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"Brain Circulation and Capitalist Dynamics: The Silicon Valley-Hsinchu-Shanghai Triangle"

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Brain Circulation and Capitalist Dynamics: The Silicon Valley-Hsinchu-Shanghai Triangle

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Howard Yang was among the first "returnees" to China in 1994. Yang was from Beijing but had spent more than a dozen years in the U.S., first obtaining a doctorate in electrical engineering from Oregon State University and then working for Silicon Valley companies like National Semiconductor, Chips & Technologies, and start-up Pericom Semiconductor. He returned in part to contribute to the growth of the Chinese IC industry.

After working worked for two years at Shanghai Beiling, China's leading state-owned semiconductor company, Yang joined two colleagues to start a firm to design ICs for telecommunications. One of the co-founders, Hau Ming, was from Taiwan and the other, Ying Shum, from Hong Kong. Both also had graduate degrees from the U.S. and many years of work experience in Silicon Valley. This common background informed their decision to create a private Silicon Valley style company with venture capital funding and stock options for workers--rather than the following the Chinese model of state ownership or a joint venture.

Yang and his co-founders tapped their professional networks in the U.S. and Taiwan as well as China to start the company. NeWave Semiconductor Corp. began operations in 1997 with venture financing of $5.4 m. from Silicon Valley and Taiwanese investors, Hua Hong Microelectronics (a state-owned enterprise in Shanghai), and several individual investors. The firm's headquarters is in Silicon Valley but most of the company's employment, including R&D and design as well as marketing, sales and administration, are in Shanghai. Taiwan's leading chipmaker, Taiwan Semiconductor Manufacturing Co. serves as its foundry. In short, NeWave was a global company from the start--leveraging the distinctive resources of three different, and distant, regional economies.

The economic impact of increased international trade and capital flows dominates most contemporary discussions of globalization. However the growing mobility of labor--particularly highly skilled workers--promises to be at least as significant a force in transforming the organization of the world economy in coming decades. As the costs of international travel and communications continue to fall, what in the past was a one-way “brain drain,” the loss of the best and brightest youth from developing to developed economies, is giving way to a more complex, two-way process of “brain circulation” that is transforming the developmental opportunities for formerly peripheral economies by accelerating long distance transfers of knowledge and information and facilitating access to leading-edge customers and partners.

While some US-educated engineers like Howard Yang return to their home countries to start new technology businesses, others start companies in the US and take advantage of their linguistic and cultural knowledge to gain access to low cost technical skill or to build partnerships in their home countries, and still others establish themselves as professional "bridge-builders" whose networks allow them to link specialized enterprises and entrepreneurs in distant regions. These returnees, entrepreneurs, and "astronauts" (so called by the Chinese because they appear to live in airplanes) are part of a transnational technical community that is transferring know-how and skill between distant regional economies faster and more flexibly than most corporations.

The paper explores the role of transnational communities in transforming the global organization of semiconductor production over the past two decades. Semiconductor manufacturing is a technically complex and demanding process that requires sophisticated technological and managerial know-how as well exacting environmental conditions. This makes it particularly difficult to transfer manufacturing to a new location, particularly in less developed economies. Nevertheless production has shifted from advanced to developing economies in a very short period. In less than 25 years the balance of semiconductor manufacturing and design shifted from the US and Japan to formerly peripheral regions in the Asia Pacific region, and to Taiwan and the urbanized east coast of China, in particular

In 1985 a handful of large integrated producers from the US and Japan accounted for 87% of world semiconductor output. When Taiwan Semiconductor Manufacturing

Co. (TSMC) pioneered the stand-alone foundry in 1985 it triggered a process of vertical fragmentation and innovation in the industry. By 1995 Taiwan's leading manufacturers had reached the world technological frontier and dominated the global foundry market. And in the first years of the 21st century the leading semiconductor producers in China gained technological capability faster than their predecessors. Industry analysts predict that by 2010 firms from the Asia-Pacific region will account for 35% of world semiconductor production (double their share in 2000), with China alone accounting for 7%. The US and Japanese share is forecast to fall to 50% of the global market.

This paper suggests that transnational technical communities-- foreign-born, US-educated engineers and scientists who establish long distance professional and economic networks linking regions in their home countries to Silicon Valley--have become important actors in the global economy.[1] Theories of capitalist development focus almost entirely on the role of the firm and the state in economic change. However the main actors driving the changing location of semiconductor production are transnational entrepreneurs and their communities--not multinational corporations or nation-states, although both play a role to be sure. These skilled immigrants boast the technical capabilities and know how as well as the professional networks to affect far-reaching transformations of their home countries, even if a majority never return permanently.

Transnational communities have the potential to change the dynamics as well as the spatial organization of capitalist development. As transnational entrepreneurs seed new centers of entrepreneurship and innovation in distant regions they undermine traditional relationship between core and periphery. The one-way flows of capital from

[1] Alejandro Portes (1996) describes the growing importance of transnational entrepreneurs and communities, but his focus is exclusively on low-skill immigrants.

the US to developing countries in Asia to take advantage of low cost skill during the 1970s and 1980s, for example, were replaced in the 1990s by complex two-way flows of capital, skill and technology between these differently specialized regions. A similar process is now underway linking both Silicon Valley and the urban centers of Eastern China. And transnational communities have played a central role in the emergence and upgrading of software capabilities in India, Ireland, and Israel.[2]

The contributions of a transnational community--seeding domestic technology entrepreneurship and innovation--should not be confused with the broader impacts of a Diaspora on the home country. The aggregate remittances, investments, or demonstration effects of a Diaspora can affect an economy in a variety of different, but largely limited, ways. The transnational networks described here, by contrast, are created by a very small subset of highly educated technical professionals whose impacts on development can be disproportionately significant. The community of engineers and entrepreneurs described in this paper, for example, is 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 Silicon Valley technical community.[3]

The next section of the paper argues that the modularization of production in the information technology (IT) industry has created new opportunities for highly skilled immigrant engineers who are ideally positioned to seed new centers of entrepreneurship in formerly peripheral regions of the world. The subsequent section summarizes briefly how Overseas Chinese engineers in Silicon Valley created the cross-Pacific

[2] See Autler (2000) on Israel, and SIEPR [a[ers etc.

[3] Taiwanese and Mainland-born engineers speak different native languages and grew up in very different political and economic systems. They have developed collective identities based on common educational and work experiences: many have attended the same elite universities in their home countries and have

collaborations that fuelled Taiwan's emergence in the 1990s as a global center of technology production. The balance of the paper suggests that regions of China are now poised to repeat Taiwan's experience a decade later, albeit under significantly different conditions. Taiwanese IT investments in the Mainland are exploding (in spite of political tensions across the straits) at the same time that returning entrepreneurs like Howard Yang are using their experience and connections in the U.S. to accelerate the upgrading of China's semiconductor industry. The Shanghai region has already become an important global center of semiconductor production and design. This is not to suggest that China will technologically surpass industry leaders like the US and Japan soon. However the circulation of world-class engineering and entrepreneurial talent between regions in the US, Taiwan and China is altering the trajectories of all three economies.

