The Silicon Valley–Hsinchu Connection: Technical Communities and Industrial Upgrading

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Silicon Valley in California and the Hsinchu-Taipei region of Taiwan are among the most frequently cited 'miracles' of the information technology era. The dominant accounts of these successes treat them in isolation, focusing either on free markets, multinationals or the role of the state. This paper argues that the dynamism of these regional economies is attributable to their increasing interdependencies. A community of US-educated Taiwanese engineers has coordinated a decentralized process of reciprocal industrial upgrading by transferring capital, skill and know-how to Taiwan, and by facilitating collaborations between specialist producers in the two regions. This case underscores the significance of technical communities and their institutions in transferring technology and organizing production at the global as well as the local level.

1. *Introduction*

Silicon Valley in California and the Hsinchu-Taipei region of Taiwan are among the most frequently cited 'miracles' of industrialization in the information technology (IT) era. Since the region's transformation from an agricultural valley into the birthplace of the semiconductor industry in the 1950s, Silicon Valley firms have pioneered a wide range of new, technology-related industries. The regional economy has adapted flexibly to fast changing markets, and local producers continue to define the state-of-the-art in successive generations of technology—from semiconductor equipment, personal computers (PCs), and networking hardware and software, to biotechnology, multimedia software, and internet-related infrastructure and services.

Taiwan's technology achievements are more recent, but no less impressive.

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The Taipei area, which served as a source of cheap labor for foreign consumer electronics multinationals as late as the 1970s, is known today as a global center of IT systems design and manufacturing. Local companies dominate the markets for a large and growing range of computer-related products, from notebook computers, motherboards and monitors to optical scanners, keyboards and power supplies (Figure 1). In addition, Taiwan's state-of-the-art semiconductor foundries account for two-thirds of global output. Not surprisingly, the industry has grown dramatically in the past two decades (Figure 2). Taiwan's IT sector now ranks third in the world, with total output of US$34 billion in 1998, ahead of larger nations like South Korea, and behind only the United States and Japan.

The IT industries in the United States and Taiwan are differently specialized and remain at different levels of technological development. As a result, the dominant accounts of their success treat them in isolation. For some scholars, national economic success in information technology industries is evidence of the dynamism of free markets (Gilder, 1989; Lau, 1994; Callon, 1995). These accounts identify high levels of human capital formation, domestic entrepreneurship and market competition in either Taiwan or the US to explain the successes of their respective technology industries. Others argue that activist states are responsible for the successes. In this view, the intervention of agencies like the US military and aerospace agencies and Taiwan's Industrial Technology Research Institute (ITRI) explain the dynamism of the new industries (Borrus, 1988; Wade, 1990; Kraemer *et al.*, 1996; Mathews, 1997).

Recently analysts have moved beyond the simple state–market debate to examine other determinants of economic performance such as the geography of production. These explanations of success look at subnational units. For example, Taiwan's technology sector is concentrated in the 50-mile industrial area linking Taipei to the Hsinchu Science-based Industrial Park. The Hsinchu region, like Silicon Valley, appears as an exemplar of Marshallian external economies, in which the localization of skill, specialized materials and inputs, and technological know-how generate cost reductions for individual firms and increasing returns to the region as a whole (Krugman, 1991).

Yet the concept of external economies cannot account for qualitative, as opposed to quantitative, sources of growth. In particular, it overlooks the contributions of technological innovation to regional growth. So, for example, the 'new' economic geography cannot explain why Taiwan outperformed Singapore in the IT industry in the 1990s. Both were poor economies and destinations for electronics foreign direct investment (FDI) in the 1960s and 1970s. While Singapore is now a leading supplier of hard disk drives, PCs and multimedia cards, it has fallen far behind Taiwan's proliferation of indigenous

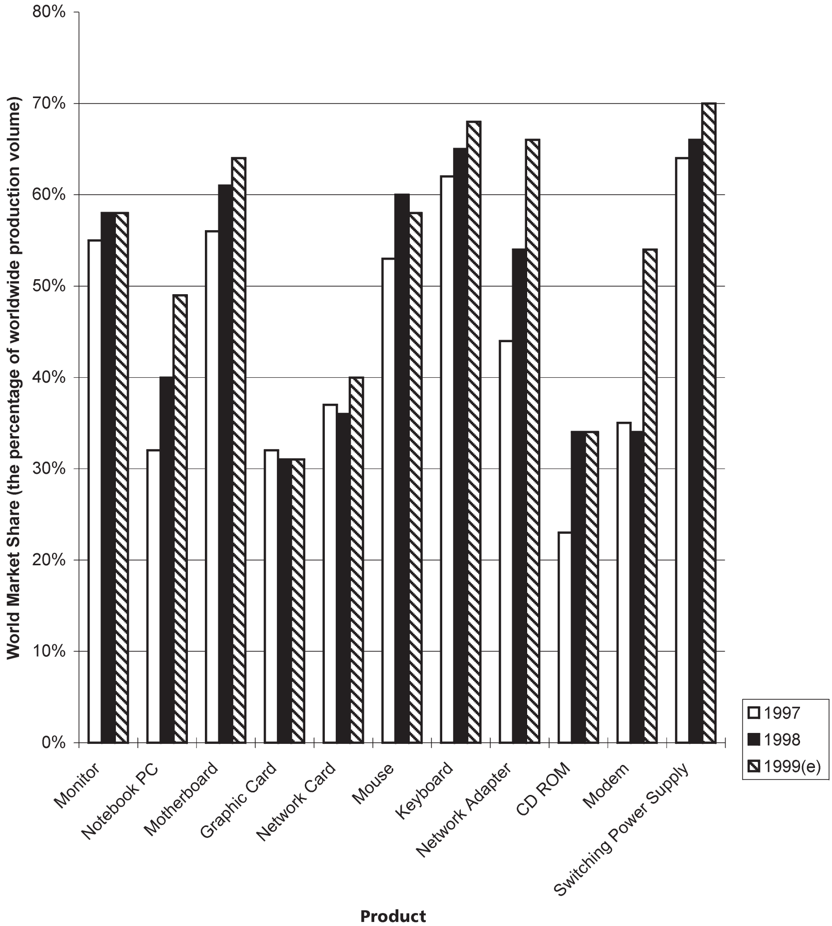

FIGURE 1. The world market share of Taiwan IT hardware products, 1997–1999. Source: MIC.

PC and integrated circuit (IC) producers that continually innovate and upgrade their manufacturing capabilities. Many observers claim that Taiwan's expertise in designing and manufacturing PCs is now unparalleled, even in the US.

