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

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Abstract. 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 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 and by facilitating collaborations between specialist producers in the two regions. This case underscores the significance of technical communities and their institutions in diffusing ideas and organizing production at the global as well as the local level.

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Silicon Valley in California and the Hsinchu-Taipei region of Taiwan are among the most frequently cited 'miracles' of industrialization in the information technology 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 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 and handheld computers, 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. The Taipei area, which served as a source of low cost labor for consumer electronics production as late as the 1970s, is known today for the unparalleled speed and flexibility of its personal computer manufacturers. These firms dominate the markets for a large and growing range of computer-related products, from motherboards and monitors to optical scanners and power supplies (Figure 1.) Meanwhile, the Hsinchu Science-based Industrial Park, established in 1980, is now a state-of-the art manufacturer of semiconductors, on par with the world market leaders in the US and Japan (Figure 2). Taiwan's total IT output is now greater than that of larger nations like Korea; in fact it is larger than the output of Germany and France combined (Anderson, 1998.)

The Silicon Valley and Hsinchu regions 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 (Callon, 1995; Lau, 1994; Gilder, 1989.) These accounts identify the 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 Defense Department and Taiwan's Industrial

Technology Research Institute (ITRI) explain the dynamism of the new industries (Mathews, 1997, Kraemer et. al., 1996, Wade, 1990, Harrison, 1994, Borrus, 1989.)

It is clear, however, that these policy interventions differ fundamentally from those undertaken by the archetypal developmental states. In Taiwan government policy supports multiple players in any technology initiative, constantly putting competitive pressure on existing producers. The notebook PC consortium sponsored by ITRI's Computer and Communications Lab in 1990, for example, brought twenty new companies into the market (Ernst, 1998.) Japanese consortia, by contrast, have tended to concentrate resources in the major firms and to reinforce market oligopoly (Callon, 1995).

This is not to suggest that the public sector in Taiwan is less involved in industrial promotion than other East Asian nations, only that differences in their developmental strategies have important consequences for market structure. While policy makers in Japan and Korea typically target large established technology companies for promotion, in Taiwan they provide universal incentives to entire sectors. ITRI has thus organized ambitious technology transfer programs while simultaneously encouraging private investments in new firm formation and industrial upgrading. This contrast suggests the need to move beyond the simple state-market debate, which diverts attention away from other equally important determinants of industrial performance, such the organization of production (see, for example, Levy and Kuo's 1991 comparison of Taiwanese and Korean personal computer industries.)

Mounting evidence suggests the need to examine the organization of technology production—at both the local and the global levels—to account for the divergent fortunes of national industries. Scholars have recently 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 computer producers, from this view, derives from their role as original equipment manufacturers (OEM's) for the leading US personal computer companies—a relationship that stimulates knowledge creation, technology transfer, and improved domestic capabilities (Ernst, 1998, Borrus, 1997, Dedrick and Kraemer, 1998.)[1]

These analyses represent an important conceptual advance. They demonstrate a significant mechanism for industrial upgrading in places like Taiwan, and one that is not reducible to arguments about the state or market. However most analyses of global production networks suggests that the growing sophistication of Taiwan's technological infrastructure is primarily attributable to its role as a supplier to foreign corporations. This focus on the sourcing strategies of multinational corporations overlooks the emergence of entrepreneurship and innovation in the periphery during the 1990s, particularly in places like Taiwan.

The connection between technology producers in the US 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 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, 1995)—has been largely overlooked in accounts of Taiwan's accelerated technological development. This paper argues that the contributions of this technical community have been the key to the successes of more commonly recognized actors: government policymakers and global corporations. Both state policies and OEM strategies rely heavily on the dense professional and social networks that keep Taiwan's policy-makers and producers close to the state-of-the-art technical knowledge and the leading edge markets in the US.

The development of a transnational technical community has also transformed the relationship between the Silicon Valley and Hsinchu economies. In the 1970s and 1980s, technology and capital resided in the US and were transferred to Taiwan, typically 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, small and medium-sized firms, 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, while Hsinchu is no longer a low-cost location, the region's producers continue to gain a growing share of global technology markets.