Technical Communities and Industrial Fragmentation

The emergence of new centers of technology, like Taiwan, in locations outside of the advanced economies has been possible because of transformations in the structure of the information technology 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 personal computer and initiated a radical shift to a more fragmented industrial structure organized around networks of increasingly specialized producers (Bresnahan, 1998).

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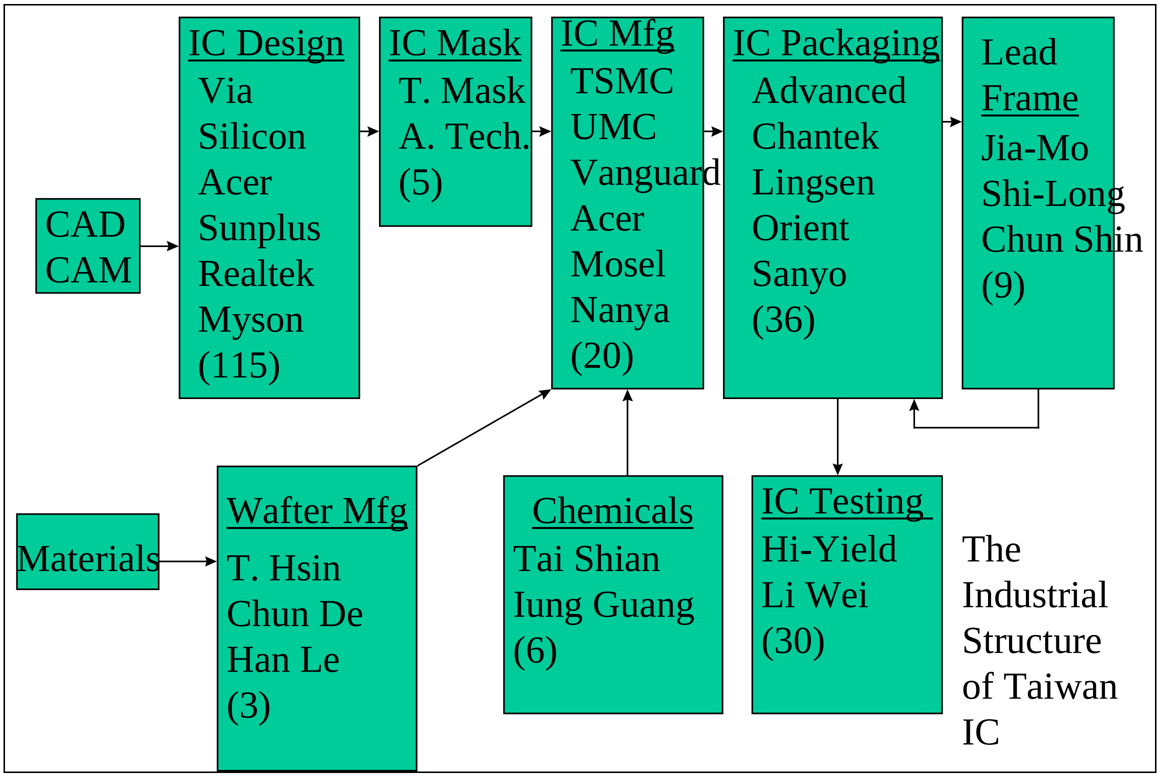
worked for the same, or related, companies in Silicon Valley. Many also participate in activities of the numerous Chinese professional and technical organizations in Silicon Valley.

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 today, independent producers specialize in chip design, fabrication, packaging, testing, marketing and distribution as well as in the multiple segments of the semiconductor equipment manufacturing and materials sectors. 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. For example, there are over 200 independent specialist companies in Taiwan's integrated circuit (IC) industry. (Figure 1.)

Figure 1: The Structure of Taiwan's IC Industry (# of establishments)



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. 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.[4]

[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

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 (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

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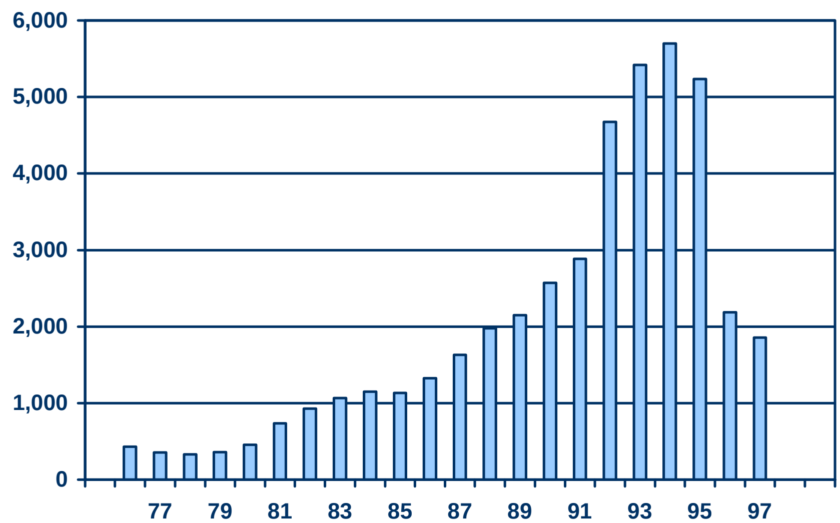
labor enhances the innovative capacity of a community: expanding opportunities for experimentation generate ideas, these ideas are in turn combined to make new ideas, and so forth in a dynamic and self-generating process. This suggests that specialization increases innovation and ultimately economic growth.

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

Thousands of US-educated Chinese engineers returned from Silicon Valley to Taiwan annually in the early 1990s. Some went to start technology companies, others to set up branches of US-based companies, and still others to work for local companies or to provide professional services to Taiwan's growing technology community. Most were lured by the promise of greater economic opportunities, particularly after the lifting of martial law; and the U.S. recession of the early 1990s undoubtedly served as a significant push factor. This "reversal" of the brain drain provided the skill, know-how and business connections that facilitated the accelerated development of Taiwan's semiconductor and personal computer (PC) manufacturing capabilities in the 1980s and 1990s. (Figure 2)

Figure 2. Returnees from the US to Taiwan, 1976-1996



Source: National Youth Council, Taiwan Ministry of Education, 1999

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 development. However the contributions of this 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 US. The close connections to Silicon Valley, in particular, help to explain how Taiwan's producers innovated technologically in the 1980s and 1990s independent of their OEM customers.

