Transnational Communities and the Evolution of Global Production Networks: The Cases of Taiwan, China and India

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TRANSNATIONAL COMMUNITIES AND THE EVOLUTION OF GLOBAL PRODUCTION NETWORKS: THE CASES OF TAIWAN, CHINA AND INDIA

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Transnational entrepreneurs—US-educated immigrant engineers whose activities span national borders—are creating new economic opportunities for formerly peripheral economies around the world. Talented immigrants who have studied and worked in the USA are increasingly reversing the "brain drain" by returning to their home countries to take advantage of promising opportunities there. In so doing they are building technical communities that link their home countries to one of the world's leading centers of information and communications technologies, Silicon Valley. As the "brain drain" increasingly gives way to a process of "brain circulation", networks of scientists and engineers are transferring technology, skill, and know-how between distant regional economies faster and more flexibly than most corporations.

The development of technical communities that span national borders and boast such shared assets as technical information, trust, and contacts have been largely overlooked in accounts of globalization (Portes 1996). This paper suggests that transnational communities may become as important as more commonly recognized actors—states and multinational corporations—in the growth of new centers of technology entrepreneurship. Moreover, these communities have the potential to play an increasingly important role in the evolution of global production networks. Transnational entrepreneurs and their communities provide a significant mechanism for the international diffusion of knowledge and the creation and upgrading of local capabilities—one that is distinct from, but complementary to, global production networks.

The first half of the paper analyzes the economic and technological context for the emergence of transnational communities and outlines their contributions to the emergence and upgrading of suppliers and nodes in global production networks. The paper then examines the cases of Taiwan, India, and China in detail to illustrate how technical communities both complement and accelerate the development of international production networks. In Taiwan, a "reversal" of the brain drain fueled the growth of a transnational community that has created new sources of supply and contributed directly to the subsequent upgrading of local capabilities, thereby insuring Taiwan's position as a supplier of high value-added, design intensive components. The Taiwanese case also illustrates how innovations seeded by transnational entrepreneurs have the potential to disrupt established hierarchies of suppliers.

Both India and China boast large numbers of US-educated scientists and engineers

and case, well-developed ethnic professional communities have built economic and social bridges to their home countries. The Indian network has contributed to the emergence of a globally competitive software services industry, however, there is little evidence of the return entrepreneurship that could accelerate the upgrading of India's capabilities. In China, by contrast, policymakers have aggressively courted return entrepreneurs from the USA, with notable successes. Most striking is the merging of the Taiwanese and Mainland Chinese transnational communities—particularly in the semiconductor industry—through shared roots in Silicon Valley's professional and technical networks. This could have a lasting impact on the development of China.

The paper concludes with speculations about the changing relationship between transnational technical communities and global production networks as well as some thoughts about directions for future research.

TECHNICAL COMMUNITIES AND INDUSTRIAL DECENTRALIZATION

Transnational technical communities are only possible because of advances in communication and transportation technologies and changes in the structure of technology markets and competition. In the 1960s and 1970s, the dominant competitors in the computer industry were vertically integrated corporations that controlled all aspects of hardware and software production (the IBM or "national champion" model). The rise of an alternative industrial model (the Silicon Valley model) spurred the introduction of the personal computer and initiated a radical shift to a more fragmented industrial structure organized around networks of increasingly specialized producers.

Today, independent enterprises produce all of the components that were once internalized within a single large corporation—from application software, operating systems and computers to microprocessors and other components. The final systems are in turn marketed and distributed by other independent enterprises. Within each of these horizontal segments again there is further specialization of production and a deepening social division of labor. In the semiconductor industry, for example, independent producers specialize in chip design, fabrication, packaging, testing, as well as different segments of the manufacturing materials and equipment sector. A new generation of firms has emerged in the late 1990s specializing in providing intellectual property in the form of design modules rather than the entire chip design.

This change in industry structure appears as a shift towards market relations. The number of actors in the industry has increased dramatically and competition within many (but not all) horizontal layers has increased as well. Yet this is far from the classic auction market mediated by price signals alone; the decentralized system depends heavily on the coordination provided by cross cutting social structures and institutions. While Silicon Valley's entrepreneurs innovate in increasingly specialized niche markets, intense communications insure the speedy, often unanticipated, recombination of these specialized components into changing end products. This decentralized system provides significant advantages over a more integrated model in a volatile environment because of the speed and flexibility as well as the conceptual advances associated with the process of specialization and recombination.

The deepening social division of labor in the industry creates opportunities for

innovation in formerly peripheral regions—opportunities that did not exist in an era of highly integrated producers. The vertical specialization associated with the new system continually generates entrepreneurial opportunities. By exploiting these opportunities in their home countries, transnational entrepreneurs can build independent centers of specialization and innovation, while simultaneously maintaining ties to Silicon Valley to monitor and respond to fast-changing and uncertain markets and technologies. They are also well positioned to establish cross-regional partnerships that facilitate the integration of their specialized components into end products.

The social structure of a technical community thus appears essential to the organization of production at the global as well as the local level. In the old industrial model, the technical community was primarily inside of the corporation (Kogut and Zander 1993). The firm was seen as the privileged organizational form for the creation and internal transfer of knowledge, particularly technological know-how that is difficult to codify. In regions like Silicon Valley, where the technical community transcends firm boundaries, however, such tacit knowledge is often transferred through informal communications or the inter-firm movement of individuals. This suggests that the multinational corporation may no longer be the advantaged or preferred organizational vehicle for transferring knowledge or personnel across national borders. Transnational communities provide an alternative and often more flexible and responsive mechanism for long distance transfers of skill and know-how—particularly between very different business cultures or environments.

In fact, as recently as the 1970s, only the world's largest corporations had the resources and capabilities to grow internationally. These multinational corporations expanded primarily by establishing marketing offices or branch plants overseas. Today, by contrast, new transportation and communications technologies allow even the smallest firms to build partnerships with foreign producers and tap overseas expertise, cost-savings, and markets. Start-ups in Silicon Valley today are often global actors from the day they begin their operations. Many raise capital from Asia, others subcontract manufacturing to Taiwan or rely on software development in India, and virtually all seek to eventually sell their products in Asian markets.

The scarce resource in this new environment is the ability to locate foreign partners quickly and to manage complex business relationships across cultural and linguistic boundaries. This is particularly a challenge in high-technology industries in which products, markets, and technologies are continually being redefined—and where product cycles are routinely as short as 6 months.