Taiwan's technological achievements are reflected in international comparisons of patenting.[1] While all the Asian newly industrializing economies ranked low in the 1980s, Taiwan received US patents at an accelerating rate in the 1990s and surpassed not only Singapore but also Korea and Hong

[1] The limits of patent data as a measure of innovation are well known. They are used here as a rough indicator of the differential technological performance of these economies.

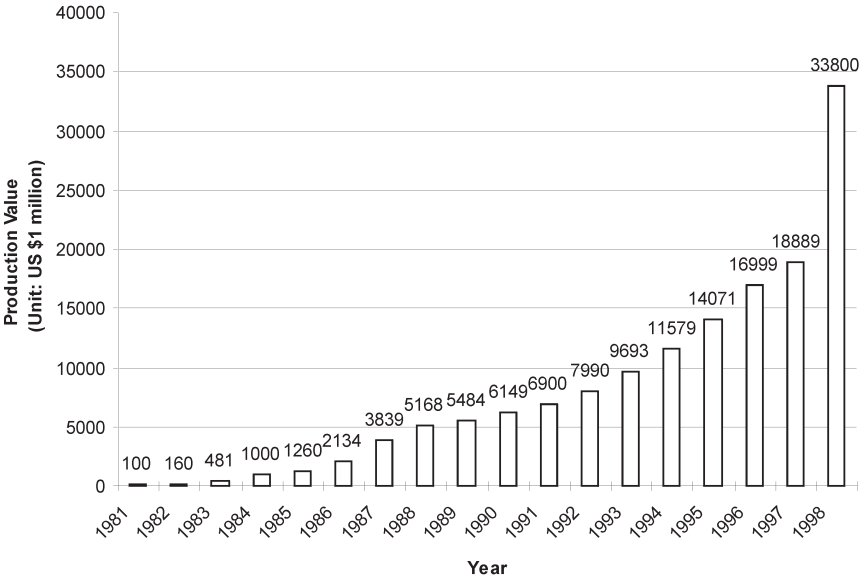

FIGURE 2. Yearly production value of Taiwan's IT hardware, 1981–1998. Sources: Huang (1995); http://mic.iii.org.tw/english/asiait/issues/special/1998/98sp-1.htm.

Kong in the number of patents granted per capita (Figure 3). In fact Taiwan, along with Israel, now ranks ahead of all of the G7 countries except the US and Japan in patents per capita (Trajtenberg, 1999).

Silicon Valley and Hsinchu might also be viewed as industrial clusters, in which competition and vertical cooperation among local firms account for rising productivity, innovation and new firm formation (Porter, 1990). Both regions boast high rates of entrepreneurship and hundreds of small and medium-sized enterprises (SMEs) alongside larger technology companies with multiple backward and forward linkages. And independent accounts of the performance of producers in these regions stress their flexibility, speed and innovative capacity relative to their leading competitors (Callon, 1995; Ernst, 1998).

The most convincing accounts document how the decentralization of the industrial systems of Hsinchu and Silicon Valley ensures the flexibility and innovative capacity needed to compete in a volatile market environment (Saxenian, 1994; Hsu, 1997; Lin, 2000). Levy and Kuo (1991), for example, compare the 'bootstrap' strategy of Taiwan's small, specialized PC firms with the high-volume PC assembly strategy of the vertically integrated Korean conglomerates. They suggested that the propensity for risk-taking and experimentation in Taiwan's SMEs produced an ongoing stream of

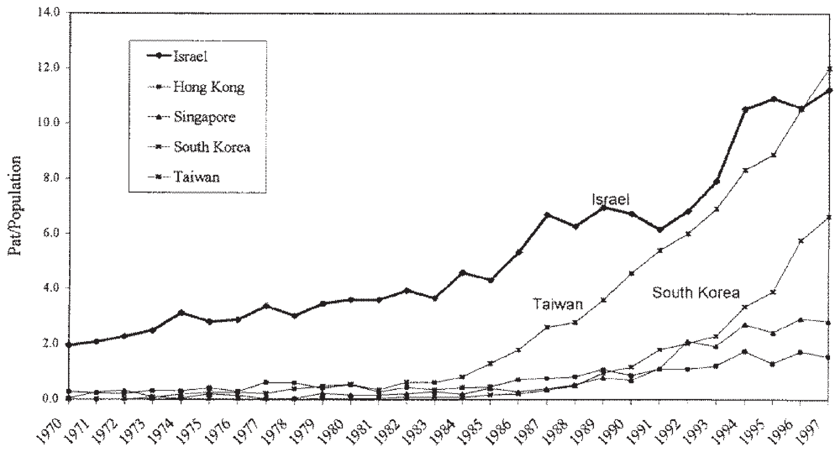

FIGURE 3. Patients per capital for Taiwan, the NICs and Israel. Source: http://www.nber.org/papers/w7022.

innovation and the opportunity for some firms to achieve technological mastery and grow large. The competitive advantages of this 'bootstrap' strategy were confirmed in the 1990s as Korea's *chaebol* fell increasingly behind the accelerating PC product lifecycle and were forced to source key components from Taiwan (Chung, 2000).

Yet this approach suffers from its focus on regions in isolation. It overlooks the growing role of international trade and investment in economic growth—and cannot explain the emergence of successful new regions such as Taiwan's Hsinchu that are located far from established centers of technology and skill. Mounting evidence suggests the need to examine the organization of production at the *global*, as well as the local level. Scholars have documented, for example, the way that global corporations organize their supply chains, or international production networks, and the opportunities this provides for industrial upgrading in less advanced economies.

The success of Taiwan's PC producers, from this view, derives from their role as original equipment manufacturers (OEMs) for the leading US and Japanese PC companies—a relationship that stimulates knowledge creation, technology transfer and improved domestic capabilities (Borrus, 1997; Dedrick and Kraemer, 1998; Ernst, 1998).[2] Analyses of global production networks represent an important conceptual advance because they demon-

[2] An OEM arrangement is one in which the brand name company (the customer) provides detailed technical blueprints and most components that allow the contractor (the supplier) to produce according to specifications. Observers site the shift to ODM (original design manufacturing) in Taiwan as evidence of industrial upgrading because the contractor takes on the responsibility for design and most component procurement as well.

strate a powerful mechanism for industrial upgrading in remote locations like Taiwan. However, the focus on the sourcing strategies of multinational corporations overlooks the emergence of indigenous entrepreneurship and innovation in the periphery during the 1990s, particularly in places like Taiwan.

The connection between technology producers in the United States and Taiwan is both more extensive and more decentralized than these top-down accounts suggest. The central and largely unrecognized actors in this process are a community of US-educated engineers who have built a social and economic bridge linking the Silicon Valley and Hsinchu economies. These highly skilled Taiwanese immigrants are distinguished from the broader Chinese diaspora (or 'overseas Chinese business networks') by shared professional as well as ethnic identities and by their deep integration into the technical communities of both technology regions.