The development of an international technical community transformed the relationship between the Silicon Valley and Taiwan economies as well. In the 1960s and 1970s 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 gave 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, Taiwan is no longer a low-cost location, yet local producers continued to gain growing shares in global technology markets. (Saxenian, 2001, Saxenian and Hsu, 2001)

Taiwan is now home to the world's most sophisticated PC manufacturers and their networks of small and medium-sized suppliers of components ranging from scanners and keyboards to motherboards and video cards--along with a world class semiconductor design and manufacturing infrastructure. As one observer notes:

> Taiwan claims an advantage as a one-stop shop for every link in the technology production chain, headed by executives with leading edge US tech firms on their CVs and client lists. Chip designer VIA Technologies can have its blueprints etched into silicon by Taiwan Semiconductor Manufacturing and then have the naked wafers packaged by Advanced Semiconductor Engineering (ASE), placed on a motherboard by Asustek Computer, then sold to PC maker Acer--all without ever leaving Taiwan. (South China Morning Post, 5/23/01)

Taiwan's advantage over the US and Japan lies in its achievements in technology logistics and management as well as process technologies: "No one beats TSMC with logistics of managing 8 fabs with 10 billion dollars of investment and 140,000 SKUs moving through on a given day to 500 customers globally all ordering different kinds of chips; and no one beats ASE in bringing package and test costs down." (John Paul Ho, speech, 2001)

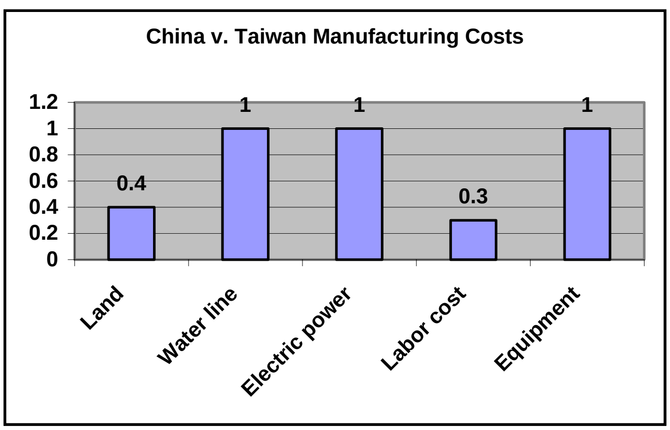
Taiwan's total IT revenues exceeded $20 billion in 2000, with the semiconductor industry reaching $16 billion, from less than half a million a decade earlier. And instead of competing directly with Silicon Valley, Taiwan's IT sector has defined and excelled in a distinctive niche. As a result, the Silicon Valley and Taiwan economies remain closely linked, with Taiwan's PC and chip manufacturing expertise complementing Silicon Valley's leading edge product development, design and marketing capabilities.

Cross-Straits Technology Transfers

The transfer of technology and skill from Silicon Valley to Taiwan that occurred in the 1980s and 1990s is now being replicated across the Taiwan straits as well as between Silicon Valley and the Mainland. In the early 1990s Taiwan's PC firms, driven by intensifying competition began locating their most labor-intensive activities like the assembly of power supplies, keyboards and scanners in China to exploit the lower cost labor and land. Following an earlier generation of Taiwanese footwear, toys and light consumer goods manufacturers, they relocated to the south of China, particularly Fujian and Guangdong provinces (Figure 3.)

By 1999 over one-third of Taiwanese PC manufacturing was located in China, and a majority of these investments were clustered in the city of Dongguan, located between Shenzhen and Guangzhou in the Pearl River Delta, and one of the five Special Economic Zones in China. While manufacturers moved to exploit lower costs in China, the superiority of Taiwanese managerial and technological capabilities means that they continue to maintain control over the production process.

Figure 3. Manufacturing Costs in Mainland China v. Taiwan



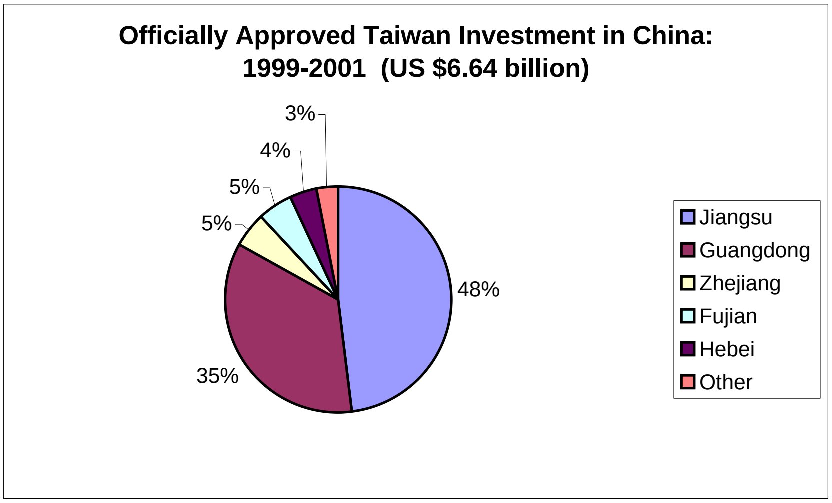
Source: Nikkei Business Times, 2001

This geography shifted significantly after 2000. Faced with intensifying cost competition, the leading Taiwanese PC firms such as Compal, Mitac, Twinhead and Acer began to move even their highest value-added activities such as motherboards, video cards, scanners and even laptop PC manufacturing to China. However rather than continuing to invest in South China, they are locating further north in Shanghai and

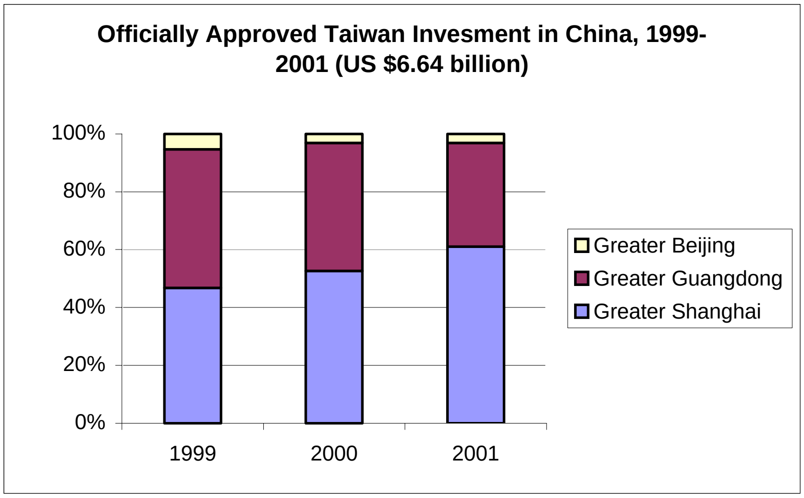
Zhejiang province and the nearby cities of Suzhou and Kunshan in Jiangsu province. For example, Quanta, the world's largest laptop manufacturer plans to build a "manufacturing city" in Shanghai that has the capacity to produce 5 million laptops a year. (Figure 4)