First-generation immigrants, like the Chinese and Indian engineers of Silicon Valley, who have the language and cultural as well as the technical skills to function well in both the USA and foreign markets are well positioned to play a central role in this environment. By becoming transnational entrepreneurs, these immigrants can provide the critical contacts, information, and cultural know-how that link dynamic—but distant—regions in the global economy. They can create social networks that enable even the smallest producers to locate and maintain mutually beneficial collaborations across great distances and facilitate access to foreign sources of capital, technical skills, and markets. The proliferation of such relationships over time can result in the creation of a transnational technical community—one that can transfer the market and technological know-how needed to support a dynamic of industrial upgrading.

Technical communities and global production networks

It is no coincidence that transnational technical communities have emerged as central actors in the world economy at the same time that global production networks (GPNs) are increasingly replacing multinational firms with their stand-alone overseas investments (Ernst and Kim 2001). Communities of technically skilled immigrants with business experience and connections in the USA are ideally positioned to accelerate the diversification and technical upgrading of supplier networks in their home countries. As entrepreneurs, they can also facilitate the emergence of new sources of supply and/or destabilize established hierarchies in GPNs.

Transnational communities thus play an important and complementary role to "network flagships" in GPNs. US-educated returnees provide a direct mechanism for transferring the skill and tacit knowledge that can dramatically accelerate industrial upgrading in their developing countries. In addition they frequently coordinate relationships between the network flagships and suppliers, particularly when they are based in regions with differing languages and business cultures. This role ranges from helping to identify appropriate original equipment manufacturer (OEM) suppliers to facilitating the ongoing (and often face-to-face) inter-firm communications required by the rapid pace of change in the industry.

Transnational communities likewise provide a mechanism for seeding entirely new centers of low-cost (at least initially) supply in less developed regions. Taiwan's leading personal computer suppliers, including Acer, Mitac, and Compeq, for example, got their initial contracts for IBM-compatible PCs in the early 1980s from Chinese entrepreneurs in Silicon Valley. Senior Indian engineers in large US corporations were similarly among the first to outsource software services to India, thereby helping to establish the reputation and credibility of producers in regions like Bangalore. Over time, if transnational business connections deepen and expand they can accelerate the upgrading of the technical capabilities in these locales.

Finally, transnational entrepreneurs are well positioned to identify new market opportunities in GPNs—and even to innovate and destabilize established hierarchies of production. When Morris Chang returned from the USA to pioneer the foundry model at Taiwan Semiconductor Manufacturing Corporation (TSMC), he accelerated the vertical fragmentation of semiconductor production and made it possible for chip designers and intellectual property producers all over the world to become part of international production networks in electronics. It also enabled a start-up like Taiwan's Via Technologies to threaten Intel's position in low-end microprocessors.

TSMC quickly became a world-class chip manufacturer because it was able to continue attracting experienced Taiwanese semiconductor engineers and managers from Silicon Valley. The Taiwanese transnational community also coordinated the ongoing relationships between TSMC and its US-based equipment suppliers (like Applied Materials) and its customers (both small chip designers and more established producers). In short, transnational technical communities can serve as important mechanisms for the coordination, upgrading, and transformation of GPNs.

TRANSNATIONAL ENTREPRENEURS AND INDUSTRIAL UPGRADING IN TAIWAN

The experience of Taiwan illustrates how a transnational community contributes to

both the creation and upgrading of nodes in GPNs. In the 1960s and 1970s, the relationship between Taiwan and the USA was a textbook First–Third World relationship. US businesses invested in Taiwan to take advantage of its low-wage manufacturing labor. Meanwhile the best and the brightest Taiwanese engineering students came to the USA for graduate education and created a classic "brain drain" when they chose to remain to pursue professional opportunities in the USA. In fact, Taiwan sent more doctoral candidates in science and engineering to the USA during the 1980s than any other country, including entire graduating classes from Taiwan's most elite engineering universities: National Taiwan University, National Chiaotung University, and Tsinghua University (see Figure 2).

This relationship changed dramatically in the late 1980s. Many of these US-educated engineers began to return home, drawn by active government recruitment and the opportunities created by rapid economic development. The upgrading of Taiwan's technological infrastructure and capacities through rapidly growing OEM ties to foreign customers as well as through local learning-by-doing, spurred a reversal of the brain drain (see Figure 1). At the same time a growing cohort of highly mobile engineers began to work in both the USA and Taiwan, regularly commuting across the Pacific. Typically Taiwan-born, US-educated engineers, or "astronauts", have the

FIGURE 1: RETURNEES TO TAIWAN FROM THE USA: 1970–97.
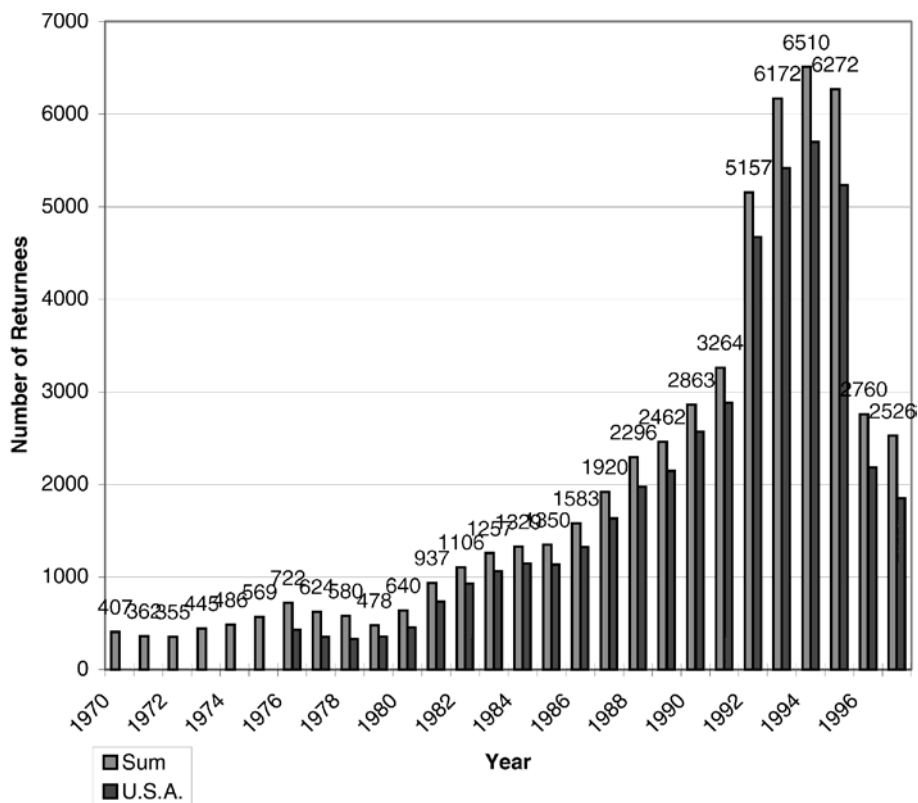
Source: National Youth Commission, Taiwan.

professional contacts and language skills to function fluently in both the Silicon Valley and Taiwanese business cultures and to draw on the complementary strengths of the two regional economies (Saxenian and Hsu 2001).