Technical Communities and Industrial Decentralization

A transnational community on this scale is only possible because of advances in communication and transportation technologies and changes in the structure of 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 rise of the Silicon Valley industrial 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 (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, testing, as well as different segments of the manufacturing materials and equipment sector. A new generation of firms has in turn emerged in the late 1990s that specializes 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 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, 1999). While Silicon Valley's entrepreneurs innovate in increasingly specialized niche markets, intense communications in turn 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.[2]

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. 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, 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 potentially more flexible and responsive mechanism for long distance transfers of skill and know-how—particularly between very different business cultures or environments.

The Silicon Valley-Hsinchu connection is thus facilitated by the growing compatibility of the decentralized industrial structures of the two regions. Technology activity in both is highly localized (in the 50-mile industrial corridor linking Taipei to the Hsinchu Science-Based Industrial Park in Taiwan, and its counterpart linking San Francisco to Palo Alto/San Jose in California.) Both regions boast high rates of indigenous entrepreneurship. In both, technology industry consists of thousands of specialized and fiercely competitive small and medium-sized enterprises as well as a handful of larger producers. And in both, local institutions and social networks support intense communications, informal collaboration, and collective learning across firm boundaries. It is striking that independent accounts of the performance of producers in these regions stress their flexibility, speed, and innovative capacity relative to their leading competitors in both the US and Asia (Ernst, 1998, Hsu, 1997, Callon, 1995, Saxenian, 1994.)

The remainder of this paper traces the evolution of the transnational community linking Hsinchu and Silicon Valley and the concomitant process of industrial upgrading. It documents: (i.) the origins of a technical community among Silicon Valley's Taiwanese engineers in the 1970s and 1980s; (ii.) the parallel reliance of Taiwanese policymakers on the expertise of the overseas Chinese in their efforts to improve the island's position in the international economy, (iii.) the institutionalization of the transnational community linking Silicon Valley and Hsinchu in the 1990s, and (iv.) the mutually beneficial collaborations between specialist producers in the two regional economies. A concluding section reexamines the relationship between transnational communities and regional development and briefly suggests policy lessons from this case.

The "Brain Drain" and the Formation of a Taiwanese Technical Community in Silicon Valley

The modern "brain drain" from Asia to the US dates to the Immigration Act of 1965, often referred to as the Hart-Cellar Act. Prior to 1965 the US immigration system limited foreign entry by mandating extremely small quotas according to nation of origin. Hart-Cellar, 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 1,321 (Chang, 1992.)

Taiwanese students came to the US by the thousands during the 1970s and 1980s, lured by the fellowship money available for graduate studies in engineering at US universities and pushed by the limited professional opportunities in Taiwan at the time. 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 elite engineering universities: National Taiwan University, National Chiao-Tung University, and Tsing-Hua University. 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 their "best and brightest" to the US.

The influx of highly skilled immigrants coincided with the growth of a new generation of high technology industries in Silicon Valley. As the demand for technical skill in the emerging 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. Of those, almost two-thirds were Asian including 51% of Chinese origin, primarily from Taiwan (Saxenian, 1999.)

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.[3] 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 community.

Old timers regard the Chinese Institute of Engineers (CIE) as the "grandfather" of the Chinese professional organizations in Silicon Valley. In 1979 a group of Taiwanese immigrants started a local branch of CIE (an older, New York-based organization) in order 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 became the largest in the country, reflecting the shifting center of technology production in the US.

CIE is a scientific and educational organization whose goal is the exchange 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.[4]

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 in the region. Like the CIE, they combine elements of traditional immigrant culture with distinctly 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.[5]

Immigrants 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 2,001 Silicon Valley-based technology companies, or 17% of the companies started in the region since 1980. The 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. It appears that the most successful Chinese businesses in Silicon Valley today are those that draw on ethnic resources while simultaneously integrating into mainstream technology and business networks.[6]

It is worth noting as well that immigrant engineers from Mainland China, who are 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 and 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.

The State and the Construction of a Transnational Community

Policymakers in Taiwan began to view US-educated engineers as a potential asset in the 1970s as they sought to upgrade the island's position in the international economy.
Drawing heavily on policy advice from overseas Taiwanese engineers, 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. During 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. They also actively recruited Chinese engineers working in the US to return to Taiwan.[7]

By exploiting this overseas resource, Taiwan's policymakers unwittingly supported the extension of Silicon Valley's technical community to include engineers based on both sides of the Pacific. In 1966, Taiwan's Minister of Communications, Dr. Y. S. Sun, initiated the bi-annual Modern Engineering and Technology Seminars (METS) in collaboration with the Chinese Institute of Engineers in New York. These two-week seminars were designed to provide state-of-the art engineering expertise to Taiwanese industry. The format was standardized: industry representatives in Taiwan met to develop a list of topics of interest for the upcoming seminar. CIE members in the US in turn identified appropriate Chinese engineers from industry or academia to travel to Taiwan to speak on the selected topics.