Most of these investments are not officially permitted under Taiwanese regulations, which until very recently prohibited investments of over US $50 million per project and in strategic sectors like advanced chip manufacturing.[5] However the channels for doing so through foreign subsidiaries are well established. This means that the official figures substantially understate total cross-straits investments A 2001 poll by the Taipei Computer Association found that 90% of Taiwan-based high tech companies have invested or plan to invest in the Mainland. And China has replaced Taiwan as the 3rd largest IT manufacturing center in the world, following only by the US and Japan.

Figure 4. Officially Approved Taiwanese Investments in China, by Region



[5] This ban was ended in late 2001 and replaced by case-by-case evaluation in a policy called "active opening, effective management."



Note: Great Shanghai includes Zhejiang and Jiangsu provinces. Greater Guangdong includes Guandong and Fujian Provinces, Greater Beijing includes Hebei province.
Source: http://www.chinabiz.org.tw/maz/Eco-Month (1999, 2000, 2001)

In another break from the past, teams of managers have moved from Taiwan to oversee these sophisticated operations and they have encouraged their networks of suppliers to move as well. A manager from component-maker Logitech reports that the firm has encouraged its entire production chain, from ICs to cable wire and plastic mouse cases, to move to Suzhou with it because of the cost advantages of having an integrated local supply base from which to serve international customers. (A typical Taiwanese PC manufacturer relies on approximately 100 different component and part suppliers.) By 2001 there were an estimated 8,000 Taiwanese companies located in the Shanghai area and between 250,000 and 400,000 Taiwanese, including the families of plant managers and engineers, living in the region. However these are far from self-contained operations: the expatriate managers and engineers typically travel back across the straits quarterly, suggesting that these firms continue to rely on their Taiwanese headquarters for strategic decision-making and direction.

Shanghai's Zhangjiang Science Park

The Chinese government designated Shanghai as the capital of the country's semiconductor industry in 2001, which should deepen as well as diversify the technology base in the region. As in Taiwan a decade earlier, this creates opportunities for mutually beneficial collaborations between local PC and systems producers and IC designers and manufacturers. The Zhangjiang High Tech Park in the Shanghai's Pudong New Area is emerging as the locus of new investments in the semiconductor industry. The Park was established in 1992 by the Ministry of Science and Technology as a national center for development of new and high technology. By 2001, with 4.4 sq km developed area (approximately three times the size of Taiwan's Hsinchu Science Park) the Park was home to 267 establishments, mostly IT-related, and reported output of close to US $1 b.

Both the Shanghai government and the Park Administration have aggressively pursued investment by offering subsidized loans, generous tax exemptions and a 50% discount on land rent in the Park. Zhangjiang's developers have also carefully planned the area's development. The Master Plan includes not only areas for high-tech research, incubation and manufacturing, but also residential, commercial and education facilities, green space (40%) and mass transit links. Zhangjiang Park has emerged as a center of foreign investment, which reached US $3.4 billion in 2000, or triple the average in previous years. This contrasts with joint ventures, which invested US $659,000, and domestic ventures, which invested only US $451,000. Motorola, Lam Research and Sun Microsystems are among the US firms with operations in the Park. However the majority (80%) of the foreign investments come from Hong Kong and Taiwan.

Figure 5. China's Tax Cuts for Semiconductor Industry

	Pre-July 2000	Post-July 2000

Value-added tax	17%	6% (3% for chip design)
Regular tax		
• First two years of profitability	33%	0
• Next three years of profitability	33%	15%
Depreciation		
• Mechanical equipment	10 years	3 years
• Electronic equipment	5 years	3 years
Materials		
• General	24-30%	0
• Selected	6-10%	0
• Value-added tax	17%	0
Equipment		
• Import	8-13%	0
• Value-added tax	17%	0
Source: Chen and Woetzel, 2002		

The semiconductor industry in Shanghai took off following the Chinese government's announcement, in July 2000, of substantial tax reductions for the industry (See Figure 5.) Later that year, three major manufacturers announced plans to build chip fabrication facilities in Zhangjiang Park: Shanghai Beilin Microelectronics Co, the leading Chinese semiconductor company and two new joint ventures: Shanghai Grace Semiconductor Manufacturing Corp (GSMC) and Semiconductor Manufacturing International Corp (SMIC.) Even Taiwan's leading foundry, TSMC, recently announced plans to invest in China in the future. According to CEO Morris Chang:

> . . .when the Mainland authorities provide such incentives like tax breaks as well as sufficient supplies of high tech personnel and water and electricity, and our competitors have started to use these advantages, we would lose our competitive edge if we did not follow suit. (SCMP, 8/27/01)

These investments have in turn attracted downstream and upstream producers, making Zhangjiang Park home to over 100 IC-related firms representing all stages of the IC production chain, from wafer manufacturing, IC design and fabrication to packaging and assembly-and-test. Taiwanese design house VIA Technologies and assembly firms ASE and Siliconware Precision Industries have also located facilities near the park. (Figure 6.)

Figure 6. The IC Industry in Shanghai Zhangjiang High-Tech Park, 2001

- **3 IC Manufacturers**: SMIC, GSMC, Shanghai Beilin
- **5 IC Research & Development Units**: Fudan Micro-analysis Center, Hua Hong R&D Center, Fudan Micro-electronics Research Institute, Research Institute of Xi'an Jiaotong University, Fudan Information College
- **19 IC Design Companies**: Huahong, Fudan Micro-electronics, Haulong, Hongsheng, Avanti!, Synopsys, SST, ISSI, and others.
- **6 IC Packaging and Testing Companies**: Alphatec, Hongyi, Tailong, Hongsheng, Qingyi and others
- **15 IC Equipment Manufacturers and Supporting Companies**: PaxAir, SAES, Lam Research, Novellus, Applied Materials, TOWA, TIC, DiAi, and more

Source: Shanghai Z.J. Hi-Tech Park Development Co., 2001

The joint ventures, GSMC and SMIC, represent a mix of resources and talent from Silicon Valley, Taiwan and China. GSMC is a high profile venture founded by Mianheng Jiang, the son of China's President Jiang Zemin, and Winston Wong, son of the Chairman of Formosa Plastics and head of Taiwan's most powerful business family. Wong is Chairman and Jiang is Vice Chairman of the Board and principal shareholder of GSMC, which raised US $1.6 billion for its first foundry.