Miin Wu is a classic transnational entrepreneur. Wu immigrated to the USA in the early 1970s to pursue graduate training in electrical engineering. After earning a doctorate from Stanford University in 1976, Wu recognized that there were no opportunities to use his new skills in economically backward Taiwan and remained in the USA, working for more than a decade in senior positions at Silicon Valley-based semiconductor companies including Siliconix and Intel. He also gained entrepreneurial experience as one of the founding members of VLSI Technology. By the late 1980s, when economic conditions in Taiwan had improved Wu returned home to start his own semiconductor company, Macronix Co. He located the firm in Hsinchu Science-based Industrial Park and brought 30 senior Silicon Valley engineers, mainly former classmates and friends, with him. In 1995, Macronix went public on the Taiwan stock exchange and the following year became the first Taiwanese company to list on NASDAQ.

While Hsinchu Science Park was not the cause of Taiwan's successes in information technology industries, its success reflects the fast expanding ties between the two regions. After its first 8 years (1980–88) the Park was home to only 94 companies with under US$2 billion in annual sales collectively and attracted only a handful of US-educated engineers annually. By the early 1990s the Park had become a destination for hundreds of returnees each year, who started new companies at an accelerating rate. By 1989, 2,840 Taiwanese had returned from the USA to work in Hsinchu Science Park, and these returnees were disproportionately likely to start their own companies; some 40 percent of the companies located in the Science Park (110 companies out of a total of 284) in 1999 were started by US-educated engineers, many of whom had considerable managerial or entrepreneurial experience in Silicon Valley. These returnees in turn actively recruited former colleagues and friends from Silicon Valley to return to Taiwan.

The Park was attractive to engineers from the USA in part because of its location, which was close to the headquarters of Taiwan's leading public research institute, Industrial Technology and Research Institute (ITRI) and its subsidiary, the Electronics Research and Service Organization (ERSO) which in the 1980s spearheaded a techno-logical leapfrogging through the government-led acquisition of semiconductor manu-facturing technology from the USA (Mathews 1997). Hsinchu is also the home of two of Taiwan's leading engineering universities which had dramatically increased enrollments and research capacity in the 1970s and 1980s. Finally, Hsinchu Science Park offered a range of fiscal incentives for qualified technology investments and provided returnees with preferential access to scarce, high quality housing and to the only Chinese-Amer-ican school in Taiwan—both of which are located on the Park grounds.[1]

In addition to permanent returnees like Wu, a growing population of "astronauts" works in *both* places, spending much of their lives on airplanes. While their families

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1   The incentives include low interest loans, a 5-year income tax break for the first 9 years of operation, the right to
    retain earnings of up to 200 percent of paid-in capital, accelerated depreciation of R&D equipment, and low-cost
    land. This information and the data on the Park in the following paragraph come from the Science Park
    Administration, Hsinchu Science-based Industrial Park.

may be based on either side of the Pacific (most often they stay in California because of the lifestyle advantages), these engineers travel between Silicon Valley and Hsinchu once or even twice a month, taking advantage of the opportunities to play middlemen bridging the two regional economies. This includes many Taiwanese angel investors and venture capitalists as well as executives and engineers from companies like Macronix with activities in the two regions.

This lifestyle is, of course, only possible because of the improvements in transportation and communications technologies. However, it does not mean these "astronauts" are rootless. Their dense personal networks and intimate local knowledge of both Silicon Valley and Hsinchu play a central role in coordinating economic linkages between the two regions. Even engineers who remain in Silicon Valley are typically integrated into the transnational community. Many work for start-ups or large firms with activities in both regions. Some moonlight as consultants on product development for Taiwanese firms. Others return to Taiwan regularly for technical seminars sponsored by government agencies or professional associations.

As engineers travel between the two regions they carry technical knowledge as well as contacts, capital, and information about new opportunities and new markets. Moreover, this information moves almost as quickly *between* these distant regions as it does *within* them because of the density of the social networks and the shared identities and trust within the community. These transnational ties have dramatically accelerated the flows of skill, know-how, and market information between the two regions. In the words of a Silicon Valley-based Taiwanese engineer:

> If you live in the United States its hard to learn what is happening in Taiwan, and if you live in Taiwan its hard to learn what is going on in the U.S. Now that people are going back and forth between Silicon Valley and Hsinchu so much more frequently, you can learn about new companies and new opportunities in both places almost instantaneously.[2]

Others say Taiwan is like an extension of Silicon Valley. The former CEO of Acer America claims that the continuous interaction between Hsinchu and Silicon Valley has generated "multiple positive feedbacks" that enhance business opportunities in both regions.[3]

A close-knit community of Taiwanese returnees, "astronauts", and US-based engineers and entrepreneurs like Miin Wu has become the bridge between Silicon Valley and the comparably sized region that extends from Taipei to Hsinchu Science Park. By transferring technical know-how, organizational models, and contacts, they have accelerated the upgrading of Taiwan's technological infrastructure—and increased the importance of its suppliers to GPNs (Dedrick and Kraemer 1998). By the end of the 1990s, Taiwan was the world's largest producer of notebook computers and a range of related PC components including motherboards, monitors, scanners, power supplies, and keyboards—and they had the capacity to shift quickly into new products such as wireless phones (see Tables 1 and 2). Less than two decades after TSMC was founded, Taiwanese firms controlled two-thirds of world foundry capacity, with integrated chip (IC) manufacturing capabilities on a par with the leading Japanese and US producers.

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2   C.B. Liaw interview, 28 August 1996.

