GLOBALIZATION OF THE HIGH-TECH LABOR FORCE

William Lazonick
INSEAD and University of Massachusetts
william.lazonick@insead.edu

This paper presents a framework, based on in-depth institutional and organizational studies, for analyzing the forces that have driven the globalization of labor in the information and communication technology (ICT) industries. Since the 1960s the development strategies of national governments and indigenous businesses in many Asian nations have interacted with the investment strategies of US-based ICT companies as well as US immigration policy to generate a global labor supply. 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 many Asian nations.

Keywords:

Globalization, education, FDI, migration, labor, Asia

1. THE “OFFSHORING” PHENOMENON

In the first half of the 2000s Americans became aware of the globalization of high-tech labor. “Offshoring” entered the lexicon as US-based companies moved large numbers of jobs overseas, with India and China as prime locations. Offshoring is by no means a new phenomenon. For decades US information and communication technology (ICT) companies have been routinely offshoring production activities, usually through foreign direct investment (FDI). Previously offshoring had been driven mainly by the search for low-wage labor to perform relatively low-skill work. New in the 2000s was the extent to which offshoring represented a search for low-wage labor to perform relatively high-skill work. In the 2000s US ICT companies have been able to access an abundance of such labor in developing countries, especially India and China.

Many of the engineering and programming jobs offshored in the 2000s are ones that observers of US high-tech industry thought could not be done abroad. The development of sophisticated products and processes generally requires interactive learning that is both collective and cumulative. Workers engaged in interactive learning have to be in close communication with one another. With the US at the center of the ICT revolution, the assumption has been that these jobs could not be relocated to a low-wage developing economy. Indeed, precisely because the US dominates ICT, it is the place to which people come from around the world for ICT-related higher education and work experience. Why would many of the best ICT jobs be migrating to India and China if Indian and Chinese people are migrating to the US to study and work in ICT?

This paper presents a framework, based on in-depth institutional and organizational studies, for analyzing the forces that have driven the globalization of ICT labor. Since the 1960s the development strategies of national governments and indigenous businesses in East Asian nations have interacted with the investment strategies of US-based ICT companies as well as US immigration policy to generate a global labor supply. This process has entailed flows of US capital to East Asian labor as well as flows of East 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 East 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 East Asian nations 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. For nations such as Korea, Taiwan, China, and India that, at certain stages of their development have experienced brain drain, however, the education and experience in the United States that their nationals received created valuable “human capital” that could potentially be lured back home. A major challenge for these East Asian nations has been the creation of domestic employment opportunities, through a combination of FDI, strategic government initiatives, and the growth of indigenous businesses, to enable the career paths of global nationals to be followed back home, thus transforming a potential “brain drain” into an actual “brain gain”.

In Section 2, I examine the extent of this potential brain drain by documenting the flow of East Asians to the United States for higher education and work experience over the last four decades. The data reveal the importance of well-educated East Asians as participants in US graduate programs in natural sciences and engineering, and as recipients of not only immigrant but also non-immigrant visas that enable their holders to work in the United States for long periods of time. Particularly striking in the 2000s has been the extent to which Indians dominate these flows of educated people seeking graduate education and work experience in the United States.

In Section 3 I analyze how, through a combination of upgrading of the capabilities of offshored facilities of multinational corporations (MNCs), government investment in science and technology infrastructures, and the emergence of indigenous high-tech companies, East Asian nations have sought to reverse the brain drain. Focusing on the cases of Korea, Malaysia, and India, this section seeks to understand how in different national contexts and over different periods of time the interaction of a national development strategy and corporate investment strategies, both foreign and indigenous, not only helped to lure back home those who had gone abroad but also encouraged growing numbers of talented nationals, who became quantitatively much more important than the transnational migrants, to seek education and experience at home as an attractive alternative to following a global career path.

Section 4 explores the case of China, which from the late 1970s engaged in economic reforms to break from, but also build upon, the anti-capitalist Maoist model. The success of the economic reforms depended upon the tapping of knowledge accumulated in the government's science and technology infrastructure by indigenous enterprises that could then strategically absorb technology transferred from abroad. The existence of these indigenous capabilities when combined with the vast potential growth of the Chinese domestic product markets bestowed upon the Chinese government enormous power in the strategic regulation of FDI. Compared with nations such as Korea, Taiwan, and India, China was much less challenged by the problem of brain drain in the early stages of the development of ICT capabilities and, as a result, much less dependent on FDI in creating the technological and market conditions for indigenous innovation. In long run historical perspective, the relations among the state, indigenous enterprise, and MNCs in China's development bear a strong resemblance to those that characterized the development of Japan, but with ten times Japan's current population and a globalized ICT labor force into which in the 2000s the Chinese have become thoroughly integrated.