The development of a transnational community—a community that spans borders and boasts as its key assets shared information, trust and contacts (Portes, 1996)—has been largely overlooked in accounts of Taiwan's accelerated development. This paper argues that the contributions of this international technical community have been key to the successes of more commonly recognized actors: government policymakers and global corporations. Both rely heavily on the dense professional and social networks that keep them close to state-of-the-art technical knowledge and leading-edge markets in the United States. The connection to Silicon Valley, in particular, helps to explain how Taiwan's producers innovated technologically in the 1980s and 1990s independently of their OEM customers.

The development of an international technical community has also transformed the relationship between the Silicon Valley and Hsinchu economies. In the 1960s and1970s, capital and technology resided mainly in the US and Japan and were transferred to Taiwan by multinational corporations seeking cheap labor. This one-way flow has given way in the 1990s to more decentralized two-way flows of skill, technology and capital. The Silicon Valley–Hsinchu relationship today consists of formal and informal collaborations between individual investors and entrepreneurs, SMEs, as well as the division of larger companies located on both sides of the Pacific. A new generation of venture capital providers and professional associations serve as intermediaries linking the decentralized infrastructures of the two regions. As a result, by the 1990s Hsinchu was no longer a low-cost location yet local producers continued to gain a growing share of global technology markets.[3]

[3] Taiwan's IT manufacturing capacity began shifting to regions of coastal China in the late 1990s to take

2. *Technical Communities and Industrial Decentralization*

The emergence of new centers of technology, like Taiwan, in locations outside of the advanced economies has been possible because of radical transformations in the structure of the IT sector. The dominant competitors in the computer industry in the 1960s and 1970s were vertically integrated corporations that controlled all aspects of hardware and software production. Countries sought to build a domestic IBM or 'national champion' from the bottom up. The rise of the Silicon Valley industrial model spurred the introduction of the PC and initiated a radical shift to a more fragmented industrial structure organized around networks of increasingly specialized producers (Bresnahan, 1998).

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 still other enterprises. Within each of these horizontal segments there is, in turn, increasing specialization of production and a deepening social division of labor. In the semiconductor industry, for example, independent producers specialize in chip design, fabrication, packaging and testing, as well as different segments of the manufacturing materials and equipment sector. A new generation of firms emerged in the late 1990s that specializes in providing intellectual property in the form of design modules rather than the entire chip design. There are, for example, over 200 independent specialist companies in Taiwan's IC industry alone (Figure 4).

This change in industry structure appears as a shift to 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 (Aoki, 2000). While Silicon Valley's entrepreneurs innovate in increasingly specialized niche markets, intense communications in turn ensure 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

advantage of significantly lower-cost labor, but the continued superiority of Taiwanese management and technology means that the business is still controlled by Taiwan-based firms.

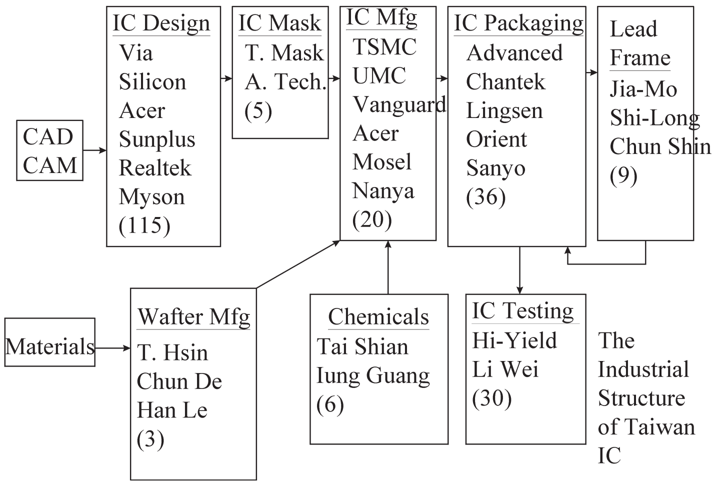

FIGURE 4. The structure of Taiwan's IC industry (no. of establishments). Source: ERSO/ITRI (1999).

as well as the conceptual advances associated with the process of specialization and recombination.[4]

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 the corporation. 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 (Kogut and Zander, 1993). In regions like Silicon Valley, where the technical community transcends firm boundaries,

[4] It is possible to specialize without innovating, and it is possible to innovate without changing the division of labor. However, it seems that the deepening social division of labor enhances the innovative capacity of a community: expanding opportunities for experimentation generate ideas, these ideas are in turn combined to make new ideas, and so forth in a dynamic and self-generating process. This suggests that specialization increases innovation and ultimately economic growth.

however, such tacit knowledge is often transferred through informal communications or the interfirm movement of individuals (Saxenian, 1994). This suggests that the multinational corporation may no longer be the advantaged or preferred organizational vehicle for transferring knowledge or personnel across national borders. An international technological community provides an alternative and potentially more flexible and responsive mechanism for long-distance transfers of skill and know-how—particularly between very different business cultures or environments.

The remainder of this paper documents the evolution of the transnational community linking Hsinchu and Silicon Valley and the concomitant process of industrial upgrading. It traces the origins of a technical community among Taiwanese engineers in the US in the 1970s and 1980s, the subsequent institutionalization of the linkages between Silicon Valley and Hsinchu, and the emergence in the 1990s of mutually beneficial collaborations between specialist producers located in the two regions. It provides recent survey data to document the nature and scale of the interactions within this cross-regional community. A concluding section re-examines the relationship between technical communities and regional development and briefly suggests policy lessons.

3. *The Construction of a Taiwanese Technical Community in Silicon Valley*

The modern 'brain-drain' from Asia to the United States dates to the Immigration Act of 1965, often referred to as the Hart–Celler Act. Prior to 1965 the US immigration system limited foreign entry by mandating extremely small quotas according to nation of origin. Hart–Celler, by contrast, allowed immigration based on both the possession of scarce skills and on family ties to citizens or permanent residents. It also significantly increased the total number of immigrants allowed into the country. Taiwan, like most other Asian countries, was historically limited to a maximum of 100 immigrant visas per year. As a result, only 47 scientist and engineers immigrated to the US from Taiwan in 1965. Two years later, in 1967, the number had increased to 1321 (Chang, 1992).