METS not only introduced up-to-date technologies to Taiwan but also helped to create personal and professional relationships between the engineers based in the two countries. Over time senior officials associated with science and technology agencies such as ITRI and the National Science Council (NSC), many of whom were also US-educated engineers, began attending the meetings as well. For example, K.T. Li, the Minister of Finance who is considered by many as the architect of Taiwan's technology strategy, was a regular METS attendee.[8]

The overseas community was not only seen as source of up-to-date technical expertise but was also increasingly tapped for policy advice. In 1974, for example, Y.S. Sun, then the Minister of Economic Affairs, invited an RCA engineer who was active in CIE New York, Dr. Pan Wen-Yuan, to advise the government on how to develop Taiwan's electronics industry. After meeting with industry leaders and top officials, including Premier Chiang Ching-kuo and senior Cabinet members, Pan recommended that Taiwan establish an organizational capacity within the state to acquire foreign semiconductor technology with the guidance of a strategic planning group composed of members in Taiwan and the US.

Pan's recommendations spurred the formation of the Industrial Technology Research Institute (ITRI) as an autonomous organization located the Ministry of Economic Affairs in 1974. The Electronics Research Service Organization (ERSO), an ITRI subsidiary, was subsequently established to promote the domestic IC industry. Both ITRI and ERSO were initially government funded, but Y.S. Sun—influenced by his US-based advisors—insisted on a growing share of private sector participation in order to avoid a civil service mentality. By 1988 ERSO received only 25% of its funds from the government, with the balance coming from private sector fees for services, and ITRI received 55% of its funds from the government and the balance from the private sector.

Dr. Pan also established the Technical Advisory Committee (TAC), a strategic planning group of Overseas Chinese engineers whose mandate was to steer and oversee the development of Taiwan's IC industry. He recruited senior Taiwanese from leading US corporations including Bell Labs and IBM as well as from US universities. During the 1970s and 1980s TAC met weekly in the US to develop recommendations and traveled to Taiwan quarterly to work with personnel from ITRI and ERSO. In these meetings they provided information on industry trends and on the experience of US researchers with different approaches to product development (e.g. those that proved to be dead ends) and they developed proposals concerning the next stages of Taiwan's IC program. The TAC experience, like METS, not only helped accelerate the pace of industrial development in Taiwan, but also further solidified the social and professional ties between Taiwanese engineers on both sides of the Pacific.

With the help of their US advisors, ITRI selected RCA as a partner for the transfer of semiconductor technology. The process was designed to emphasize training as well as technology transfer and, as a result, helped form a network of engineers who subsequently played a key role in building Taiwan's semiconductor industry. In 1978 ITRI recruited 40 young engineers (35 from Taiwan and 5 from the US) and sent them to RCA for a year of training in chip design, process technology, and testing. After the US training was completed, the group returned to the Taiwan to run ERSO's newly constructed IC pilot production facility. Several of these trainees were classmates, having graduated from National Taiwan University in the late 1960s, and many went on to play key leadership roles at ERSO, ITRI and the local semiconductor industry.[9]

When Y.S. Sun became Premier of Taiwan in 1979 he sought to institutionalize public support for high technology projects. One of his most significant innovations was the creation of the Science and Technology Advisory Group (STAG)—a small, very high level group of independent policy advisors. With K.T. Li as its head, STAG was to formulate "action plans" to promote the rapid development of science and technology in Taiwan, and to report directly to the Premier and his Cabinet. K.T. Li recruited all of the 15 members of STAG from the US: the group included prominent Chinese engineers from Bell Labs, IBM and other large corporations (including some TAC members) as well as several senior executives who were not of Chinese origin.[10]

The members of STAG became known in Taiwan as "foreign monks"—outsiders who gain special respect in Chinese society in their status as foreigners and as experts. STAG returned Taiwan annually for a National Development Conference and worked closely with their local counterparts in industry and government to learn about emerging problems and to create a policy consensus. STAG was particularly influential in directing resources toward improving engineering education and training, and toward continued upgrading the domestic technological infrastructure. For example, their support allowed the National Science Council (NSC) to make major financial commitments to collaborative research with local universities in spite of criticism within the government.