The senior executives and managers in both firms have extensive experience in the semiconductor industry in both the US and/or Taiwan. SMIC, for example, recruited 300 engineers away from Taiwan's leading IC manufacturing firm, TSMC, and another 50 directly from leading Silicon Valley companies. According to one of these recruits: "The salaries here [in China] are lower than they are in the US--but there is a greater upside. Things are moving very fast here. SMIC built its fab in one year, which may be record time. There is tremendous room for growth in China." (Interview, Jan 2001)

The financing for these deals typically comes from U.S. and foreign investors with experience in either Taiwan or China, as well as from local partners. Both are financed from abroad to avoid Taiwan's investment limits and the complex regulatory system in China. SMIC, for example, is incorporated in the Cayman Islands, and is structured as a US Delaware-style corporation so that will follow US corporate and securities law and governance, which preserves the option of raising capital in the public markets in the US or Asia. And following Silicon Valley practice, employees of SMIC receive stock options as part of their compensation.

SMIC had also relied almost exclusively on legal and financial advice from Silicon Valley professionals. Carmen Chang, a partner from Silicon Valley's leading law firm, Wilson Sonsini, managed the legal details of the SMIC financing and incorporation. She has also played an active role in related business details, from lobbying the US government to open to leading edge chip making equipment to advising the Chinese policymakers on opening a second board in Shenzhen. Her main clientele in the 1990s was Taiwanese entrepreneurs starting firms either in the US or Taiwan. Today she says that business is overwhelmingly from Mainland Chinese--both returnees and Chinese firms setting up operations in the US--and there are far more requests than she can accept.

Figure 7. Semiconductor Manufacturing International Corporation (SMIC)

SEMICONDUCTOR MANUFACTURING INTERNATIONAL CORP

- Established: April 2002
- Incorporation: Cayman Islands
- Location of IC Production: Shanghai Zhangjiang Park
- Equity raised: US $1.5 billion
- President & CEO: Richard Chang, former CEO World Semiconductor of Taiwan
- Products: SRAM, Standard Logic, Analog IC, Flash Memory & LCD Driver ICs
- Technology: 8" wafers, sub-0.25 micron (2002), LT goal 12" wafers, 0.11 micron
- Production Capacity: 30,000/month by end of 2002, 85,000/month by end 2004
- Employees: Approximately 1600
- First Round Investors: Shanghai Industrial Holdings Limited, Walden International, Goldman Sachs, H&Q Asia Pacific Limited, and a Singapore consortium led by Vertex Management
- Future Plans: Total of 6 fabs in Shanghai Zhangjiang Park

Source: http://www.smics.com

Experienced industry observers report that the clustering of the IC industry in Shanghai and the market, technology, talent pool, government support, and capital supply in China today looks resembles that of Taiwan's Hsinchu region ten or fifteen years ago. Some predict the industry will grow faster than it did in Taiwan because it has a large base of experience from the US and Taiwan to tap and an existing model to follow. The Chinese market is also a key factor in these predictions: China's accounts for 6% (US $13 billion in 2000) of worldwide demand for semiconductors, following only the US, Japan and Taiwan. This market is predicted to grow at a compound annual rate of 17% in the next five years as domestic output of electronics goods grows. Yet domestic companies currently supply only 5% of the total Chinese demand.

While there is tremendous room for growth of the domestic semiconductor industry, it is likely that China will continue producing relatively low-end chips (the type used in watches, radios, cell phones and other consumer electronics products) for the next 5-10 years. The IC manufacturing technology in China remains two or three generations behind Taiwan, and U.S. regulations on export of the most advanced manufacturing equipment to China will slow the adoption of leading edge process technologies.

McKinsey & Co. consultants in Shanghai predict that the large supply of low cost engineering talent will allow China to grow more quickly as a center for semiconductor design than for advanced manufacturing, which requires sophisticated technology and management skills. Salaries for chip designers in China are about 20% of those in the U.S., and the domestic market for IC design in China will reach an estimated $10 billion in 2010. (Figure 8)

Figure 8. Salaries of IC Design Employees, US $thousand

	China	United States
Senior design engineer (5 years experience)	14-30	80-150
Junior design engineer (<5 years experience)	9-20	50-100
Other design employees	9-20	50-100

Source: Chen and Woetzel, 2002

This suggests the possibility that the relationship between China and Taiwan, like that between the US and Taiwan will be complementary, rather than competitive, with Taiwan moving up the value chain to provide leading edge manufacturing services and high value added design while China becoming a center of low-end, labor-intensive design and assembly-and-testing as well as non leading-edge manufacturing.

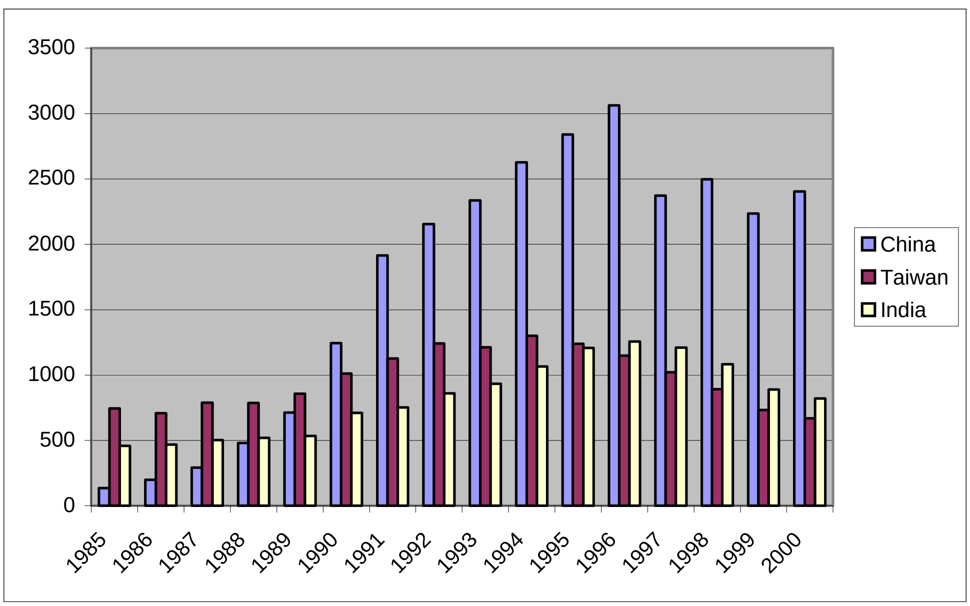
China and Silicon Valley: From Brain Drain to Brain Circulation