Taiwanese students came to the US by the thousands during the 1970s and 1980s. In fact, Taiwan sent more doctoral candidates in engineering to the US during the 1980s than any other country, including entire graduating classes from Taiwan's most élite engineering universities: National Taiwan University, National Chiaotung University and Tsinghua University. These students were lured by the ample fellowship money available for graduate studies at US universities and pushed by the limited professional opportunities in Taiwan at the time. Most stayed in the US after graduation, recognizing that there would be little demand for their skills back home. Taiwanese policymakers complained bitterly at the time about losing the 'best and brightest' to the United States.

The influx of highly skilled immigrants coincided with the growth of a new generation of technology industries in Silicon Valley. As the demand for technical skill in the electronics industry exploded, it attracted recent graduates to the region. By 1990, one-third of all scientists and engineers in Silicon Valley's technology industries were foreign-born, primarily from Asia (Saxenian, 1999). By 2000, there were approximately 9000 US-educated Taiwanese engineers and scientists working in Silicon Valley, the majority of whom arrived prior to 1990.

Early Chinese immigrants to Silicon Valley saw themselves as outsiders to the region's mainstream technology community. While most held graduate degrees in engineering from US universities and worked for established technology companies, they often felt personally and professionally isolated. Some responded to this sense of exclusion by organizing collectively.[5] They typically found one another socially first, coming together to celebrate holidays and family events. Over time, they turned the social networks to professional purposes, creating associations to provide resources and role models to assist the advancement of individuals within the technology community.

The Chinese Institute of Engineers (CIE) is commonly regarded as the 'grandfather' of the Chinese professional organizations in Silicon Valley. A small group of Taiwanese immigrants started a local branch of CIE (an older, New York-based organization) in 1979 to promote communication and cooperation among the region's Chinese engineers. Its early growth built on pre-existing social ties, as most of its members were graduates of Taiwan's top engineering universities. These alumni relations, which seemed more important to many Taiwanese immigrants when living abroad than they had at home, provided an important basis for solidarity among the region's immigrant engineers. The San Francisco Bay Area chapter of CIE quickly surpassed the original New York chapter to become the largest in the country, reflecting the shifting center of technology production in the United States.

The CIE is a scientific and educational organization whose goal is the ex-

[5] Ironically, many of the distinctive features of the Silicon Valley business model were created during the 1960s and 1970s by engineers who saw themselves as outsiders to the mainstream business establishment in the East coast. The region's original industry associations like the American Electronics Association were an attempt to create a presence in a corporate world that Silicon Valley's emerging producers felt excluded from. These organizations provided role models and support for entrepreneurship similar to that now being provided within immigrant communities.

change of engineering information. However, the initial meetings of the Bay Area chapter focused heavily on teaching members the mechanics of finding a job or starting a business, getting legal and financial help, and providing basic management training to engineers who had only technical education. Over time CIE also became an important source of role models and mentors for newly arrived immigrants. Gerry Liu, who co-founded Knights Technology with four Taiwanese friends reports:

> When I was thinking of starting my own business, I went around to call on a few senior, established Chinese businessmen to seek their advice. I called David Lee . . . I contacted David Lam and Winston Chen. I called up Ta-lin Hsu. They did not know me, but they took my calls. I went to their offices or their homes, they spent time with me telling me what I should or shouldn't be doing.[6]

Liu was one of the first generation of Taiwanese to start a company in Silicon Valley, and he has in turn become a role model for later generations of Chinese immigrants.

CIE was just a start. In subsequent years, Silicon Valley's Taiwanese immigrants organized a variety of other technical and business associations, including the Chinese American Semiconductor Professionals Association, the Chinese American Computer Corporation, the Chinese Software Professionals Association and the North American Taiwanese Engineers Association. These organizations are among the most vibrant and active in the region. Like the CIE, they combine elements of traditional immigrant culture with distinct high-technology practices: they simultaneously create ethnic identities and facilitate the professional networking and information exchange that aid success in Silicon Valley's decentralized industrial system (Saxenian, 1999).

Taiwanese engineers like Gerry Liu turned increasingly to entrepreneurship in the 1980s and 1990s, in response both to the perception of a 'glass ceiling' in the established companies and to the emergence of supportive ethnic networks and role models. It is difficult to accurately measure the rate of immigrant entrepreneurship, but data on the number of Chinese CEOs in the region serves as a useful proxy. While Chinese engineers were the chief executives of 9% of all Silicon Valley companies started between 1980 and 1984, they were running 20% of those started between 1995 and 1999. By 1999, Chinese were at the helm of 2001 Silicon Valley-based technology companies, or 17% of the companies started in the region since 1980. The

[6] Interview, Gerry Liu, 22 January 1997.

next largest group of foreign-born CEOs was Indians, who were running 774 firms, or 7% of the total (Saxenian, 1999).

First-generation immigrants from Taiwan thus constructed a technical community in Silicon Valley, one that met both social and professional needs. This is not to suggest that they became a self-contained ethnic enclave. While many Taiwanese engineers socialize primarily with other Taiwanese immigrants and support one another when they start businesses, they also work closely with immigrants from other countries as well as with native-born engineers. There is growing recognition as well that while a start-up might be spawned with the support of ethnic networks, it must become part of the mainstream in order to grow. The most successful Chinese businesses in Silicon Valley today are those that draw on ethnic resources, at least initially, while integrating over time into the mainstream technology and business networks.[7]

It is worth noting as well that immigrant engineers from mainland China, a fast-growing presence in Silicon Valley in the 1990s, are creating their own social and professional associations rather than joining those established by their Taiwanese predecessors. This divide underscores the dangers of overstating the power of race or nationality in creating cohesive ethnic identities, which is often done in discussions of the business networks of the overseas Chinese. Collective identities are constructed over time, often through the kinds of face-to-face social interactions that are facilitated by geographic, occupational or industrial concentration. The initial social connections often have a basis in shared educational experiences, technical backgrounds, language, culture and history. Once established, these concentrations promote the frequent, intensive interactions that breed a sense of commonality and identification with members of the same group—and at the same time, exclude others, even of similar racial characteristics.[8]

4. *Institutionalizing the Silicon Valley–Hsinchu Connection*

Policymakers in Taiwan began to recognize that the 'brain-drain' could become a potential asset as they sought to upgrade the island's position in the international economy in the 1970s. They sponsored frequent technical meetings and conferences that brought together engineers based in both the

[7] This parallels Granovetter's (1995) notion of balancing coupling and decoupling in the case of overseas Chinese entrepreneurs.

[8] This emphasis on the construction of professional identities differs from the often-cited role of *guanxi* in Chinese business relationships. See Hsu and Saxenian (2000).