3   Ron Chwang interview, 25 March 1997.

TABLE 1: PERSONAL COMPUTER OEM CUSTOMERS AND TAIWANESE PARTNERS, 1999

Taiwan companies	OEM customers
Mitac (desktop PC)	HP, Compaq
FIC (desktop PC)	HP, Compaq
Tatung (desktop PC)	HP
GVC (desktop PC)	HP
Mitac (notebook PC)	Compaq, HP, SUN
Inventec (server, desktop PC, notebook PC)	Compaq
Quanta (notebook PC)	Dell, Gateway, Apple, Siemens, IBM, HP
Arima (notebook PC)	Compaq
FIC (notebook PC)	NEC Japan
Twin-Head (notebook PC)	NEC, HP, Sharp, Winbook
Compal (notebook PC)	Fujitsu, HP, Dell, Toshiba
GVC (notebook PC)	PBNEC
Acer (notebook PC)	Acer/TI, IBM, Apple
Alpha-Top (notebook PC)	Apple, PBNEC
Clevo (notebook PC)	Hitachi, Epson

Sources: C. Wang, "The Information Technology Industry @ Taiwan", *The Financial Information*, Taipei, Taiwan, 1999; "Taiwan Notebook PC is the World No. 1", *Global Views Monthly*, 162, Taipei, Taiwan, December 1999.

TABLE 2: MOBILE PHONE OEM CUSTOMERS AND TAIWANESE PARTNERS, 2000

Customer	Product	Taiwanese OEM partner
Motorola	Mobile phone	DBTEL Inc. (cordless phone); Acer Peripheral
	IC mfg.	TSMC; UMC
	PCB	Wus Printed Circuit Co.; United PCB Co.; Zio-De
	LED	I-Kwon
	Voltage converter	Fe-Hon
	Power supply	Lite-On (power supply, LED)
	Panel	Picvue Elec. (LCD/CRT)
Ericsson	PCB	Compeq
	Receiver	Mei-Lui
	Panel	Compeq (PCB)
Alcatel	Mobile phone	GVC (desktop PC, motherboard)
	Panel	Compeq (PCB)
Qualcomm	PCB	Wus Printed Circuit Co.
	Panel	Compeq (PCB)

Source: *Telecommunication Network*, Special Edition, Taiwan, 2000.

The growing integration of the technological communities of Silicon Valley and Hsinchu offers benefits to both economies. Silicon Valley remains the center of new product definition and the developer of leading edge technologies, while Taiwan offers world-class manufacturing, flexible development and integration, and access to key customers and markets in China and Southeast Asia. Taiwan has also become a significant and fast-growing source of capital for Silicon Valley-based start-ups. Unlike the arms-length and top-down technology transfers between large firms that characterized the relations between Japan and the USA in the 1980s, the Silicon Valley–Hsinchu

relationship today consists of formal and informal collaborations between individual investors and entrepreneurs, small and medium-sized firms, as well as the divisions of larger companies located on both sides of the Pacific.

In this complex mix, the social and professional ties among Taiwanese engineers at home and their counterparts in the USA are often as important as more formal corporate alliances and partnerships. These relationships have been essential to establishing, maintaining, and upgrading Taiwan's role in GPNs—through OEM and ODM relationships and the myriad of other inter-firm partnerships that exploit the distinct and complementary capabilities of Silicon Valley and Hsinchu-based producers.

Taiwan's policymakers created an environment that attracted US-educated engineers to return home in growing numbers, but only after two decades of investment in the domestic environment. The elements of this environment included: a well-developed skill base and technical infrastructure; an attractive physical environment for entrepreneurs, a growing venture capital industry; and close professional ties to Silicon Valley. Once in place, the transnational community accelerated the pace of innovation and industrial upgrading of Taiwan's PC and semiconductor industries beyond the expectations of the policymakers. This experience suggests that foreign-born engineers are only likely to return permanently to their home countries when they perceive that the professional opportunities outweigh, or at least match, those available to them in the USA.[4]

REVERSING THE BRAIN DRAIN? THE CASE OF INDIA AND CHINA

India and China have both suffered greatly from brain drain. In the 1990s these two countries each sent more students to the USA for higher education than any other country. In 1998–99 alone, for example, 10.4 percent of international students enrolled in US higher education (51,001 students) were from China, excluding Hong Kong, and 7.6 percent (37,482 students) were from India (Open Doors 2000). The dominance of Chinese and Indian students in US higher education is most pronounced at the doctoral level, and in science and engineering fields in particular. Between 1990 and 1996, 16,749 Chinese and 8,211 Indian students received PhDs in the USA, with 92 percent of the Chinese and 83 percent of Indian degrees in science and engineering (NSF 1998) (see Figure 2).

China and India therefore are particularly well positioned to benefit from "brain circulation" and reversal of the brain drain. Data on the number of foreign students returning from the USA to their home countries are limited, however, it is clear that students from India and China have tended to remain in the USA in greater numbers than their other foreign-born counterparts. An NSF study reports, for example, that in 1996, 87 percent of Chinese and 84 percent of Indian PhD students with temporary work visas planned to stay in the USA after graduation, compared with only 48 percent of Taiwanese students (NSF 1998).

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4   For more on the Taiwanese case, see Ernst (2000), Saxenian (1999), Hsu (1997) or Saxenian and Li (2003).

FIGURE 2: FOREIGN-BORN PhDs IN USA, SCIENCE AND ENGINEERING: 1985–2000.
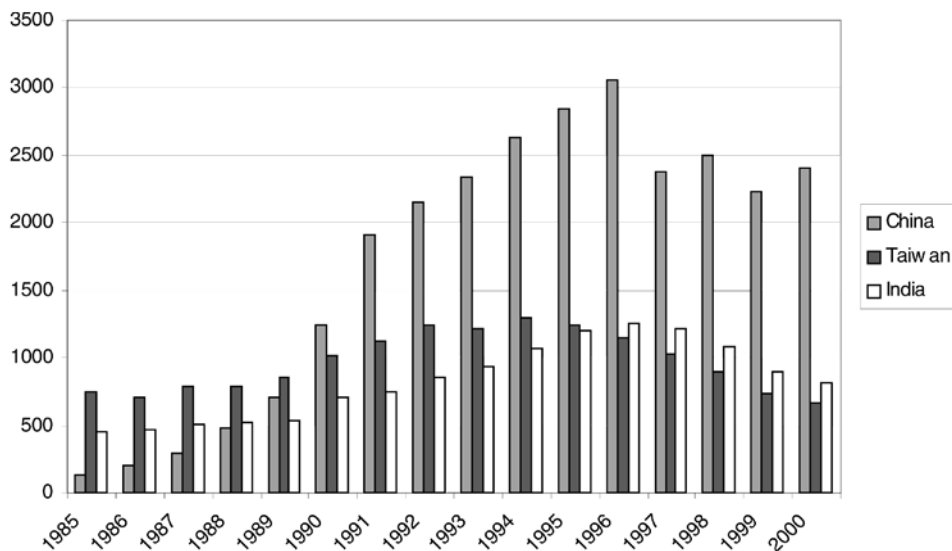
Source: National Science Foundation (2001).