STAG also prevailed in defining a very ambitious and competitive approach to Taiwan's technological development—one that was strongly resisted by more technologically conservative forces within the state. They argued, successfully, that if Taiwan did not develop state-of-the-art technology, its small and medium-sized firms would be vulnerable to capture by the vertically integrated producers from Korea and Japan. This aggressive stance helped push Taiwan to develop leading edge manufacturing capabilities at an unprecedented pace. ITRI's promotion of the micro-computer industry in the 1980s, for example, paralleled that undertaken a decade earlier in the IC industry, including heavy reliance on outside technology and expertise.

The "foreign monks" also helped shape an industrial strategy that differed fundamentally from that of Taiwan's East Asian counterparts: one that limited direct state intervention in favor of reliance on the private sector and market opportunities.[11] So, for example, while ERSO financed and incubated leading edge semiconductor companies such as United Microelectronics Corporation (UMC) and Winbond, they ultimately spun them off to the private sector. The Hsinchu Science-Based Industrial Park (HSIP) was established in 1979 in part to accelerate the movement of technology out government laboratories and into the private sector. UMC was the first ERSO spin-off to locate in the Science Park in 1980, but more than half a dozen others followed during the decade.

Reliance on the expertise of overseas Chinese continued throughout the 1980s. The government agencies involved with science and technology policy, including ITRI, HSIP, the Science Division of the NSC, and III all established offices in Silicon Valley in the early 1980s. These offices served as listening posts for domestic producers and aggressively recruited overseas engineers to return to Taiwan. They built databases of US-based engineers and computer scientists and shared them with Taiwanese talent scouts. They also provided information and contacts to individuals considering setting up technology businesses in Taiwan. The National Youth Commission sponsored visits by overseas scholars and professionals and even financed the airfare for professionals returning to Taiwan permanently. When the Taiwanese government initiated major engineering projects—from a transit system to a power station—they consulted CIE.

In 1985 K.T. Li further expanded the links to the US technology industry by recruiting Morris Chang (Chang Tsung-Mo), a senior executive from Texas Instruments to head ITRI. Chang in turn spearheaded the formation of the Taiwan Semiconductor Manufacturing Corporation (TSMC)—a joint venture of the Taiwanese government (49%), Phillips (27%), and local private investors (24%)—with the goal of creating a world-class semiconductor manufacturing facility that could compete with Japan and Korea. While ITRI provided lab facilities and skilled personnel for TSMC, Chang's status as a foreign expert was critical in mobilizing financial support from reluctant local investors. In addition, Chang's vision of TSMC as a foundry that only manufactures wafers for clients but does no design or marketing, reflected state-of-the-art thinking about the advantages of vertical disintegration in the semiconductor industry. By remaining highly focused, TSMC quickly achieved parity with world industry production standards and gained a growing share of global semiconductor markets. It also stimulated the formation of over 55 independent chip design companies in the Hsinchu Science Park by freeing these specialists of the need to make the heavy capital investment necessary for in-house manufacturing.[12]

K. T. Li also created the venture capital industry in Taiwan—thus deepening institutional support for entrepreneurship while also deepening the ties to Silicon Valley. Li, who visited Silicon Valley regularly in the 1980s to meet with Chinese engineers, was especially impressed by the US venture capital industry. In 1983 he spearheaded legislation to create and regulate a venture capital industry in Taiwan. Under his guidance, the Ministry of Finance created significant tax incentives for venture investment: for example, 20% of the capital invested in new technology ventures was tax-deductible for up to five years. This was a major achievement as the concept of venture capital was foreign to traditional Taiwanese business practice, in which family members closely controlled money management.