United States and Taiwan.[9] They actively recruited Taiwanese engineers in the US to return home, either temporarily or permanently. And drawing heavily on policy advice from overseas Chinese, they developed strategies to upgrade the technological capabilities of the private sector and to promote new firm formation and competition in the emerging information technology industries. In the 1970s and 1980s, government agencies in Taiwan aggressively transferred state-of-the-art technology from the US, created a venture capital industry long before it became fashionable elsewhere in the world, and developed other measures to diffuse technology, including the formation of the Hsinchu Science-based Industrial Park.

By exploiting this overseas resource, Taiwan's policymakers unwittingly supported the extension of Silicon Valley's Chinese network to include their counterparts in Taiwan. Frequent advisory meetings and technical interactions supported the creation of personal and professional relationships between engineers, entrepreneurs, executives and bureaucrats on both sides of the Pacific. On indicator of this process is the list of recipients of the Chinese Institute of Engineers (USA) Annual Awards for Distinguished Service and for Achievement in Science and Engineering, which reads like a who's who of Chinese technologists based in the US and Taiwan over the past three decades.[10] In short, an unintended consequence of Taiwan's outward-looking technology strategy was creation of an international technical community, one that is now self-sustaining.

The accelerated growth of the Taiwanese economy in the 1980s, combined with active government recruitment, ultimately spurred a reversal of the 'brain-drain'. Lured primarily by the promise of economic opportunities as well as the desire to return to families and contribute to their home country, growing numbers of US-educated engineers returned to Taiwan in the 1990s. Approximately 200 engineers and scientists returned to Taiwan annually in the early 1980s. A decade later, more than 1000 were returning annually. According to the National Youth Commission, by 1998 more than 30% of the engineers who studied in the US returned to Taiwan, compared to only 10% in the 1970s (see Figure 5).

The Silicon Valley–Hsinchu business connection was institutionalized in 1989 with the formation of the Monte Jade Science and Technology Association. Monte Jade was started in 1989 by a group of senior Taiwanese executives with the intention of promoting business cooperation, investment and technology transfer between Chinese engineers in the Bay Area and

[9] This section draws heavily from account provided in Meany (1991). For more detailed accounts of the development strategies for Taiwan's technology industry, see Liu (1993) and Chang *et al.* (1994, 1999).

[10] For the list of recipients, see www.cie-gnyc.org/Rwinner.htm.

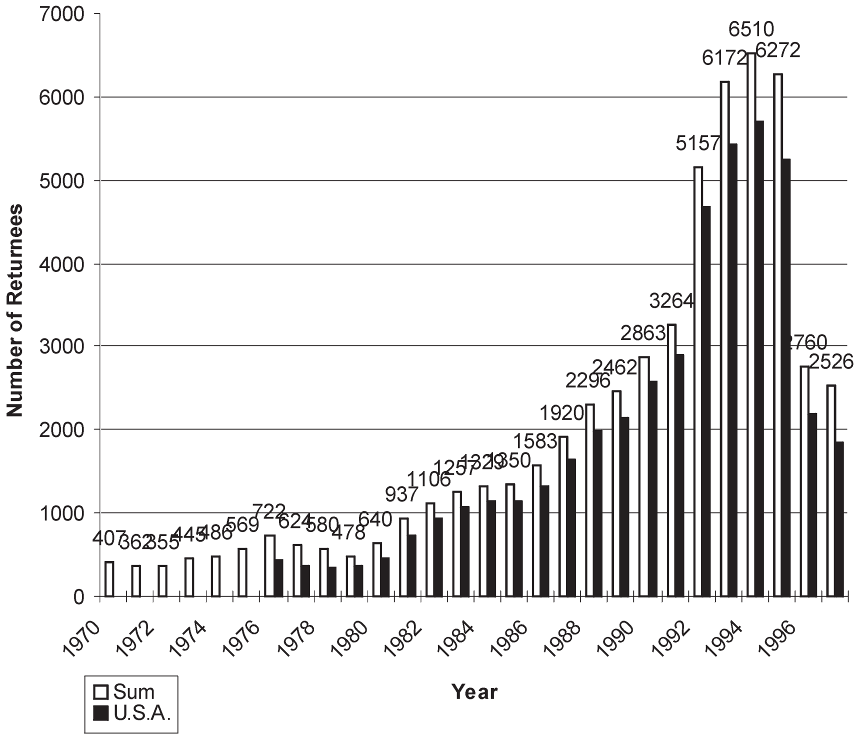

FIGURE 5. Returnees to Taiwan from the US, 1970–1997. Source: National Youth Commission, Taiwan.

Taiwan. The name Monte Jade, after the highest mountain peak in Taiwan, was chosen to signify 'cross cultural and technological foresight and excellence at the highest level'. Today the organization has 150 corporate members in the Silicon Valley branch, including the leading Taiwanese technology companies, and 300 individual members, almost all of Taiwanese origin.

The primary objective of Monte Jade is to 'open up opportunities for professionals and corporations at both ends of the Pacific to network and share their valuable experiences'. While officials claim that there is no financial connection between Monte Jade and the Taiwanese government, the informal connections are clear. Monte Jade's main offices are in the same office suite as the Science Division and the local representatives of the Hsinchu Science-based Industrial Park. Proximity supports close and ongoing interactions, and these interactions are by no means unintentional. A founding member described his vision for Monte Jade:

I felt that at the time we were right in the throes of a huge change in

> the Valley in terms of what Chinese-Americans role could be. Many of us had worked hard and long as engineers, had managed to get to the point where we were either head of the company or a key member of the management team of a company. It was very clear that the Chinese American contribution can [*sic*] go far beyond engineering and scientific contribution into the business domain . . . what you need is a forum so that people can help each other, mentoring the younger generation, in terms of how to manage, how to run a business, how to get capital, and so on. . . . At that time Taiwan was doing quite well . . . the economic miracle had created a lot of wealth so a two-way bridge was needed between here and Taiwan.

He went on to note that these ties could not have developed earlier because Taiwan had not developed to the point that people like him could contribute. If they had gone back during the 1970s, he said, 'they would have been sweeping floors'.[11]

Monte Jade sponsors a large annual meeting that typically draws an audience of more than 1000 Chinese engineers from both the US and Taiwan for a day of technical meetings as well as an evening banquet. There are also smaller monthly dinner meetings as well as a variety of social events, both planned and unscheduled. These social gatherings, which typically include family members, are often as important as the professional activities in building shared identities. One indication of the association's success is that its monthly newsletter, which is in Chinese, can be easily found in both Silicon Valley and Hsinchu.