India: from brain drain to brain circulation

In the 1970s and 1980s, Indians were second only to Taiwanese as recipients of US PhDs in engineering and science. The technical and managerial capabilities of these US-educated Indian professionals are clear from their continued entrepreneurial successes in Silicon Valley. By 2000 Indian engineers were at the helm of 972 Silicon Valley-based technology companies, which accounted for approximately US$5 billion in sales and 25,811 jobs. Moreover, the pace of Indian entrepreneurship accelerated rapidly in the 1990s: while Indians were running only 3 percent of the technology companies started between 1980 and 1984, they were running 10 percent of those started between 1995 and 2000 (Saxenian 1999). However, in contrast with their Taiwanese counterparts, few of these highly skilled Indians have returned home to become transnational entrepreneurs. Today, most play an arms-length role linking US firms with India's software programming skill.

US-educated Indian professionals institutionalized their social networks in the 1990s through the formation of two of Silicon Valley's most vibrant associations—The Indus Entrepreneur (TiE) and the Silicon Valley Indian Professionals Association (SIPA)[5]—however, they were slow to build direct ties to India. As they gained seniority in US corporations during the 1980s and 1990s, many non-resident Indians (NRIs) were instrumental in convincing senior management to establish operations in India to take advantage of the substantial wage differentials for software skill. By the late 1990s, as India's reputation as a supplier of software talent grew, a large proportion of large American corporations were subcontracting programming to Indian suppliers (an

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5 For more information on the development and organization of the Indian community in Silicon Valley see Saxenian (1999).

OEM relationship), and most large Silicon Valley technology companies had their own development laboratories in regions like Bangalore.

In 1999 some of Silicon Valley's most successful Indian entrepreneurs began actively to build bridges to India. Within 2 years, TiE had established chapters in Bangalore, Bombay, Delhi, Hyderabad, Calcutta, and Chennai. The growing attention in India paid to these successful NRI entrepreneurs combined with the market successes of Indian firms like Infosys, Wipro, and Satyam created role models for young Indian engineers. The NRIs in turn invested in promising start-ups and venture funds and begun to serve as role models and advisors for local IT entrepreneurs.

While traffic between India and the USA has increased substantially in recent years, the great majority of US-educated engineers remain reluctant permanently to return home. There are no data on these trends, but long-time residents of Bangalore report there has been only "a trickle" of permanent returnees to that city. Interviews in Silicon Valley suggest that Indian professionals in the USA are likely to turn to India for software programming and development resources, and that many are interested in working in India for a limited time period, running a US subsidiary or development office. Few have followed the Taiwanese and Chinese pattern of returning home permanently to start new technology companies or work for established or returnee firms.

One of the most significant roles the Silicon Valley community has played in India is in its attempts to influence government policy. In 1999, for example, Silicon Valley entrepreneur K.B. Chandrasekhar led a Committee on Venture Capital for the Securities and Exchange Board of India. The committee's report developed a comprehensive vision for the growth of India's venture capital industry, and proposed a series of regulatory and institutional reforms to achieve this goal based on a survey of the global experience.[6] They have also convened forums bringing together top policymakers and NRIs to discuss deregulation of the telecommunications industry. Efforts such as these could contribute to the creation of a more attractive context for returning entrepreneurship, particularly if accompanied by other policy reforms directed at improving the local and regulatory environment for innovation.

Indian engineers in Silicon Valley report that business conditions improved dramatically in India in the 1990s. The establishment of the Software Technology Parks (STPs) scheme has provided export-oriented software firms in designated zones tax exemptions for 5 years and guaranteed access to high-speed satellite links and reliable electricity. The economic liberalization that began in 1991, particularly the removal of duties and licenses on imports of software and industrial equipment, were essential to the growth of the software industry (Schware 1992; Heeks 1996). Yet even today expatriates complain about bureaucratic restrictions, corrupt and unresponsive officials, and an infrastructure that causes daily frustrations—from unreliable power supplies, water shortages, and backward and costly telecommunications facilities to dangerous and congested highways (Krueger and Chinoy 2000).[7]

The Indian software industry boomed in the late 1990s, with US$4 billion in software

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6 See the *Report of K.B. Chandrasekhar Committee on Venture Capital* to the Securities and Exchange Board of India at http://www.sebi.gov.in/.

7 A 1999 study by McKinsey & Co. estimates that as much as US$23 billion in IT export revenues and 650,000 jobs failed to materialize in India over an 8-year period because of limitations of the telecom infrastructure.

exports by 2000, but most of the growth was still driven primarily by low value-added services (Arora *et al*. 2001). Indian companies have moved beyond body shopping exclusively (hiring low-cost Indian programmers to work onsite for foreign customers) and shifted to offshore production (in India) that allows for the local accumulation of experience and learning. Over time, OEM relationships with major US customers have led to significant improvements in quality and the ability to take on increasingly complex projects.[8] However, Indian software companies have been so profitable that they face few incentives to address higher value-added segments of the market—or to support entrepreneurs, either internal or external, to do so. As a result, the industry remains dominated by a small number of large export-oriented corporations which serve as an important node in GPNs, but that have minimal ties with each other, local entrepreneurs, or the science and technology base in India (Parthasarathy 2000).

India still lacks a critical mass of returnees or transnational entrepreneurs, and there are few Taiwan-style "astronauts" or US-educated Indian engineers who have their feet sufficiently in both worlds to transfer up-to-date information and know-how about markets and technologies or to build the long-term relationships that would accelerate the upgrading of India's technological infrastructure. This would include not simply transforming the software industry, but also developing a viable hardware and manufacturing sector.

Communication between the technology communities of India and the USA continue to grow. Alumni associations from the Indian Institutes of Technology are starting to organize events in Silicon Valley. Some of the large software companies have established subsidiaries and alliances in the USA, and venture capital firms are emerging to invest in firms that link Silicon Valley's technology and market access with India's software skills. So while reversal of the "brain drain" is not yet on the horizon, there is a small but fast growing professional community linking Silicon Valley and regions like Bangalore—one that could play an important role in upgrading the Indian IT sector in the future.