In the conclusion I reiterate the analytical framework that has been used in this study, and I consider some of the implications of this analysis of the globalization of the ICT labor supply for national development trajectories.

2. BRAIN DRAIN

For an investment in high-tech education to contribute to the growth of a developing nation requires employment opportunities in the domestic economy that can make productive use of educated labor. Employment experience in turn augments the productive capabilities of the 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 science and engineering (S&E) education but the most attractive employment opportunities for university graduates are abroad rather than at home.

The S&E brain drain has been a major problem for the developing Asian economies since the 1960s (Adams 1968). Encouraging the 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). By one account over 30,000 college graduates, 60 percent with S&E degrees went abroad from Taiwan between 1956 and 1972, with only 2,586 returning (Ho 1975, 40). In the 1950s and 1960s Korea also had a serious brain drain; in 1953-1972 10,412 students, of whom 5,376 were in S&E, went to study in the United States, with over 90 percent not returning after graduation (Yoon 1992, 6). One study estimated that, given the cost of educating scientists and engineers and their lost value-added, India transferred $51 billion to the United States between 1967 and 1985. 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).

The US Immigration Act of 1990 increased the annual number of employment-based (EB) visas that could be issued (including family members) from 54,000 to 140,000. Indians received 11.0 percent of the EB visas in 1996-2000 but 23.8 percent in 2001-2004, with the increased share beginning to climb in 2000. The next largest share of EB visas went to China, with 12.9 percent in 1996-2000, and 11.2 percent in 2001-2004 (US INS, 1997-2001; US DHS, 2002-2004b).

Also of great importance in enabling the flow of educated Asians to the US for high-tech employment have been H-1B and L-1 non-immigrant work visas. Indians have been the top nation in terms of numbers of H-1B visas issued since 1993 when they surpassed Filipinos. Indians have also been the leading recipients of L-1 visas since 2000, when they surpassed both the Japanese and British. The proportion of L-1 visas that went to Indians climbed dramatically from 4.5 percent in 1997 to 38.1 percent in 2004 (US Department of State, 1997-2005). 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 H-1B 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 six 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" (11percent) (US DHS 2002-2004a).

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 another three years. H-1B visa holders can apply for permanent resident status, with employers of H-1B visa holders often sponsoring the non-immigrant. Under the American Competitiveness for the 21st Century Act of 1998, an H-1B visa holder can obtain one-year extensions while waiting to become a permanent resident, prompting some to contend that H-1B is a "pre-immigrant" rather than "non-immigrant" program. In 2001 more than 228,000 NIV 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 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 an 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.

3. REVERSING THE BRAIN DRAIN

3.1 Korea

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. In its 1993 report on the development of Asia's human resources in science and technology, the US 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." Korea in particular was very aggressive from the late 1960s in the implementation of policies designed to reverse the brain drain. 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).

How was such a reversal achieved? From the outset, MNCs such as Motorola, Fairchild, and Signetics that had come to Korea in the late 1960s in search of low-wage labor for labor-intensive chip assembly operations also employed Koreans as engineers and managers. In so doing, they created a demand for indigenous university-educated high-tech labor that had not previously existed in Korea. Over time, as these companies invested in higher value-added activities, high-end employment opportunities increased. 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. In many cases highly educated and very experienced Koreans who had been pursuing successful careers in the United States played key roles in building indigenous research institutes and companies (Kim and Leslie 1998). This indigenized knowledge in turn supported the emergence of indigenous Korean companies as world-class competitors.

Linsu Kim (1997) has provided a lucid account of how, through cumulative and collective learning, Samsung transformed its electronics division into a world leader in semiconductors. Between 1980 and 1994 Samsung Electronic's sales soared from 2.5 billion Won to 115.2 billion Won. In the process R&D as a proportion of sales increased from 2.1 percent in 1980, to 3.0 percent in 1985, 4.2 percent in 1990, and 6.2 percent in 1994. In 1980 Samsung Electronics employed 690 R&D staff, who produced only 18 local patent applications and four local patent awards, and no foreign patent applications or awards. In 1994 the company's 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.