At the same time that networks of Taiwanese PC and semiconductor makers were moving their low-end manufacturing to the Chinese Mainland, the "best and brightest" of China's youth were leaving to pursue their education abroad. The brain drain, which increased significantly after the 1989 and the Tianamen Square events, has been so great that Mainland Chinese are now the largest and fastest growing group of foreign-born students in US universities, with 54,466 students (or 10.5% of the total) enrolled in 1999-2000. Moreover they have not returned to China in large numbers. One source reports that while approximately 320,000 Chinese students have studied abroad since 1978 only one-third have returned (Science, 288, 5473)

The loss of talent is especially acute in technical fields. Chinese students in the U.S. are concentrated at the graduate level and in science and engineering fields: about

2,500 Chinese students per year received doctoral degrees in science and engineering from the U.S. in the 1990s--for a total of 28,000 S&E doctorates between 1985 and 2000 (NSF, 2001.) This is more than double those from the next largest groups of foreign students in the US, from Taiwan and India. (Figure 9.) Mainlanders also have historically had the highest stay rates of all of these groups. An NSF study found that 88% of Chinese who earned doctorates in science and engineering in 1990-91 were still working in the U.S. in 1995. This is consistent with the data on visas issued by the U.S. for workers with exceptional skills: Mainland Chinese received 20,885 H-1B visas between 1990 and 1999, second only to immigrants from India.

Figure 9. U.S. Doctorates in Science & Engineering to Foreign-born Students



Source: National Science Foundation, 2001

Chinese policymakers have recognized the opportunity to tap this pool of foreign-educated technology professionals for domestic development purposes. Over the past decade, governments at both local and central levels have pursued two strategies in their efforts to counteract the brain drain. Following Taiwan's model, Chinese agencies have sought to increase professional connections and communications with the overseas community by sponsoring study tours, conferences, joint research projects and short-term work and teaching opportunities. The Ministry of Education, for example, established the Chun Hui Program to finance trips to China by technologists trained abroad to participate in conferences and academic research (Figure 10.) Other programs provide opportunities for short term lecturing, teaching, and postdoctoral appointments in China. Participants from the U.S. report that these programs have succeeded in increasing technical exchange between Chinese scholars based in China and the US.

Figure 10. Policies on technical exchange with overseas Chinese

- Ministry of Education: policies for overseas talent to return for conferences or short-term academic programs (Chun Hui program); policies for overseas talent to participate in scientific education and research (Chang Jiang Scholar project); start-up funds for research by Chinese overseas talent.
- Ministry of Personnel: financial aid for short-term work in non-educational departments for overseas talent and financial support for overseas talent to return for science activities in non-educational fields
- National Natural Sciences Foundation: funds for overseas talents to do short term research or teaching in China; control of use of funds for international cooperation and communications
- Chinese Academy of Science: one hundred talents project; high level program for visiting scholars; funds for overseas talent to return to work in China

Source: Dahlman, World Bank, 9.3, 2002

The other approach to the brain drain is to directly recruit engineers and scientists with business experience to return to work or to start companies. Representatives of cabinet-level ministries as well as municipal governments from large cities such as Shanghai and Beijing paid regular visits to the U.S. throughout the 1990s to recruit Chinese professionals. These visiting officials typically hold dinners or meetings to publicize the favorable incentives and business environment in China.

Competition between municipal and provincial governments for returnees has increased significantly in recent years. There is now an almost continuous flow of delegations of company and government representatives recruiting in Silicon Valley, and they come from all over China--not just coastal urban areas, but central and western provinces as well.

Many municipal governments have also established Returning Students Venture Parks (or Overseas Student Parks) within the new and high tech development zones. These parks are reserved exclusively for companies started by returnees. They offer not only low rent, tax relief, shared infrastructure and financial benefits like other science parks in China, but they also address the special needs of returnees, such as accelerating the bureaucratic process involved with establishing residency to insuring access to housing and prestigious, often bilingual, schools for their children. Figure 11.

Figure 11. *Distributed electronically to Bay Area China Network (8/11/98) with subject heading:*

A Great Business Opportunity for You

A Briefing on China Suzhou Pioneering Park for Overseas Chinese Scholars

Sponsors:
Chinese Scholarly Exchange Service Center, Ministry of Education
Torch Program Office, Ministry of Science and Technology
Jiangsu Service Center for the Shift of Qualified Personnel
Jiancsu Science and Technology Commission
The Administrative Committee of the Suzhou New Technology District
Suzhou Science and Technology Commission

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

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

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

Incentives for tenants:

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

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

Building:
The park owns one four-story building with floor space of 10,000 square meters. It hosts 88 units ranging from 20 to 100 sq meters. Services and facilities include the following:
-Conference room with conferencing facilities
-Seminar room
-Product display chamber
-Internet access, central air conditioning
-Reception
-Fax, typing , word-processing, and photocopying services
-Air ticket booking, hotel room reservations
-24-hour security services

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

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

By 2000 there were 23 Returning Students Science Parks across China and many other municipalities had policies to attract returning students but no park. The "Overseas Students Science Park" in the Zhongguancun (Haidian) district of Beijing, the largest and oldest of the three overseas student parks located in Beijing housed 48 companies and 68 returning students in 1998. There is no aggregate data on how many returnees these policies have attracted overall, and now way to determine the extent to which they have succeeded in producing successful companies. However some Silicon Valley returnees who have started companies in China say that they would never locate their companies in such a facility, primarily because it would involve closer government ties and scrutiny.

Silicon Valley's Mainland Chinese immigrants, like their Taiwanese predecessors, has built extensive professional and social networks both in Silicon Valley as well as back to China. These ties are often coordinated through the alumni associations of the elite technical universities such as Beijing University, Tsinghua University, and Shanghai Jaiotong University. These alumni ties appear to gain importance when living abroad. In addition, there are close to a dozen specialized Chinese professional and technical associations in Silicon Valley ranging in size from 200 to over 2000 members. These organizations breed shared understandings and world-views among their members while providing forums for mentoring and the exchange of contacts, capital, know how, and information within the community. While Taiwanese immigrants started, and historically dominated some of the associations, and Mainland Chinese in turn started parallel associations, largely because of distrust bred by lack of familiarity, the two communities are increasingly drawn together by the shared goal of building business links to China.