China: reversing the brain drain?

US-educated students from Mainland China—like their Taiwanese counterparts a decade earlier—started to return home in growing numbers in the late 1990s. A survey by the China Research Center and the US International Education Association found that 30,000 (18.8 percent) of 160,000 students who studied in the USA between 1978 and 1998 had returned to China (*World Journal* 29 August 1999). A more recent study by the Beijing Science & Technology Committee claims that 140,000 students returned to China between 1996 and 2000 and that this group of returnees had started 3,000 firms with a total output of US$1 billion (*People's Daily* 3 January 2001). Another report claims that over 20,000 overseas students have returned to Beijing to start companies since 1988.[9] (The findings of the latter studies should be treated with some caution because of their source and more likely reflect trends rather than accurate numbers.)

There have been two observable waves of Chinese returnees from the USA. In the

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8   There are more Carengie Mellon Maturity Index (CMM) level five companies in India than elsewhere in the world.

9   *People's Daily*: http://www.zgc.gov.cn/news/dailynews/000911–4.htm

mid- and late 1990s, a sizeable cohort of US-educated Mainlanders moved to Beijing to start telecommunications and Internet-related companies, or to run branches of US-based companies targeting the China market. These returnees were typically recent graduates, drawn from all over the USA, with graduate training in business management or engineering, but limited work experience. One of the most successful firms of this era is AsiaInfo, a NASDAQ-listed company started by returnees from Texas that is now China's largest systems integrator for the telecommunications and Internet industry.

A distinct second, and apparently larger, wave of returnees began in 2000 as a result of substantial foreign investments in semiconductor manufacturing capabilities. The Semiconductor Manufacturing International Corp. (SMIC) and Shanghai Grace Semiconductor Manufacturing Corporation, for example, both received over US$1.5 billion from consortia of US, Taiwanese and Chinese investors to build IC production lines in Shanghai to serve the China market. The returnees joining these ventures are likely to be older and more experienced semiconductor engineers and managers from Silicon Valley and/or Taiwan than the earlier wave of Mainland returnees. Hundreds of Silicon Valley and Taiwan-based enterprises in chip design, packaging and testing, equipment installation, and ancillary services have been lured to the region as well, in part by aggressive recruitment by Shanghai officials, constituting an increasingly integrated and complete industrial production chain for microelectronics.

While this certainly does not amount to a full-scale "reversal" of the brain drain, the increasing return of US-educated engineers and scientists has contributed greatly to China's growing role in GPNs. In the 1990s, Taiwanese PC firms shifted manufacturing of low-end components such as power supplies, mice, keyboards, cases, and monitors, to China, particularly the Dongguan region in southern China to take advantage of substantially lower cost labor and land (Tong 2000) (Figure 3).[10]

In the late 1990s, Taiwanese producers of higher value-added products such as scanners, motherboards, video cards, and laptop computers began shifting activities to China as well, this time further north, to Shanghai and nearby Suzhou and Kunshan, in Jiangsu Province. These companies increasingly moved their supplier networks and management teams as well, setting up integrated production centers from which to serve international OEM clients. By 2001, it was estimated that some 250,000 Taiwanese, including the families of plant managers and engineers, were living in the greater Shanghai area.

This latter wave, which has been associated with the merging of Taiwanese and Mainland Chinese transnational communities, appears to be transferring high-level PC and semiconductor-related skill, know-how and capabilities to Shanghai more rapidly than they were transferred to Taiwan in the 1980s and 1990s. Many observers predict that China will be the world's largest producer of information technology hardware within a decade—and an important new node in the industry's GPNs.

Building the bridge to Silicon Valley.   Since China began allowing large numbers of students abroad for study in the early 1990s, policymakers have recognized the opportunity to tap this pool of foreign-educated Chinese for domestic development

10   These high-tech investments represent an extension of the earlier wholesale shift of labor intensive Taiwanese industries such as plastic and rubber products, electric and electronic appliances, and garments and footwear in the Pearl River Delta region of southern China (Chen 2001).

FIGURE 3: ANNUAL VALUE OF IT PRODUCTION, TAIWAN, 1981–98.
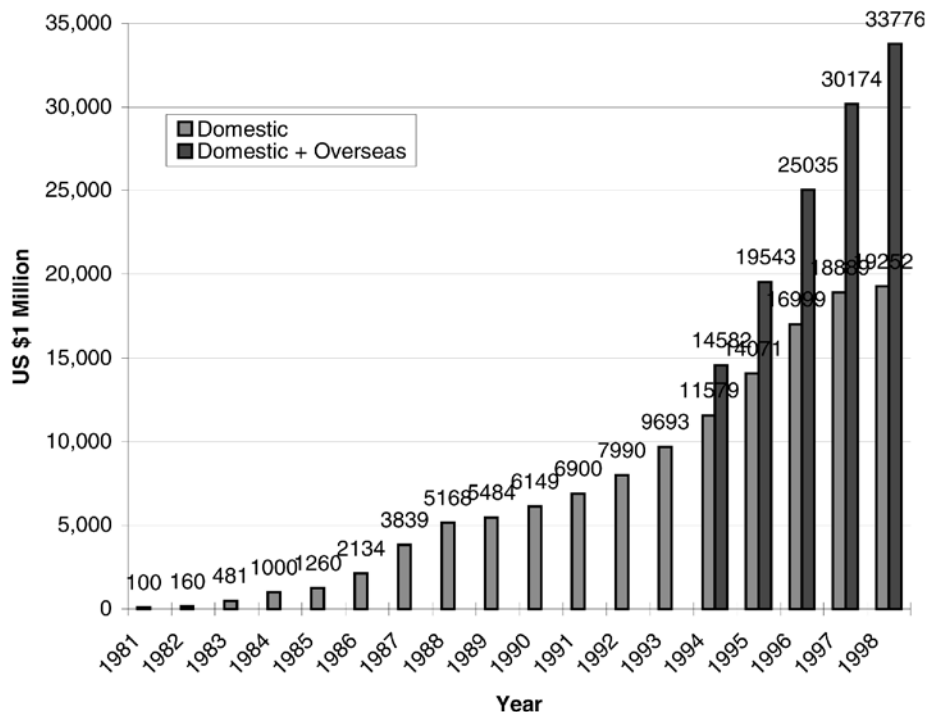
Note: The majority (90 percent) of Taiwan's overseas production is in Mainland China.

