Pei, Jianfeng, 1994, "Intel may produce chips in Shanghai," Business Weekly, September 11.
Pernia, Ernest M., 1976, "The Question of the Brain Drain from the Philippines," International Migration Review, 10, 1: 63-72.
Poletti, Therese, 2004, "IBM to sell majority stake in PC business to Chinese firm," San Jose Mercury News, December 8.
Pollack, Andrew, 1985b, "US-Korea chip ties grow," New York Times, July 15.
Rai, Saritha, 2003, "In India, a high-tech outpost for US patents," New York Times, December 15.

Ramstad, Evan, and Qin Juying, 2006. "Intel Pushes Chip Production Deep into China," Wall Street Journal, May 23.
Raskin, Kenneth A., Sharon Parella, Tal Marnin, Colleen Hart, Marko C. Maglich, Stuart Lasky, 2007, "Fiscal 2008 H-1B visas update," Executive Compensation, Benefits and Employment Law Focus, April at http://www.whitecase.com/ecbelfocus_0407_5/.
Ribeiro, John, 2005, "Microsoft to increase development staff in India," IDG Computerworld, September 28.
Riley, James, 1994, "Intel out to expand China PC activities," South China Morning Post, September 6.
Sabin, Russell, 1986, "Intel's man in China chips away at vast market," San Francisco Chronicle, April 28.
Salih, Kamal, and Mei Ling Young, 1987, "Social Forces, the State and the International Division of Labour: the Case of Malaysia," in Jeffrey Henderson and Manuel Castells, eds., Global Restructuring and Territorial Development, Sage: 168-202.
Saxenian, AnnaLee, 2006, The New Argonauts: Regional Advantage in a Global Economy, Harvard University Press.
Saxenian, AnnaLee and Jinn-Yuh Hsu, 2001, "The Silicon Valley-Hsinchu Connection: Technical Communities and Industrial Upgrading," Industrial and Corporate Change, 10, 4: 893-920.
Schmeck, Jr., Harold M., 1973, "Asia biggest source of brain drain to U.S.," New York Times, January 13.
Scott, A. J., 1987, "The Semiconductor Industry in South-East Asia: Organization, Location, and the International Division of Labour," Regional Studies, 21, 2:143-160.
Sebaly, Kim Patrick, 1972, The Assistance of Four Nations in the Establishment of the Indian Institutes of Technology, 1945-1970, unpublished Ph.D. dissertation, University of Michigan.
Shabecoff, Philip, 1970 "South Korea's economy booming with cheap labor," New York Times, May 12,
Sharma, Dinesh, 2004, "AMD to open engineering center in India," CNETNews.com, April 22.
Sharpston, Michael, 1975, "International Sub-Contracting," Oxford Economic Papers, 27, 1: 94-135
Shenkman, Albert S., 1954, "Higher Education in India," Far Eastern Survey, 23, 2,: 24-28.
Sigurdson, Jon, 1980, Technology and Science in the People's Republic of China, Oxford University Press.
Spaeth, Anthony, 1984, "Korean companies set expensive plans to make microchip plants competitive," Wall Street Journal, February 8.
Sporck, Charles E., with Richard L. Molay, 2001, Spinoff: A Personal History of the Industry That Changed the World, Saranac Lake Publishing.
Subramanyam, R., 2005, "Intel sets up circuit research lab in B'lore," Economic Times, May 25.
Suttmeier, Richard P., 1975, "Science Policy Shifts, Organizational Change, and China's Development," China Quarterly, 62, 207-241.
Szabo, Joan C., 1989, "Opening doors for immigrants," Nation's Business, August 1: 48.
Tarrant, Bill, 1991, "IBM set to return to India," Reuters News, August 28.
Tenorio, Vyvyan, 1985, "The big computer catch-up begins," Australian Financial Review, July 31: 13.
Tilton, John E., 1971, International Diffusion of Technology: The Case of Semiconductors, Brookings Institution.
Tripathi, Salil, 1992, "India approves seven foreign investment plans worth S$685m.," Business Times Singapore, January 15.

US Department of Homeland Security, 2002-2004, “Characteristics of Specialty Occupation Workers (H-1B),” US Government Printing Office, April 2002, September 2003, July 2004.

US Department of Homeland Security, 2002-2007, Yearbooks of Immigration Statistics, US Government Printing Office.

US Department of State, 1997-2006, Tables on Non-Immigration Visas Issued, Fiscal Years, available at http://travel.state.gov/visa/frvi/statistics/statistics_1476.html.

US Immigration and Naturalization Service, 1997-2001, Statistical Yearbooks of the Immigration and Naturalization Service, US Government Printing Office.

Van der Kroef, Justus M., 1968, “Asia’s ‘Brain Drain’: The Causes Are Complex and Not Wholly Economic,” Journal of Higher Education, 39, 5: 241-253.

Vaughan, Jessica, 2003, “Shortcuts to Immigration: The ‘Temporary’ Visa Program is Broken,” Center for Immigration Studies, January.

Vogel, Ezra, 1989, One Step Ahead in China: Guangdong Under Economic Reform, Harvard University Press.

Wade, Robert, 1990, Governing the Market: Economic Theory and the Role of Government in East Asian Industrialization, Princeton University Press.

Wadhwa, Vivek, Gary Gereffi, Ben Rissing, and Ryan Ong, 2007, “Where the Engineers Are,” Issues in Science and Technology, Spring: 73-84.

Wallace, Richard, 2005, “Intel spies opportunities aplenty for China growth,” Electronic Engineering Times, August 8.

Wohn, Dong-Hee, 2005, “Chip developers see Korea as ideal for R&D centers,” Joins.com, May 20.

World Bank, 1993, The East Asian Miracle: Economic Growth and Public Policy, Oxford University Press.

Xie, Wie, and Steven White, 2004, “Sequential Learning in a Chinese Spin-Off: The Case of Lenovo Group Ltd.,” R&D Management, 34, 4: 407-422.

Yale-Loehr, Stephen, 2003a, “Examining the Importance of the H-1B Visa to the American Economy,” Testimony before the US Senate Committee on the Judiciary, Washington DC, September 16.

Yale-Loehr, Stephen, 2003b, “The L-1 Visa and American Interests in the 21st Century Global Economy,” Testimony before the US Senate Committee on the Judiciary Subcommittee on Immigration and Border Security, Washington, DC, July 29.

Yang, Dori Jones, and Laxmi Nakarmi, 1989, “Is the era of cheap Asian labor over?”, Business Week, May 15.

Yee, Ho Siew, 2005, “Intel to spend RM800m on new centres,” Business Times, December 9: 1.

Yoder, Stephen Kreider, 1989, “Costly exports: Reverse ‘brain drain’ helps Asia but robs US of scarce talent,” Wall Street Journal, April 18.

Yonekawa, Shin-ichi, 1984, “University Graduates in Japanese Enterprises before the Second World War,” Business History, 26, 3: 193-218.

Yoon, Bang-Soon L., 1992, “Reverse Brain-Drain in South Korea: State-Led Model,” Studies in Comparative International Development, 27, 1: 4-26.

Young, Doug, 2003, “Interview: Intel sees China PC market overtaking US by 2010,” Reuters News, October 15.

Young, Doug, and David Lin, 2006, “Interview: Intel aims for increased market share in China,” Reuters News, March 16.

Zachary, G. Pascal, 1994, “Trading places: Malaysians become stars at U.S. electronic firms,” Asian Wall Street Journal, October 3.