The Hua Yuan Science & Technology Association was formed in Silicon Valley in 2000 to: "promote the technological, professional and scientific development of the Chinese business community." Its membership has grown very fast: over 1000 Chinese engineers attended the 2002 Hua Yuan Annual Conference entitled "Opportunities and Challenges: Riding the China Wave." Their website describes the association's mission: "Hua Yuan assists and encourages professional development and entrepreneurship of our members, facilitates exchange between Chinese and other business communities in the United States, and strengthens cross-border business relationships between Silicon Valley and China." (http://www.huayuan.org/) Hua Yuan maintains a Chinese office in Beijing and describes its role as a "bridge between Chinese and US high tech industries:"

> Hua Yuan has established strong associations with Chinese business community, and has built up a close working relationship with the Chinese regulatory authorities. Members of Hua Yuan exploring business opportunities in China are backed by our strong networks in China. Such supports include concrete administrative helps (sic) from Hua Yuan's Chinese office located in the center of high-tech development in Beijing. Hua Yuan continues to engage in high-level exchanges between business executives from Silicon Valley and China.

A recent Hua Yuan meeting featured a keynote address by Dr. Char-pin Yeh, President of Macronix Electronics IC design operation in Suzhou, China. Macronix was started by a Taiwanese engineer who studied and worked in Silicon Valley for 15 years before returning to start one of the first companies in the Hsinchu Science Park. Dr. Yeh, also Taiwan-born, earned a PhD in electrical engineering from Georgia Institute of Technology, holds 26 US patents in microelectronics-related fields, and worked in the US semiconductor industry for almost fifteen years. His speech was a technical analysis of the "Strengths and Weakness Analysis of Cross-Straits IC Design Industries." He also participated in a forum on the trade offs between a corporate career and entrepreneurship, the business environment in China, and steps to "start the wheel of business in China."

Hua Yuan and other Chinese professional associations also sponsor regular business tours to China, receive government delegations, and serve as conduits for Chinese firms recruiting in the US. The delegation from the 2001 Back to China trip sponsored by the Chinese Internet and Networking Association (CINA) gave a series of public presentations on the topic of "The China Wave--A Reality Check" soon after their return. The speakers provided detailed information on the challenges as well as opportunities facing those considering returning to the Mainland, with individuals addressing issues relevant to the telecommunications, wireless, software and IC sectors.

These associations also provide multiple forums for information exchange and technology transfer between Chinese engineers in the US, Taiwan, and China. The Chinese Institute of Engineers (CIE), which has branches in all three places, has sponsored technical conferences that attract practicing engineers as well as scholars for decades. Business oriented organizations are also starting to play this role. In 1998 the Chinese American Semiconductor Association (CASPA) sponsored a delegation of local technologists for a two-week study tour of the Shanghai semiconductor industry. After returning the group produced a technical report assessing the status of the Chinese microelectronics industry that was widely circulated among in the Valley.

Equally important, according to on of the group's leaders, Peter Yin of ICT Inc: "… we were instrumental in helping our Shanghai counterparts solve current technical problems, [but] we also served as vehicles of knowledge transfer and new modes of thinking." He described an exchange with sessions organized according to detailed technical specializations of the semiconductor engineers and commented:

> They benefited a great deal from exposure to advanced technologies and novel analytical methodologies during the sessions, as much as their Silicon Valley colleagues gained first-hand knowledge of China's determination to develop its indigenous IC base and challenges that lie ahead. (CASPA press release, 1998)

These exchanges also help pave the way for returnees. Four of the former heads of CASPA were among those successfully recruited in 2001 to become senior executives in SMIC's newly announced in Shanghai's Zhangjiang Park.

The impetus for these technology transfers is not just one-sided. The Zhangjiang High Tech Park Administration has been quite entrepreneurial in creating opportunities for exchange. One of its recent activities is the institutionalization of a 2-hour monthly video conference allowing about 50 Chinese engineers--some based in the Park and others in Silicon Valley--to communicate face-to-face on areas of shared interest. In recent months they have sponsored forums focusing on the software industry, recent trends in the IC industry, and the development of telecommunications technologies.

The first notable wave of high technology returnees from the US to China began in the late 1990s, triggered by a combination of Internet enthusiasm, the lure of the large China market, and various government incentives. This group located their businesses primarily in Beijing to be part of the fast-growing Internet and dot.com industries. While accurate data is not available, it appears that these returnees came from all over the U.S., many were young (recent graduates) with little or no work experience in the U.S., and many had business rather than technology backgrounds. Two of the high profile firms of this era are AsiaInfo, started by returnees from Texas and now China's largest systems integrator for the telecommunications and Internet industries, and Sina.com, the leading

Internet portal in China. Both firms are now publicly listed on NASDAQ, although their future remains uncertain. Most of these Internet start-ups failed within a couple of years and this flow of returnees ended abruptly with the collapse of the dot.com bubble.

A distinct, and apparently larger, wave of returnees began in 2001 with the acceleration of foreign investment in China's semiconductor industry. The recruits to these ventures were typically older engineers with substantial experience in the semiconductor industry in Silicon Valley and/or Taiwan. Many returned to work the fast growing IC industry cluster in Shanghai, lured by stock options and the promise of professional opportunities not available to Chinese in the US. The recession in the US economy served as a push factor as well, with layoffs growing and new jobs hard to find. By one count, returnees to China started 166 firms specializing in semiconductor and software development during 2001 and 2002 (Naughton, 2003.)

The Shanghai Pudong District High Tech Delegation that visited the US in late 2001, for example, attracted close to 4,000 Chinese students to recruitment sessions in New York, Chicago, and San Francisco (including over 1,000 at the Silicon Valley session.) The delegation, which included executives from 35 Shanghai businesses along with political officials, reportedly received over 2,500 applications for the 238 positions available. While these numbers must be treated with a grain of salt because they are from China's Xinhua News Agency, individuals who attended the meeting in the Bay Area report being amazed at the turnout and the interest in the employment opportunities.

The return rate among US-educated Mainland Chinese has historically been low, below 30% according to most estimates and as low as 10% among engineers and scientists. However the Taiwanese case suggests that such trends can reverse quickly and then accelerate because of the networked nature of these communities: news of successes and opportunities travels quickly. In Taiwan the recession of the early 1990s triggered a tripling of returnees within three or four years. The events of 9/11 appear to have had a similar impact on Mainlanders. One career search Web site in China reports a dramatic increase in resumes in early 2002: "In the past couple of months we have about 10,000 to 15,000 interested in returning to China to work. Six months ago we would get only10 to 100 resumes in the same period." (SFC, 1/2/02) Another Chinese observer describes the growth of the B2C trend, or "Back to China."