Monte Jade actively promotes entrepreneurship as well—a reflection of the extent to which the Taiwanese immigrants have adopted the Silicon Valley business model. The Annual Monte Jade Investment Conference draws hundreds of aspiring entrepreneurs, venture capitalists and other service providers from the United States, Taiwan and the rest of Asia. A special committee of the board of directors offers assistance to individual members who are considering starting companies regarding corporate formation, growth and development. It also helps member firms with the flow of investment funds, technology transfer, and mergers and acquisitions. One executive reports building connections with individuals the Taiwan Stock Exchange in order to help a new Silicon Valley company go public in Taiwan. Another claims that Monte Jade has been critical to giving confidence to a new generation of entrepreneurs, both in the US and Taiwan, because 'most of us know each

[11] Leonard Liu interview, 3 April 1998.

other socially and we tend to refer problems and situations back and forth. This definitely helps our businesses.'[12]

While the Hsinchu Science Park was not the cause of Taiwan's success in IT, its success reflects the fast expanding ties between the two regions. After its first eight years (1980–88) the Park was home to only 94 companies with under $2 billion in annual sales collectively, and it attracted only a handful of US-educated engineers per year. By the early 1990s, as the 'brain-drain' reversed, the Park became a destination for hundreds of returnees annually and they started new companies at an accelerating rate. The Park was attractive to engineers from the US in part because of its location close to the headquarters of ITRI and ERSO as well as two of Taiwan's leading engineering universities, and because it offered a range of fiscal incentives for qualified technology investments.[13] Equally important, the Park provided returnees with preferential access to scarce, high-quality housing and to the only Chinese-American school in Taiwan—both of which are located on the park grounds.

While only 184 Taiwanese had returned from the US to work in the Hsinchu Science Park in 1989, a decade later the total had increased more than 10-fold to 2840. And these returnees were disproportionately likely to start their own companies. Some 40% 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.

Take Miin Wu, who immigrated to the US in the early 1970s to pursue graduate training in electrical engineering. Like virtually all of his classmates from National Taiwan University, he took advantage of the ample fellowship aid available in the US at the time for poor but talented foreign students. After earning a doctorate from Stanford University in 1976, Wu recognized that there were no opportunities to use his newly acquired skills in economically backward Taiwan and he chose to remain in the US. He worked 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, economic conditions in Taiwan had improved dra-

[12] Lester Lee interview, 1 July 1997.

[13] The incentives include low interest loans, a five-year income tax break for the first nine years of operation, the right to retain earnings of up to 200% 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 comes from the Science Park Administration, Hsinchu Science-based Industrial Park.

matically and Wu decided to return home. In 1989 Wu started one of Taiwan's first semiconductor companies, Macronix Co, in the Hsinchu Science-based Industrial Park, with funding from H&Q Asia Pacific. He initially recruited 30 senior engineers, mainly former classmates and friends from Silicon Valley, to return to Taiwan. This team provided Macronix with the specialized technical skills and experience to develop new products and move into new markets quickly. Wu also transferred elements of the Silicon Valley management model to Macronix, including openness, informality and the minimization of hierarchy—all significant departures from traditional Taiwanese corporate models. Macronix went public on the Taiwan stock exchange in 1995 and the following year became the first Taiwanese company to list on NASDAQ. The firm is now the sixth largest semiconductor maker in Taiwan, with over $500 million sales and some 3300 employees.

Although most Macronix employees and its manufacturing facilities are based in Taiwan, the firm has an advanced design and engineering center in Silicon Valley, and Wu regularly recruits senior managers from the Valley. Macronix has also established a corporate venture capital fund that invests in promising start-ups based both in Silicon Valley and Taiwan. The goal of these investments is not to raise money but to develop technologies related to their core business. In short, Miin Wu's activities bridge and benefit both the Hsinchu (Taiwan) and Silicon Valley economies.

In addition to permanent returnees like Wu, a growing population of 'astronauts' work in *both* places and spend much of their lives on airplanes. While their families 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 like CIE.

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 Hsinchu and Silicon Valley 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 US. 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.[14]

In the words of another engineer who worked for IBM in Silicon Valley for 18 years before returning to Taiwan: 'There's a very small world between Taiwan and Silicon Valley' (Barnathan, 1992). Others say Taiwan is like an extension of Silicon Valley. The former CEO of Acer America claims that the continuous interaction between the Hsinchu and Silicon Valley has generated 'multiple positive feedbacks' that enhance business opportunities in both regions.[15]

Taiwanese returnees like Miin Wu have accelerated the transfer of organizational models from Silicon Valley as well. An engineer who returned from the US in 1993 and now works for Taiwan Semiconductor Manufacturing Company (TSMC) reports that the corporate culture of TSMC is more American than Taiwanese (Gargan, 1994). This is true of most Hsinchu-based technology companies, which have adopted variants of Silicon Valley management model with its relative informality, minimization of hierarchy and orientation toward entrepreneurial achievement.

While Taiwan's traditions of entrepreneurship, collaboration, relationship-based business, and resource-sharing among SMEs have provided fertile ground for many aspects of Silicon Valley management models (Hamilton, 1997), others, such as the heavy reliance on family ties, have largely been abandoned. As a result, Taiwanese businessmen are often far more comfortable than their Asian counterparts setting up branches in Silicon Valley. Virtually all of the leading Taiwanese companies have research labs or design operations in the region.

[14] C. B Liaw interview, 28 August 1996.

[15] Ron Chwang interview, 25 March 1997.

5. *Cross-regional Collaborations and Industrial Upgrading*

A community of Taiwanese returnees, 'astronauts' and US-based engineers has become the bridge between Silicon Valley and Hsinchu. What was once a one-way flow of technology and skill from the United States to Taiwan has become a two-way thoroughfare allowing producers both regions collaborate to enhance distinctive but complementary strengths of these comparably decentralized industrial systems. Fred Cheng, who runs Winbond North America, claims that: 'The best way to start a technology company today is to take the best from each region, combining Taiwanese financial and manufacturing strength with Silicon Valley's engineering and technical skill.'[16] This appears to be a classic case of the benefits of comparative advantage. However, the economic gains from specialization and trade depend on the social structures and institutions that ensure flows of information and facilitate joint problem-solving between distant producers.

These cross-Pacific collaborations extend the localized processes of innovative upgrading through experimentation and recombination that occur *within* each region. The producers in both Silicon Valley and Hsinchu are organized to respond to uncertainty rather than to try to predict or plan for it. Taiwan's PC makers, for example, typically source components and parts from over 100 different local suppliers and subcontractors (Lin, 2000). The extensive social division of labor provides systems firms with the flexibility to shift rapidly, as they did in the early 1990s from low-margin desktop PCs into more profitable notebooks, and the specialization of producers allows each to remain at the leading edge of design and/or manufacturing capabilities. Today Taiwan manufactures PCs for the dominant computer firms from Dell and Compaq to Sony and Toshiba. More recently, Taiwanese producers have shifted into manufacturing mobile phones and information appliances.