Equally important, Li invited senior Chinese-American financiers to establish venture capital companies in Taiwan. The first, Ta-lin Hsu, a former IBM executive who had been a key senior policy advisor and STAG member, set up Hambrecht & Quist Asia Pacific in Taipei 1986. The initial fund was not easy to raise. KT Li himself had to "twist lots of arms" to raise the $21 m. (51%) from leading Taiwanese industrial groups such as Far East Textile, President Enterprises, and Mitac. Another $20 m. (49%) came from three branches of the government (the Bank of Communications, the Executive Development Fund, and the Sino-American Foundation.)[13] H&Q Asia Pacific's early investments included Acer, UMC, Microtek and Tai Yan. The early successes of these investments in turn made successive rounds of fund-raising easier. In 1987 Peter Liu and Tan Lip-Bu—both US-educated Chinese engineers—responded to Li's invitation as well, and established Taiwan's second US-style venture fund, the Walden International Investment Group (WIIG). WIIG is a branch of the San Francisco-based Walden Group and has invested in Taiwanese startups in both Silicon Valley and Taiwan.

Both H&Q Asia Pacific and WIIG remain important actors in the Taiwanese venture capital industry, which has grown dramatically in the past decade. Acer started Taiwan's first local venture capital firm in 1984. In 1990 there were 20 firms; and by 1998 Taiwan was the home of 110 venture capital firms. The total capital invested by these firms has increased dramatically as well, reaching 43.5 billion NT dollars, or US $1.3 billion, in over 1,800 companies by 1997 (Figures 3 and 4.) Industry watchers claim that Taiwan now has the world's largest and most dynamic venture capital industry, after Silicon Valley.

Reliance on US-based engineers for technical and managerial expertise as well as for policy advice fundamentally shaped the direction and pace of Taiwan's technology development. It also created close personal and professional relationships between a growing circle of Taiwanese engineers, entrepreneurs, executives, and bureaucrats on both sides of the Pacific. The recipients of the Chinese Institute of Engineers—USA Annual Awards for Distinguished Service and for Achievement in Science and Engineering over the past three decades reads like who's who of Taiwanese technologists based in the US and Taiwan.[14] In short, the unintended consequence of Taiwan's outward-looking technology policies was the creation of a transnational technical community—one that now has its own self-sustaining dynamic.

Institutionalizing the Silicon Valley-Hsinchu Connection

The accelerated growth of the Taiwanese economy in the 1980s combined with active government recruitment ultimately spurred a reversal of the "brain drain." Lured 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 during the 1980s and 1990s. Approximately 200 engineers and scientists returned to Taiwan annually in the early 1980s. A decade later, more than 1,000 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.

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 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 all of the leading Taiwanese technology companies, and 300 individual members, almost exclusively of Taiwanese origin.

One of Monte Jade's primary objectives is to "opens 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."[15]

Monte Jade sponsors a large annual meeting that typically draws an audience of more than 1,000 for a day of sophisticated analysis, as well as smaller monthly dinner meetings with speakers from the US and Asia. Social events, both planned and unscheduled, are often as important as the professional activities, and typically include families as well as members. One indication of the association's success is that its monthly newsletter, which is in Chinese and reports on recent activities and individual accomplishments, can be easily found in both Silicon Valley and Hsinchu.

Monte Jade actively promotes entrepreneurship as well. The Annual Monte Jade Investment Conference is a matchmaking and networking event that draws hundreds of aspiring entrepreneurs, venture capitalists, and other service provides from the US, Taiwan and the rest of Asia. In addition, 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 Mt 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 other socially and we tend to refer problems and situations back and forth. This definitely helps our businesses."[16]

The growth of the Hsinchu Science-Based Industrial Park reflects the rapidly expanding ties between the two regions. In the early 1980s, the Park was home to less than 50 companies and attracted only a handful of returnees from the US each year. By the late 1980s and especially during the 1990s, the number of companies and returnees increased dramatically, and in tandem. The Science Park helped attract returnees who in turn started new companies at an accelerating rate. The park was attractive to engineers coming from the US for several reasons: First, it is located close to the headquarters of ITRI and ERSO as well as two of Taiwan's leading engineering universities. In addition, the Park Administration offered a wide range of fiscal incentives for qualified technology investments[17] and provided returnees with preferential access to scarce, high quality housing and to the only Chinese-American school in Taiwan—both of which were located on the park grounds.

In 1990, the Park had attracted 422 returnees cumulatively. By 1997 the total had increased five-fold to over 2,850—with an average of 350 returning per year (Figure 5.) Moreover, these returnees were disproportionately likely to start their own businesses. Almost half of the companies in the Science Park (97 companies) in 1997 were started by US-educated engineers, many of whom had considerable managerial or entrepreneurial experience in Silicon Valley (Figures 6 and 7.) 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 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 dramatically 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 6th largest semiconductor maker in Taiwan, with over $300 m. in sales and some 2,800 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 to Taiwan 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 in 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.[18]

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 President and 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.[19]

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 and orientation toward entrepreneurial achievement.