Sources: C. Huang, "R.O.C.: Republic of computers", *The Common Wealth*, Taipei, Taiwan, 1995;
http://mic.iii.org.tw/english/asiait/issues/special/1998/98sp-1.htm

purposes. While the most desirable option would be to recruit all of the "overseas students" back to China, this initially proved difficult because of the large gap in living and working conditions between China and the more developed West. As a result, local and central governments pursued two types of strategy in attempts to reverse the brain drain:

• *Government support of technical and business exchange*. Chinese policymakers have devoted substantial resources to promoting technical and business exchanges that involve overseas Chinese students. This typically involves events such as conferences, investigation tours, joint research projects, and exhibits. Such activities are designed to involve scientists and researchers, business people, and policy-makers in cross-regional exchanges of know-how and information. They also provide opportunities for overseas Mainland professionals to build relationships with their domestic counterparts. In some cases a local and central government agency will develop a program that directly funds such events, in others it will subsidize non-government agencies and the private sector to sponsor such activities.

In the late 1990s, Chinese policymakers, academic institutions and technology companies increased their commitment to improving external communications, particularly with Silicon Valley's Chinese community. They sponsored a growing number of events and programs in the USA, while also inviting Overseas Chinese

academics and industry representatives to China to attend conferences and other events. In addition, the Ministry of Education established the "Chunhui Program" to finance short-term trips to China by Overseas Chinese who were trained abroad to participate in technology-associated activities such as conferences, research projects or other authorized programs. Many of Silicon Valley's Chinese professionals have participated in these programs.

- *Programs to encourage return entrepreneurship*. Policymakers in China, at both local and central levels, have also attempted to attract overseas students home to start their own technology companies. Representatives of cabinet-level ministries as well as municipal governments from large cities such as Shanghai and Beijing pay regular visits to Silicon Valley to recruit Chinese technology professionals to return home. The visiting Chinese officials usually hold dinners or meetings with Mainlanders and use the occasion to publicize the favorable policy and business environment in China.

   Many municipal governments have established "Returning Students Venture Parks" within the Development Zones of High & New Technology Enterprise. These parks are exclusively for enterprises run by returnees and while they offer infrastructure and financial benefits like other science parks, they also address special needs of returnees, from accelerating bureaucratic processes involved with establishing residency to insuring access to prestigious primary and secondary schools for their children (see Figure 4).

By 2000, there were 23 "Returning Students Science Parks" across China, and many other municipalities had policies to attract returning students but no park. The "Returning Students Science Park" in the Zhongguancun (Haidian) district of Beijing, for example, reports that it housed 48 companies and 68 returning students in 1998. This is the oldest and largest of the three overseas student parks located in Beijing— which collectively housed 114 companies. It is difficult to determine the extent to which such policies toward returning students have contributed to China's success in technology industries, or even to the rate of return of overseas students. However, it is worth noting that these policies are quite similar to those policies pursued by Taiwanese policymakers in the 1970s and 1980s that played a central role in the creation of a transnational community linking Taiwan and Silicon Valley.

The evidence from Silicon Valley suggests that Mainland Chinese professionals, like their Taiwanese predecessors, maintain professional as well as personal ties to China even while working in the USA. There are half a dozen Chinese professional associations in the region that range in size from 200 to over 1,000 members.[11] While originally formed to organize social activities and help new immigrants overcome the feeling of isolation in a foreign culture, they have become important forums for exchanging news, contacts, and business information about China. These associations sponsor regular business tours to China, receive delegations of Chinese government officials, and serve as conduits for Chinese firms recruiting in the Valley. In 1998, for example, the North American Chinese Semiconductor Association co-sponsored a 2-

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11   These are separate from an equal number of Taiwanese professional associations in the Valley. The Taiwanese and Mainland Chinese have established separate organizations for many reasons having to do with history and culture, as well as timing of their arrival in the USA, but this may change in the future.

FIGURE 4: DISTRIBUTED ELECTRONICALLY TO BAY AREA CHINA NETWORK (11 AUGUST 1998)
WITH SUBJECT HEADING: A GREAT BUSINESS OPPORTUNITY FOR YOU.

A Briefing on China Suzhou Pioneering Park for Overseas Chinese Scholars

Sponsors

Chinese Scholarly Exchange Service Center, Ministry of Education

Torch Program Office, Ministry of Science and Technology

Jiangsu Service Center for the Shift of Qualified Personnel

Jiangsu Science and Technology Commission

The Administrative Committee of the Suzhou New Technology District

Suzhou Science and Technology Commission

Location

The Park is located in the Suzhou New District (Suzhou National New & High Technology Industrial Development Zone) to the west of the old city proper of Suzhou. The district is only 80km away from Shanghai and 1.5 hour drive from Shanghai Hongqiao Airport.

Mission

To create a favorable environment for exploitation of research results and development of small and medium-sized technology based enterprises by providing all around service and quality facilities

Target clients

Technology-based companies and research institutes run by students and scholars studying or working or returned from abroad

Incentives for tenants

- Three year refund of business tax starting the first day of operation
- Three year refund of the local part of VAT
- Exemption from income tax in the first two profit-making years, six-year reduction of the rate by 50% that and then levied at a special rate of 15% for the next three years
- Minimum registered capital of US$10,000 provided for technology consultancy or service provider, US$60,000 for manufacturing enterprises
- Application priority for different-level grants and funds
- Application priority for certificate of new & high technology product/enterprise
- Building management and business services
- Free provision of registration formalities
- Provision of advice on policy and technical issues
- Business promotion
- Assistance in obtaining financing and refunds of duties
- Provision of training programs

Progress to date:

A news conference was held in Beijing this February to declare the establishment of the Park. The six sponsors have jointly set up the Torch New & High Technology Investment and Guarantee Company and registration is now underway. The company is not-for-profit and will specialize in venture capital and credit guarantees for tenants of the park.

Building

The park owns one four-story building with floor space of 10,000 square meters. It hosts 88 units ranging from 20 to 139 sq. meters. Services and facilities include the following:

- Conference room with conferencing facilities
- Seminar room
- Product display chamber
- Internet access, central air conditioning
- Reception
- Fax, typing, word processing, and photocopying services
- Air ticket booking, hotel room reservations
- 24-hour security services

Applicants and companies

To now the Park has received more than 50 applications and 30 of them are in operation. Business of theses companies mainly covers electronics, biotech, mechanics (sic), computer software, and environmental protection. Presidents or managing directors of these companies have studied in U.S.A., Japan, France, and U.K.