This adaptation requires shifting patterns of collaboration, with new combinations emerging as markets shift and as local producers develop new technical capabilities. Taiwanese firms began producing CD-ROMs, modems and TFT-LCDs in the 1990s, for example, and while they remain technological imitators in these products, they are now leading producers in each market. In short, Taiwan excels at both incremental product innovation and rapid development and commercialization.

The integration of the technical communities in Silicon Valley and Hsinchu has facilitated a new division of labor between the two regions. In some cases this is reflected in the location of divisions within a firm. Manufacturing-oriented firms like Macronix are based in Hsinchu and maintain design

[16] Fred Cheng interview, 25 March 1997.

centers in Silicon Valley. Alternatively, Integrated Silicon Structures Inc. (ISSI) which designs ICs, is headquartered in Silicon Valley but works very closely with its manufacturing division in Hsinchu. Today more than 67 Taiwanese technology firms have operations in Silicon Valley, including not only large established companies like Acer but also more recent startups like Via Technology. Division managers in these firms are typically well connected in the local labor market and technical community while also maintaining close working relationships with their colleagues in the main office. Winbond's Fred Cheng, for example, has worked in Silicon Valley for 20 years, but knows Taiwan's technology community very well because he travels to headquarters at least 10 times a year.

The transnational community thus allows companies like Winbond to avoid the problems that many corporations face when they establish operations in Silicon Valley. Foreign firms need to be able to integrate into the region's social networks to gain access to up-to-date technology and market information, while simultaneously maintaining the ability to communicate quickly and effectively with decision-makers in the headquarters (Weill, 2001). More hierarchical European and Asian corporations often face difficulties developing such a two-way bridge to Silicon Valley.

The cross-regional collaborations between Hsinchu and Silicon Valley frequently involve vertical partnerships between producers at different stages in the supply chain. Take the relationship between Taiwan's foundries and their Silicon Valley equipment manufacturers. Steve Tso, a senior vice president in charge of manufacturing technology and services at TSMC, worked at semiconductor equipment vendor Applied Materials in Silicon Valley for many years before returning to Taiwan. He claims that his close personal ties with senior executives at Applied Materials provide TSMC with an invaluable competitive advantage by improving the quality of communication between the technical teams at the two firms—in spite of the distance separating them.

The interactions between TSMC and Applied Materials engineers are continual, according to Tso, and, for the most part, must be face-to-face because the most advanced processes are not yet standardized and many of the manufacturing problems they face are not clearly defined. Tso travels to Silicon Valley several times a year, and reports that teams of TSMC engineers can always be found in the Applied Materials' Silicon Valley facilities for training on the latest generations of manufacturing equipment. Engineers from Applied Materials, likewise, regularly visit TSMC. He argues that this close and ongoing exchange helps TSMC develop new process technologies quickly while minimizing the technical problems that invariably arise when introducing new manufacturing processes. It also keeps his firm abreast of the latest trends and functions in equipment design.[17]

A comparable level of collaboration is required between the semiconductor foundries and their customers, the firms that design the integrated circuits. According to Tso, the engineers from Silicon Valley-based customers like AMD, National Semiconductor, S3 and Trident can always be found in the TSMC offices in Hsinchu, which are flexibly divided in order to allow their customers' technical teams to work closely with TSMC teams. Likewise, TSMC engineers spend significant amounts of time in their customers' facilities in Silicon Valley.

Taiwan's other leading semiconductor foundry, United Microelectronics Corporation (UMC), has gone a step further and institutionalized collaboration with Silicon Valley's 'fabless' chip designers. United Integrated Circuits Corporation (UICC) joins UMC with more than eight Silicon Valley design firms including Oak Technology, Trident Semiconductor, Opti, ISSI and ESS—all of which were started by Chinese entrepreneurs. Each of the US partners holds 5–10% share in the $600 million fab, with UMC holding the 40% balance. UICC guarantees the design firms with secure foundry space even in the case of industry-wide capacity shortages, and it ensures UMC the capital it needs to build the fab as well as guaranteeing full capacity utilization.

A new breed of venture capitalists mediates these cross-regional collaborations (Saxenian and Li, 2001). Like their Silicon Valley-based predecessors, these transnational financiers often have technical training and work experience in either Taiwan or the United States. However, unlike older generations of venture capitalists, whose networks and investments tend to be very close to home, these investors see their role as bridging geographically distant centers of skill and excellence. In the words of Peter Liu (co-founder of WIIG who went on to start another venture firm, WI Harper):

> WI Harper distinguishes itself from its Sand Hill counterparts through its personal and professional ties with key management in Asia. . . . In Asia it is very difficult to get good information, and through our established network of contacts we are in an excellent position to help the companies in which we invest. . . . We see ourselves as the bridge between Silicon Valley and Asia. (Hellman, 1998)

Ken Tai is a good example. Tai was a co-founder of Multitech, the fore-

[17] Steve Tso interview, 15 March 1999.

runner of Acer, along with several classmates from Taiwan's Chaio-tung University. After working for 17 years at Acer, he worked for two start-ups before starting his own venture capital firm, InveStar. In 1996, its first year of operations, InveStar invested $50 million in Silicon Valley companies. Like Peter Lui, Tai sees his firm as a bridge linking Silicon Valley's new product designs and technology and Taiwan's semiconductor manufacturing and system integration capabilities.

> The new technology is all in Silicon Valley, but when you want to integrate that technology into a final product, Taiwan is the best place. Taiwan is the best place to integrate technology components together in a very efficient way because it excels at production logistics and information handling.

Tai goes on to describe InveStar's role as an intermediary in this process:

> When we invest in Silicon Valley startups we are also helping bring them to Taiwan. It is relationship-building . . . we help them get high-level introductions to the semiconductor foundry and we help establish strategic opportunities and relationships in the PC sector as well. This is more than simply vendor–customer relationships. We smooth the relationships.[18]

The case of Platform Technology, a Silicon Valley start-up founded by US-educated Chinese entrepreneur Paul Tien, illustrates the benefits of the cross-Pacific relationships.[19] InveStar provided Platform with $3 million in 1996 when the firm was already several years old and was struggling to find customers, in spite of its state-of-the-art audio chip design. The InveStar partners also introduced Tien to senior executives at the leading PC companies in Taipei. Platform became known within Taiwan's technology circles, and got so many design wins that it quickly became one of the world's largest producers of audio chips. Platform was also having problems with the manufacturing process at its foundry, TSMC. As a small US-based start-up they could not get the attention of the giant chip manufacturer. Once again, the InveStar partners intervened by calling their friends at TSMC to ensure that Platform's calls were returned and that its problems were addressed immediately.