As a result of the employment opportunities that Samsung as well as other leading chaebol such as Hyundai and Lucky-Goldstar created, by the late 1980s the brain drain had been reversed. In 1989 a Wall Street Journal article entitled "Costly Exports", had the subtitle, "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 director-general of Korea's Ministry of Science and Technology was quoted as saying that the 6,000 Korean scientists and engineers in the United States "have become a very precious resource for us." The article went on to point out that "[t]he 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."

3.2 Malaysia

Not all of the East 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 Taiwan, see Mathews 1997; Saxenian 2006). Malaysia in particular has over the past three decades become a world center for electronics manufacturing based on FDI. During 2003-2005, the Malaysian economy grew at about six percent per annum, with electronics dominating its manufacturing base and exports.[1] The fact that Malaysia has prospered on the basis of FDI implies that over time MNCs have been successfully upgrading their productive capabilities there, thus making it possible to pay employees higher wages and still remain globally competitive. Indeed, such has been the case.

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) in Penang 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. Intel was one of the first semiconductor manufacturers to offshore to BLFTZ when it was launched in 1972, and the Penang facility was Intel's first offshore plant. 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." At the same time Barrett reportedly warned "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."[2] FPT

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[1] *See http://www.tdctrade.com/mktprof/asia/mpmal.htm; more generally see Best 2001, ch. 6.*

TP[2]PT "Intel to expand capacity with RM152m investment," UBusiness TimesU, August 27, 2003.

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; Ho 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 Ismail 2005).

3.3 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 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 connect to an internal 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, facing a major competitive challenge from the Japanese in commodity memory chips, TI's stock-in-trade. 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 current 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.[3]

TI India employed 17 engineers and programmers when it began operations in 1986. This number increased to 85 in 1990, 275 in 1995, 500 in 2000, and 1300 in 2005, by which time TI India employment represented four percent of TI's worldwide labor force. A report in 2002 stated that among the 750 engineers and programmers who TI employed in Bangalore, there were no expatriates.[4]

Almost two decades after it had been the first MNC to locate in Bangalore, TI was not alone. 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."[5] In September Microsoft announced that over the next six months the 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.[6] 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.[7] 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.[8]

HP set up a subsidiary in India in 1989, but waited until 2002 to launch its first Indian research lab.[9] The company

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

[4] *"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.*

[5] *"Intel opens platform definition centre in Bangalore, Asia Pulse, August 1, 2005.*

[6] *"Cisco pledges $50 million more for Bangalore campus," CMP TechWeb, October 21, 2005.*

[7] *"Juniper sets eye on Indian telecom market," Business Standard, November 24, 2005.*

[8] *"Intel announces $1 billion investment plan for India," Computer Reseller News, December 15, 2005.*

[9] *"Hewlett-Packard launches research lab in India," Agence France-Press, February 22, 2002.*

employed about 2,200 people in India just before its merger with Compaq as well as after a post-merger acquisition (Dataquest 2002 and 2003). At the end of 2003, after making an Indian affiliate, Digital Globalsoft, a wholly-owned subsidiary, HP found itself with more than 10,000 employees in India, making it the nation's largest foreign employer, just surpassing IBM.[10] By the end of 2006 HP had doubled that headcount to about 20,000 employees in India, or about 13 percent of its global labor force.[11] Meanwhile IBM's expansion in India was even more aggressive than that of HP; during 2006 IBM added 14,500 employees in India, bringing its year-end employment in India to 53,000, or 16 percent of its global labor force (Kulkarni 2007).

As for TI India, with the increased demand for engineers and programmers in India, it does not simply wait for qualified labor to apply for jobs. Rather, through an initiative called UniTI, the company has become deeply involved in the Indian system of higher education.[12] With more than 275 operational DSP labs at Indian engineering institutions, UniTI is TI's second largest program of this type worldwide. The company views UniTI as "a mutually beneficial relationship between academia and industry in the field of digital signal processing, and is the forum in which TI India interacts with universities and interested technical institutions in the role of a facilitator."