While traditions of entrepreneurship, collaboration, relationship-based business, and resource-sharing among small and medium-sized producers in Taiwanese industry have provided fertile ground for many aspects of Silicon Valley management models (Hamilton, 1998), 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, and virtually all of the leading Taiwanese companies have research labs or design operations in the region.

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 US to Taiwan has become a two-way thoroughfare allowing producers both regions collaborate to enhance distinctive but complementary strengths. 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."[20] This appears to be a classic case of the benefits of comparative advantage. However, in this case the economic gains from specialization and trade depend on the social structures and institutions that insure flows of information and facilitate joint problem solving between distant producers.

Chinese entrepreneurs in Silicon Valley are increasingly the recipients of funding from Taiwan. In the 1970s and 1980s overseas Chinese typically acquired start-up capital informally through friends, family, and classmates. By the 1990s, as Taiwan's economy boomed, the capital generated in traditional industrial sectors such as plastics and textiles was increasingly channeled into local venture capital funds—much of which in turn was invested in Silicon Valley. Most Chinese entrepreneurs in Silicon Valley today report having been approached informally by Taiwanese angel investors; and a growing number of Taiwanese venture capital firms like InveStar and China Development Corporation (the venture arm of the KMT) have established offices in Silicon Valley. It is difficult to accurately assess the total, but informed observers place the amount of Taiwanese capital available for investment in Silicon Valley technology businesses through formal channels at over $500 million; with an equal amount flowing in through informal, angel investments.[21]

The integration of the technical communities in the two regions has created new models of global production as well. In some cases, there is a division of labor between the specialized divisions of a single firm. This includes start-ups like Macronix, (which is based in Hsinchu with a design center in Silicon Valley) and ISSI (which is based in Silicon Valley with a manufacturing division in Hsinchu) as well as large established companies like Acer. In these cases, the division managers are typically well connected in the local labor market and technical community while 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 as well because he travels to headquarters so frequently.

The transnational technical community thus allows companies like Winbond to avoid many of the problems that many multinational 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. More hierarchical, centralized 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 partnerships between independent 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 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, 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.[22]

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 TSMC offices. In fact the TSMC facility in Hsinchu is flexibly divided into workspaces 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 one step further and institutionalized collaboration with their customers. Robert Tsao, President and CEO of UMC refers to the joint ventures as "cross-Pacific consortia" that pair Silicon Valley's "fabless" chip designers with UMC's fabrication capabilities. The most ambitious consortium, 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, while insuring UMC the capital needed to build the fab as well as full capacity utilization.

A new breed of venture capitalists mediates these cross-regional collaborations. Like their Silicon Valley-based predecessors, these transnational financiers often have technical training and work experience. However unlike older generations of venture capitalists, whose networks and investments tend to be 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 forerunner of Acer, along with several classmates from Taiwan's Chaio-tung University. After working for 17 years at Acer he worded with two Taiwanese start-ups before starting his own venture capital firm, InveStar. In 1996, its first year of operations, InveStar invested $50 m. 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.[23]

The case of Platform Technology, a Silicon Valley start-up founded by a US-educated Chinese entrepreneur, Paul Tien, illustrates the benefits of the cross-Pacific relationships.[24] InveStar provided Platform with $3 m. 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 personal computer 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 couldn't get the attention of the giant chip manufacturer. Once again, the InveStar partners intervened by called their friends at TSMC. They made sure that Platform's calls were returned and that its problems were addressed immediately.

One year later, Platform was so successful that it posed a major threat to ESS, another Chinese company in Silicon Valley that had historically dominated the PC audio chip market. In early 1997, ESS founder Fred Chen called the InveStar partner who had previously worked with ESS and asked what he could do to help. As a result of these conversations, Investar arranged the sale of Platform to ESS. They coordinated a small, simple acquisition—one that was done completely informally. There were no lawyers involved; in fact there was nothing written. This was the sort of trust-based deal that could only be made by partners who have a high degree of confidence in one another.

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 US 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.