Or take the start-up Allayer, which was formed in Silicon Valley in 1997 to focus on the design of high bandwidth networking ICs. One of Allayer's investors and largest shareholders is Acer Capital America, the venture arm

[18] Ken Tai interview, 16 May 1997.

[19] Herbert Chang interview, 22 July 1997.

of Taiwan's Acer Group. The President of Acer Capital America, Ronald Chwang, sits on the Allayer Board of Directors and has actively helped them establish a partnership with D-Link, Taiwan's leading manufacturer of networking hardware, as well as with their OEM suppliers (foundries) TSMC and UMC. As a result, Allayer is now in the process of establishing an R&D subsidiary in Taiwan to design IC products to meet the special requirements of the local network industry, while also enhancing technical support and cooperation with other customers like D-Link.

These examples suggest that Taiwan's transnational entrepreneurs are well positioned to quickly identify promising new market opportunities, raise capital, build management teams and establish partnerships with other specialist producers—even those located at great geographical distances. The speed of personal communications and decision-making within this community as well as their close ties to Silicon Valley accelerates learning about new sources of skill, technology, capital, and about potential collaborators. It also facilitates timely responses. This responsiveness is difficult for even the most flexible and decentralized multinational corporations.

While Silicon Valley and Hsinchu remain at different levels of development and differently specialized, the interactions between the two regions are increasingly complementary and mutually beneficial. As long as the United States remains the largest and most sophisticated market for technology products, which seems likely for the foreseeable future, new product definition and leading-edge innovation will remain in Silicon Valley. However, Taiwanese companies continue to enhance their ability to design, modify and adapt as well as rapidly commercialize technologies developed elsewhere. As local design and product development capabilities improve, Taiwanese companies are increasingly well positioned to take new product ideas and technologies from Silicon Valley and quickly integrate and produce them in high volume at relatively low cost.

6. *Concluding Comments*

The Taiwanese experience demonstrates that the social structure of a technical community is as important to organizing production at the global level as it is at the local level. Moreover it suggests that the multinational corporation is no longer the privileged vehicle for transfers of knowledge and skill. A transnational technical community allows distant producers to specialize and collaborate to upgrade their capabilities, particularly when the collaborations require close communications and joint problem-solving. The trust and local knowledge that exist within technical communities, even those that span continents, provide a competitive advantage in an environment where success depends on being very fast to market. And rather than competing for a relatively fixed market, these specialists are jointly growing the market by continually introducing new products, services and applications. As a result, while the relationships between producers in the two regions have deepened over time, they remain complementary and mutually beneficial rather than zero-sum.

The case also suggests that localization is not at odds with the globalization of economic activity. Rather they are mutually reinforcing. Globalization is increasingly a process of integration of specialized components through collaboration at an international level. This is best viewed as a process of recombination in which firms specialize in order to become global, and their specialization in turn allows them to be better collaborators. The best environments for breeding such specialist firms are the decentralized industrial systems of places like Silicon Valley and Hsinchu. Just as the social structures and institutions *within* these regions encourage entrepreneurship and learning at the regional level, so the creation of a transnational technical community facilitates collaborations between individuals and producers in the two regions and supports a process of reciprocal industrial upgrading.

The enduring importance of the technical community linking Silicon Valley and Hsinchu is reflected in current survey data (see Appendix). Silicon Valley's Taiwanese engineers and scientists continue travel to Taiwan regularly (7.3% travel to Taiwan more than five times a year for business purposes, 22% travel between two and four times a year). The great majority (85.3%) have friends and colleagues who have returned to Taiwan to work or start a company, with 15.8% reporting more than 10. They regularly exchange information with friends and colleagues in Taiwan about technology and about job opportunities in both locations. More than one-third (38.9%) have helped to arrange business contracts in Taiwan, one-quarter of them (24%) have served as advisors and consultants for Taiwanese companies, and one-fifth (19.2%) have invested their own money in start-ups or venture funds in Taiwan. Many have caught the Silicon Valley bug as well, with 58.8% reporting that they plan to start their own business sometime in the future, and 50% that say they would consider locating their business in Taiwan.

Transnational communities are not unique to Taiwan. Transnational entrepreneurs have been important actors in the development of new technology industries in Israel, India and China. In each of these cases, engineers and entrepreneurs with ties to Silicon Valley's technical community have built the long-distance bridges that allow them to take advantage of specialized skill and resources in their home regions, while simultaneously maintaining a presence in Silicon Valley. And in each of these cases, venture capitalists and ethnic social networks and professional associations have played a central mediating role in the process (Autler, 2000; Saxenian, 1999; Tuebal, 2000).

As governments around the world clamor to establish venture capital industries and technology parks in efforts to replicate the Silicon Valley experience, the Taiwanese case suggests that new centers of technology and entrepreneurship cannot be created in isolation. Rather they require ongoing connections to the US market—often through integration into Silicon Valley's technical community. The Taiwanese case also suggests that regions seeking to participate in global technology networks should devote as much attention to expanding education and training, creating institutions to support new firm formation, and building ties to Silicon Valley as to attempting to lure foreign investment.

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Appendix. The Silicon Valley–Hsinchu Technical Community

The following data are from a web survey of foreign-born professionals in Silicon Valley conducted during May 2001.

Taiwanese sample, $n = 180$. Of this group, 85% have postgraduate degrees (Masters or Ph.D.), 92% of which were obtained in the US, and 78% are in technical, scientific, or engineering fields.

How many of your friends and/or colleagues have returned to Taiwan to work or start a company?

None	14.7%
1–9	69.5
10–20	10.5
21	5.3

How often have you traveled to Taiwan for business purposes on average during the past three years?

5 or more times a year	7.3%
2–4 times a year	22.0
Once a year	31.2

How often do you exchange information about the following with family, friends, classmates or business associations outside of the US?

	Jobs in the US	Jobs in Taiwan	Technology
Regularly	12.0%	7.6%	15.2%
Sometimes	69.6	62.0	66.3
Never	18.5	30.4	18.5

Have you ever served as an advisor or a consultant for a company from Taiwan?

Yes	24%
No	76

Have you helped others arrange business contracts in Taiwan?

Yes	38.9%
No	61.1

Have you invested your own money in start-ups or venture funds in Taiwan?

Yes, more than once	12.2%
Yes, only once	5.0
Never	80.8

Do you have plans to start your own business on a full-time basis?

Yes, this year	3.2%
Sometime in the future	55.6
Never	12.7
Don't know	28.5

Would you consider locating your business in Taiwan?

Yes	50%
No	50