Just in case UniTI does not yield the quality and quantity of new recruits that TI India requires, the TI website informs Indians working in the US that "the time has never been better to come back to India."[13] To quote TI's 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.
- 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. In fiscal 2006 the five leading Indian information technology (IT) companies – Tata Consultancy Services (TCS), Wipro, Infosys, Satyam, and HCL Technologies – generated a total of $9.1 billion in revenues and employed a total of more than 237,000 people worldwide, up from a combined $2.4 billion in revenues and 46,000 employees in 2001.[14] Of their combined 2006 revenues, about 59 percent were generated in the Americas, mainly the United States, 23 percent in Europe, and 10 percent in India.

TCS is the largest of these five IT companies with $2.5 billion in sales in 2006. 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 employed 2,000 people in 1991, 12,000 in 2001, and almost 63,000 in 2006. While in 2006 TCS had operations in 47 countries and offices in 160, over 92 percent of its employees were Indian nationals (Narayanan 2006).

Close behind TCS are Wipro and Infosys, both based in Bangalore, with 2006 revenues of $2.4 billion and $2.2 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

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[10] "HP marks Indian employment milestone," ZDNet UK, December 4, 2003.

[11] "HP outsourcing chief wants to take it offshore," CMP TechWeb, November 8, 2006.

[12] http://www.ti.com/asia/docs/india/dsp-universities.html

[13] http://www.ti.com/recruit/docs/india/info.shtml.

[14] The end of the fiscal year is March 31 for Infosys, Satyam, TCS, and Wipro, and June 30 for HCL.

1992 the company had 1,640 employees of whom at least 1,000 had a Bachelor of Science degree.[15] Ten years later Wipro employed more then 14,000 people, and in 2006 about 55,000.

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 Nestle. In 1992 the company employed more than 300 software engineers.[16] Infosys employment soared to 9,800 employees in 2001, and then more than quintupled to 52,700 in 2006.

Based in Hyderabad, Satyam Computer Services generated sales of $1.1 billion in fiscal 2006. The company was founded by B. Ramalinga Raju and his brother, B. Rama Raju, in 1987. Six years later, in performing a $900,000 contract with Chicago-based John Deere & Co., Satyam was the first Indian software company to deliver its product over private satellite high-speed data links (Freeman 1993). The following year Satyam formed a joint venture with Dun & Bradstreet to develop software for the US company.[17] By 1997, ten years after it was founded, Satyam employed 1,175 people in India and had set up offices in five cities in the United States. In 2001 the company's employment stood at 9,700 and in 2006 at over 28,600.

Based in Noida, Uttar Pradesh, HCL was founded as Hindustan Computers Limited in 1976 by a group that included current chairman and CEO, Shiv Nadar. By the last half of the 1980s HCL had emerged as India's largest computer manufacturer; in 1989 it had a 25 percent market share and employed 3,400 people.[18] In 1991 HCL entered into a joint venture with Hewlett-Packard to sell computers in India. At the time, HP's investment of $23 million in the deal was a greater amount than all US FDI in India in the previous year.[19] As a result of this relation, HCL began developing software for HP (Nadkarni 1995). In 1995, when HCL was still India's largest computer maker, it was reported that the company "regarded developing software packages and doing consulting work for American and other foreign companies as the key to its growth" (Hazarika 1995). In building the business, a company spokesperson was quoted as saying that "comparatively low salaries are not going to sustain growth. What is going to count is professional competence, utilizing our own skills and technology." For the year ending June 30, 2001, HCL Technologies had $297 million in revenues and 4,692 employees. For the year ending December 31, 2006, the company had $1,155 million in revenues and 38,317 employees.[20]

4. CHINA AND THE DYNAMICS OF INDIGENOUS INNOVATION

While India's emergence as a force in the world of ICT has been focused mainly on IT services, China's growth has been much more diverse. As foundations for its multifaceted development path, a fundamental advantage that China had over India in the last half of the 20th century was a much more extensive system of mass education, as shown in Table 1. Note that in both 1980 and 2000 India had a much higher proportion of the population that had completed post-secondary education, although in each of the nations the group that attained this level of education represented an elite. An important difference between China and India in the 1980s was that China emphasized undergraduate degrees in engineering while India emphasized undergraduates degrees in science (Lazonick 2006). 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.