China Suzhou Pioneering Park for Overseas Chinese Scholars invites you to apply today!

week tour of China's semiconductor industry for a delegation of local engineers. The group produced a scientific report that was widely circulated among Mainland Chinese in the Valley. The alumni associations of the elite Chinese secondary schools such as Beijing University and Qinghua University have active Bay Area chapters that provide an additional direct link back to China.

Mainland Chinese have primarily arrived in the USA during the 1990s, and so have started far fewer companies than the Taiwanese and Indian engineers who began coming to the USA in the 1970s. However, those who have started companies have focused almost exclusively on developing products and services for the Chinese market. The dominant model among Mainland start-ups is to incorporate in the USA and locate headquarters in Silicon Valley while operating primarily in the Mainland. While there may be an R&D office in Silicon Valley, all other functions are located in China. As a result, these firms have more employees in China than the USA, and their top executives spend most of their time in China—or on airplanes between Silicon Valley and China!

UTStarCom, for example, provides telecommunications network infrastructure for the Chinese market. It was started by a US-educated engineer and is headquartered in Silicon Valley, where it has 30 employees, but has 1,000 employees in China, making it the third largest producer in Beijing's Zhongguancun Science Park. Sina.com, which has followed a similar model, with its origins and base in Silicon Valley, is now the leading Internet portal in China. Both companies went public on NASDAQ in 2000. Jason Wu's NetFont, an Internet security software products company primarily targeting the Mainland market, likewise has 10 people in Silicon Valley and 60 in Beijing. CEO Wu reports that he spends 90 percent of his time in the China operations.

In sum, Mainland Chinese engineers returned home at an increasing rate in the late 1990s and early 2000s, spurred at least in part by active recruitment by local and provincial governments. Many became entrepreneurs, starting telecommunications and Internet-related companies to serve the domestic Chinese market, while also maintaining close ties to the USA. The growth of a transnational community linking Silicon Valley and China parallels that established a decade earlier between Taiwan and Silicon Valley—and, in spite of the many constraints on entrepreneurship (Naughton 1997; Chen 2001), is accelerating the development of China's information technology-related capabilities.

The large-scale commitments made by US and Taiwanese investors in semiconductor manufacturing in 2000 and 2001 illustrate how a transnational community can radically accelerate the emergence of new nodes in the GPNs. As US-educated Mainland Chinese integrated into the technical communities established by their Taiwanese predecessors in the late 1990s, they identified new entrepreneurial opportunities associated with exploiting China's relatively low-cost skill base while also targeting the potentially vast domestic market. In this case, the technical and managerial know-how as well as the business and market connections accumulated among the Taiwanese transnational community are being transferred to Shanghai.

As Chinese engineers extend their technical networks from Silicon Valley and Taiwan to the Mainland, they are not only creating an important new global source of information and communications technology-related production, but also further deepening the division of labor and compelling greater specialization of existing nodes in the GPN such as Taiwan and Silicon Valley.

CONCLUSIONS

This paper has explored the close and complementary relationships between transnational communities and GPNs. A transnational technical community is not necessary for a region or nation to participate in global production, but such a community can significantly improve a region's position in the global hierarchy by providing a source of world-class skill and tacit knowledge, as well as close connections to leading edge markets and technologies. At the limit, transnational entrepreneurs supported by a technical community and supportive domestic infrastructure can even establish new flagship companies that destabilize existing hierarchies.

Taiwan, India and China have all emerged as important new nodes for the production of information and communications technologies over the past two decades, but they have followed different trajectories. Taiwan's well-developed transnational community was critical to the formation and subsequent upgrading of a localized cluster of producers, who benefited greatly from direct links to Silicon Valley's technology and markets. A reversal of the brain drain and the growth of transnational entrepreneurship in Taiwan's PC and IC industries in turn accounts for its participation in global networks as a higher level supplier than many of its East Asian counterparts.

India's emergence as a major exporter of software programming and development skill owes its growth in part to the early contracts provided by the Indian business community in the USA; the transnational community that has emerged recently linking Silicon Valley to regions like Bangalore has promoted a beneficial dynamic of "brain circulation". However, India has failed to tap large and highly educated pools of US-educated Indian engineers and scientists to become transnational entrepreneurs, and so remains a relatively low value-added producer in GPNs.

Finally, China appears poised to follow Taiwan's trajectory a decade later. While the transnational community is in its formative stages, the Mainland Chinese have already benefited from growing ties with the Taiwanese technical community. Domestic policymakers have aggressively, and apparently successfully, recruited transnational entrepreneurs from Silicon Valley. While there remains uncertainty in the political environment, China has emerged as a node in GPNs with the potential to surpass Taiwan as an international IT manufacturing and logistics center. Indeed, the combination of close ties to Silicon Valley and a huge domestic market means that in time China could even become a source of innovative new flagship companies, not simply a secondary or tertiary tier in global networks.

This paper explores Chinese and Indian transnational communities because they are the largest groups of immigrant engineers in the USA, and their technical communities are heavily concentrated in Silicon Valley. However, other groups of US-educated immigrant engineers provide sources of transnational entrepreneurship. A transnational community of Israeli engineers and entrepreneurs has played a similar role in developing Israel's technology industry—in this case at a higher technological level than either India or Taiwan (Autler 2000). Likewise US-educated Irish immigrants have built strong ties to the Boston (Massachusetts) technology community and many have returned home and contributed directly to the growth of Ireland's software and IT industries (O'Riain 2000). It would be worthwhile, for example, to explore the

experience of Korean and Japanese immigrant engineers and scientists in the USA. Future research should also explore the nature and extent of transnational communities from other parts of the world that have attracted large numbers of immigrant engineers and scientists, including Australia, the UK, and Japan.

For policymakers, the lessons from this research are clear. The brain drain offers substantial unintended benefits, but only to countries that actively pursue them. By actively recruiting returnees and providing an attractive environment for transnational entrepreneurs, policymakers in Taiwan and China have capitalized on their overseas Chinese engineers and scientists. Indian policymakers, with a more laissez-faire approach toward the overseas community, have not yet fully exploited this resource, in part because of failures to improve the domestic infrastructure and regulatory environment. A transnational technical community provides a developing country with privileged connections to world-class technical talent as well as access to the world's leading technology producers. In today's volatile and fast-changing economy, these personal connections are far more flexible and responsive than multinational corporations, and can facilitate the rapid adaptation of domestic capabilities to facilitate the upgrading of the position of local firms in GPNs.

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