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 flows of knowledge or skill. A transnational technical community allows distant producers to specialize and collaborate to upgrade their capabilities, particularly when the collaborations require close and 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 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 <u>within</u> these region 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 mutually beneficial process of industrial upgrading.

Transnational communities are not unique to Taiwan. Transnational entrepreneurs have been important actors in the development of dynamic technology industries from Israel to Ireland. 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, professional and technical associations, and entrepreneurial state agencies have played a central mediating role in the process (O'Riain, 1999, Autler, 1999.)

Of course transnational communities work within the institutional and economic contexts of their home countries. The actions of government agencies and the structure of existing industries can hinder as well as facilitate their entrepreneurial efforts. While there are thousands of highly skilled Indian engineers and entrepreneurs in Silicon Valley, for example, few have chosen to return to India to start businesses. Most cite the inadequate state of the physical infrastructure and the cumbersome bureaucratic regulations as significant limitations on opportunities for domestic technology growth. As a result, while Indian managers in multinational companies have often championed the establishment of programming in India, the growth of software activity in regions like Bangalore remains primarily driven by the search for low cost-skill (Saxenian, 1999.)

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 close and 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 technical education and training, creating institutions to support new firm formation, and building ties to the Silicon Valley community as to luring foreign investment.

References

Anderson, Christopher "In Praise of Paranoia: Survey of Taiwan" *Economist,* November 7, 1998

Aoki, Masahiko "Information and Governance in the Silicon Valley Model" Stanford Institute for Economic Policy Research, Discussion Paper, forthcoming 1999

Borrus, Michael "Left for Dead: Asian Production Networks and the Revival of US Electronics" in Naughton, ed. *The China Circle* Washington, DC: Brookings, 1997

Borrus, Michael *Competing for Control: America's Stake in Microelectronics* NY: Ballinger, 1988

Bresnahan, Timothy "New Modes of Competition: Implications for the Future Structure of the Computer Industry" Conference paper, March 1998

Callon, Scott "Different Paths: The Rise of Taiwan and Singapore in the Global Personal Computer Industry" Asia/Pacific Research Center, Stanford University, January 1995

Callon, Scott *Divided Sun: MITI and the Breakdown of Japanese High Tech Industrial Policy, 1975-1993* Stanford, CA: Stanford University Press, 1995

Chang, Pao-Long, Chiung-Wen Hsu, Chien-Tzu Tsai "A stage approach for industrial technology development and implementation—the case of Taiwan's computer industry" *Technovation* 19, 1999: 233-241

Chang, Pao-Long, Chintay Shih, Chiung-Wen Hsu "The formation process of Taiwan's IC industry—method of technology transfer" *Technovation* 14 (3) 1994: 161-171

Chang, Shirley L. "Causes of Brain Drain and Solutions: The Taiwan Experience" *Studies in Comparative International Development*. Spring 1992, 27 (1): 27-43

Chung-Yuan Liu "Government's role in developing a high-tech industry: the case of Taiwan's semiconductor industry" *Technovation* 13 (5) 1993: 299-309

Dedrick, Jason and Kenneth Kraemer *Asia's Computer Challenge: Threat or Opportunity for the United States and the World?* NY: Oxford, 1998

Ernst, Dieter. "What Permits David to Defeat Goliath? The Taiwanese Model in the Computer Industry" Berkeley: Unpublished Paper, BRIE, University of California at Berkeley, 1998

Granovetter, Mark "The Economic Sociology of Firms and Entrepreneurs" in A. Portes, ed. *The Economic Sociology of Immigration* NY: Russell Sage, 1995

Hamilton, Gary "Organization and Market Processes in Taiwan's Capitalist Economy" in Marco Orru et al, eds. *The Economic Organization of East Asian Capitalism* Thousand Oaks, CA: Sage, 1997

Hellman, Thomas "WI Harper International: Bridge between Silicon Valley and Asia" Graduate School of Business, Stanford University, SM-39, 1998

Hobday, Mike "East Asian Latecomer Firms: Learning the Technology of Electronics" *World Development.* v. 23, n. 7, 1995

Hsu, Jinn-yuh. "A Late Industrial District? Learning Networks in the Hsinchu Science-Based Industrial Park" Berkeley: Doctoral Dissertation, Geography, University of California at Berkeley, 1997