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[15] *"India's electronics industry," The Economist, May 4, 1991.*

[16] *"More US software jobs going to foreign workers," The Boston Globe, July 5,1993*

[17] *"Dun & Bradstreet and Satyam Computer Services join forces for new enterprise," Business Wire, January 27.*

[18] *"AUDRE Recognition Systems launches Far East distribution," Business Wire, July 20.*

[19] *"A computer connection," Mergers & Acquisitions, July-August, 1991.*

[20] *http://www.hcltech.com/Investors/FastFacts/index.asp.*

Table 1: Highest levels of educational attainment of the populations of China and India, 1980 and 2000

	China		India	
Educational Attainment	**1980**	**2000**	**1980**	**2000**
No schooling, % of pop. 15 years old and over	34.0	18.0	72.2	66.6
Completed 1st level, % of pop. 15 years old and over	11.8	12.8	4.7	10.5
Completed 2nd level, % of pop. 15 years old and over	9.9	14.8	5.4	6.5
Average years of school, pop. 15 years old and over	4.8	6.4	3.3	5.1
Completed post-secondary, % of pop. 25 years old and over	0.9	2.3	1.7	3.3
Average years of school, pop. 25 years old and over	3.6	5.7	2.7	4.8

Source: Barro and Lee 2000

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; 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.

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 the conclusion of his chapter on Legend, Lu stressed the fact that whereas most previous studies of the China-Hong Kong industrial relationship had focused on Hong Kong’s access to cheap Chinese labor in Guangdong (e.g., Vogel 1989), the case of Legend was one of much greater complementarity of capabilities. China brought more technology and managerial capability to Hong Kong than vice versa. Lu also emphasized that, 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, with 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). 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 acquisition of the IBM PC business, a deal that was completed in May 2005.

Over the 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 the United States but also exports of US MNCs that have offshored to China. While the United States is by no means the only player in the China FDI game, leading US ICT companies such as Cisco, Dell, HP, IBM, Intel, Microsoft, Motorola, Oracle, and Sun Microsystems have been very active in China in recent years. 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.[21] 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 Intel's fastest growing market, notwithstanding the fact that it has lost significant market share to AMD.

In 2005 Intel employed over 5,000 people in China, about five percent of its global labor force and a doubling of Chinese employment 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, and its fifth in China, to come on line in 2007.[22] As in Malaysia, virtually all of the people who Intel employs in China are home-grown.

5. GLOBAL LABOR FLOWS AND NATIONAL ECONOMIC DEVELOPMENT

I began by asking why, with so many educated people coming from East 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 East Asian entrepreneurs who have spent time starting or managing companies in Silicon Valley, AnnaLee Saxenian (2006) has characterized these flows as "brain circulation", an apt characterization for the global career paths that increasing numbers of East Asians are pursuing. What I have outlined in this essay 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. 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 (see Ernst 2002).

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[21] "Intel begins shipment under Chinese contract," Wall Street Journal, December 12, 1984.

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

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.[23] 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 indigenous 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 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 of FDI 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 Korea, indigenous investments by government and business rather than FDI have since the late 1980s driven the development of domestic high-tech capabilities. In the 2000s these indigenous investments are creating new opportunities for high-end investment by MNCs in Korea, including new investments by a company such as Motorola that has been doing business there for almost 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. Like Motorola in Korea, Intel originally went to Malaysia in search of low-wage assembly labor in a politically stable country that had made a commitment to mass education. And like Motorola Korea, Intel Malaysia upgraded its capabilities over time, employing a higher proportion of high-skill labor in higher value-added activities at rising wages.

Like Motorola in Korea and Intel in Malaysia, TI originally went to India in the mid-1980s in search of low-wage labor. TI, however, was not searching for low-skill labor. What first attracted TI to India 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 Infosys, TCS, and Wipro are taking the lead, and in which MNCs continue to be attracted to India much 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 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. Some of these companies – Lenovo and Founder are prime examples – have become leading competitors not only in China but also internationally. While there are large numbers of Chinese ICT employees who have acquired higher education and work experience in the US, the vast majority have been receiving that education and experience in China. 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).

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. The combined populations of India and China are 33 times those of Korea and Taiwan. India and China have rapidly growing domestic 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 ongoing liberalization of US immigration policy (impeded just temporarily by the reaction to 9/11), the global career path is much more of a "mass" phenomenon for Indian and Chinese scientists and

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[23] *For detailed analyses of the development dynamics set in motion by the investment triad, see Lazonick 2007.*

engineers than it has been for the Koreans and Taiwanese. History tell 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 growth of India and China will go hand in hand.

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