Kogut, Bruce and Udo Zander "Knowledge of the Firm and the Evolutionary Theory of the Multinational Corporation *Journal of International Business Studies* 24, 4, 1993

Kraemer, Kenneth, Jason Dedrick, Chin-Yeong Hwang, Tze-Chen Tu, and Chee-sing Yap "Entrepreneurship, Flexibility, and Policy Coordination: Taiwan's Computer Industry" *The Information Society* 12: 215-249, 1996

Lau, Lawrence J. "The Competitive Advantage of Taiwan" *Journal of Far Eastern Business*, Autumn 1994

Levy, Brian and Wen-Jeng Kuo "The Strategic Orientation of Firms and the Performance of Korea and Taiwan in Frontier Industries: Lessons from Comparative Case Studies of the Keyboard and Personal Computer Assembly" *World Development*. v. 19, n. 4, 1991

Mathews, John A. "A Silicon Valley of the East: Creating Taiwan's Semiconductor Industry" *California Management Review.* v. 39, n. 4, Summer 1997

Meany, Connie Squires "Creating a Competitive Niche: State Policy and Taiwan's Semiconductor Industry" Center for Chinese Studies, UC Berkeley, April 27 1991

Naughton, Barry, ed. *The China Circle: Economics and Technology in the PRC, Taiwan and Hong Kong*. Washington, D.C.: Brookings Institution Press, 1997

O'Riain, Sean "Rethinking the Developmental State: The Irish Software Industry in the Global Economy" Unpublished dissertation, Department of Sociology, UC Berkeley, Spring 1999

Portes, Alejandro. "Global Villagers: The Rise of Transnational Communities" *The American Prospect.* pp. 74-77, March-April 1996

Romer, Paul. "Two Strategies for Economic Development: Using Ideas and Producing Ideas" *Proceedings of the World Bank Annual Conference on Development Economics 1992*. Washington, DC: The International Bank for Reconstruction and Development, 1993

Saxenian, AnnaLee *Silicon Valley's New Immigrant Entrepreneurs* San Francisco, CA: Public Policy Institute of California, 1999 http://www.ppic.org/publications/PPIC120/index.html

Saxenian, AnnaLee. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Cambridge: Harvard University Press, 1994

Seeley Brown, John and Paul Duguid. "Organizing Knowledge" California Management Review. Vol 40, No 3: 90-111, Spring 1998

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

[1] 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.

[2] 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.

[3] 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.

[4] Interview, Gerry Liu, 1/22/97

[5] For information on these and other ethnic professional organizations in Silicon Valley, including several associations started by immigrants from Mainland China and India, see Saxenian, 1999.

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

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

[8] Li Kuo-Ting and Sun Yuan-Sun are typically regarded as the architects of Taiwan's technology strategy. Both were foreign-educated engineers who held senior government positions during the 1960s and 1970s. Li is generally regarded as the architect of the overall technology strategy. Sun, who followed Li as Minister of Economic Affairs before becoming Premier, spearheaded the semiconductor industry strategy.

[9] For example, Yang Ting-yuan went on to become President of Winbond Electronics and Robert Tsao became President of UMC, while Shih Chin-tay and CC Chang went on to hold senior positions at ERSO and ITRI.

[10] This included former Texas Instruments executives Paul Haggerty and Fred Seitz as well as Bob Evans and Dr. Mackay, formerly of IBM and Bell Labs respectively.

[11] Mathews (1997) describes it as "non-dependent development" that relies on "leverage and learning" rather than on either multinationals or established domestic firms.

[12] Reliance on foreign expertise continues today. In 1996 Genda Hu returned to Taiwan from the US to become General Director of ERSO, bringing two decades of experience and networks of contacts in Silicon Valley research institutions and technology firms.

[13] Ta-lin Hsu interview, June 1, 1997.

[14] All of the individuals cited in this account, for example, have been award recipients, along with many more. See http://www.cie-gnyc.org/Rwinner.htm

[15] Leonard Liu interview, April 3, 1998

[16] Lester Lee interview, July 1, 1997

[17] 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.

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

[19] Ron Chwang interview, March 25, 1997
[20] Fred Cheng interview, March 25, 1997
[21] Ken Hao interview, April 15, 1997.
[22] Steve Tso interview, March 15, 1999
[23] Ken Tai interview, May 16, 1997
[24] Herbert Chang interview, July 22, 1997