As professional opportunities places like Shanghai grow, strengthened by the cross-straits transfers of manufacturing operations and skill, it is likely that more Mainland engineers and managers will return from the US. According to Lu Chunwei, a software developer who recently returned from a job at Microsoft to start his own B2Bcompany: "it's a big trend now, people just want to return to China. Its like the Gold Rush. They're successful in the US, but in their hearts they still feel like immigrants. They feel welcome here in China. . . There are not many new opportunities in the US." He added that that cheaper labor, lower rents, and better business opportunities in the Mainland were important factors in his decision. (SCMP, 1/12/02)

Chris Xie returned from Silicon Valley to China to start a peer-to-peer computing company after failing to find funding in the Bay Area. He built a partnership with a Shanghai based biotech company that has provided seed funding and is allowing the start-up to share its office space. Xie reports that the environment for his start-ups was more attractive in China because of government incentives that include $36,000 in cash grants and 390 square feet of free office space, as well as substantially lower cost labor.

He reports that he hired a staff of 10 in Shanghai for what it would have cost to hire a single comparable employee in Silicon Valley. (SFC, 1/2/02)

Of course this does not amount to a reversal of the brain drain. It is likely that the net loss of talent from China will continue for a long time. However the acceleration of the brain circulation and the growing interest in returning to China among US-educated engineers and scientists (particularly those with experience in Silicon Valley) could have a lasting impact on the economy of the centers of IT production along China's coast. There are many broader political, regulatory and institutional factors that will shape the precise trajectory of the economy and the impact of returnees and the circulation of brains on the IT industry. But there have already been important technology and know how transfers from both Silicon Valley and Taiwan and they show not sign of slowing.

The emergence of successful role models--either successful start-ups or large firms that provide sizable economic returns for employees with stock options--is likely to be an important turning point in this process. UTStarCom is one such model. The firm, which provides telecommunications network products for the Chinese market, was founded in 1991 by a group of US-educated Chinese engineers. Most of the original founders are classmates from a Ministry of Posts and Telecommunications-run university, and almost of the senior management team worked at Bell Labs in the U.S.

UT Starcom is headquartered in Silicon Valley but ninety-nine percent of its 1,800 employees are at manufacturing and R&D facilities in China as well as its primary market focus. According to founder Hong Lu, UTStarcom has leveraged its "many connections in China" including its access to Chinese officials, intimate knowledge of the China market, and the ability to combine modern business structures from the US with this ethnic and cultural know-how. The firm went public on NASDAQ in 2000 and is currently valued at $1.4 billion.

Successes like UT Starcom remain limited so far. While Mainland entrepreneurs have done well in Silicon Valley success in China has been more elusive thus far. The growing interest of U.S. venture capitalists in funding returning Chinese entrepreneurs from Silicon Valley suggests, however, that the opportunities are there. The Walden International Investment Group (WIIG), for example, was one of the original investors in NeWave Semiconductor. The firm was sold in 2002 to a Silicon Valley semiconductor company for $80 million--making money both for WIIG and also the Chinese government-owned Hua Hong Microelectronics that entity that had invested $1.5 million.

According to WIIG chairman Lip-Bu Tan, the NeWave experience has taught him that the best strategy in China is to invest in US-educated students who want to return home to start firms. He tried in the early 1990s to invest in Chinese state-owned enterprises, but learned that there was no way to get his money out. Then he tried to create joint ventures between US-based and local Chinese companies, but the challenge of bridging the two management cultures was insurmountable. The key, says Tan, is to find graduates of US universities who have stayed and worked in companies in a place like Silicon Valley for many years. "You have to be reasonably brain-washed in the U.S." As the Mainland Chinese community in the U.S. matures, such seasoned start-ups seem increasingly plausible.

The Acorn Campus was established in Silicon Valley by a team of experienced (and unusually successful) Overseas Chinese engineers. They serve as angel investors and provide mentoring and connections, as well as space, for promising new local ventures with Chinese founders. One of their portfolio firms, Newtone Communications, a telecom software firm, realized that their seed money of $500,000 would go much further in China, where they could to hire five of the nation's best engineers for the price of one engineer in the Bay Area. By moving to Shanghai, Netwone doubled its employment without increasing the budget. This experience spurred the creation of a new Acorn Campus in Shanghai. The founders' mission is, according to their website: to "leverage the highest level of Silicon Valley entrepreneurial experiences to create, invest, and incubate high technology startups in China. . . . and promote global leadership through Silicon Valley-Asia value chain partnerships." They have targeted Chinese entrepreneurs returning from Silicon Valley, and they seek to access the best resources from three different locations: R&D, new product development and marketing in US, high end logistics, design and manufacturing in Taiwan, and low cost engineering and manufacturing talent in China.

The Silicon Valley-Taiwan-China Connection

This case underscores suggests the importance of space and geography to understanding the developmental dynamics of capitalism. The transnational networks linking Silicon Valley and China parallel those established a decade earlier between Taiwan and Silicon Valley--and are creating the third leg in a triangle of social, professional and business ties between Silicon Valley, Hsinchu, and Shanghai. As Overseas Chinese technologists extend their professional and technical networks to the Mainland, they are contributing to the growth of an important new global center of technology entrepreneurship as well as deepening the division of labor between these increasingly specialized—and mutually interdependent—regional economies.

And they are doing so from the bottom-up, through the networks of entrepreneurs and enterprises that make up a transnational technical community, rather than as individuals or through the activities of multinational corporations or the direction of state policymakers. The state and multinationals have facilitated the development of the semiconductor industry in both Taiwan and China, to be sure, but it is the networks of Chinese entrepreneurs and managers with ties to Silicon Valley who have contributed the critical transfers of know how as well as the business connections that are essential to technological learning in the current era.

In short, neither the state nor the multinationals, either individually or jointly, could have achieved the rapid technological upgrading that occurred in Taiwan in the 1980s and 1990s and that is underway today in China. This is clear from the experience of Singapore and Malaysia. Both have benefited from extensive foreign direct investment by Silicon Valley semiconductor and computer corporations--investments that began in the 1960s and continue today. And in both, policymakers have developed explicit and aggressive strategies for encouraging the development of technology production. Yet neither has achieved the technological level or responsiveness of Taiwan's semiconductor design and manufacturing enterprises--capabilities that have growth through two decades of transnational entrepreneurship linking Hsinchu and Silicon Valley.

This is not to suggest that returnees are creating replicas of Silicon Valley in their home countries. These regions differ from the original Silicon Valley in a multiplicity of small and large ways. Different economic and political institutions, the product of varied histories and cultures, insure that each region will pursue its own distinctive trajectories. It is more appropriate to see these new regions as hybrids that merge elements of the Silicon Valley industrial system with indigenous institutions and resources.

The power of the transnational community is most evident in the case of the semiconductor industry, which originated in Silicon Valley and has been transferred by Chinese entrepreneurs first to Taiwan and then from Taiwan as well as from Silicon Valley to China. However a similar process is occurring in linked sectors as well. Of course these are not one-way flows. While the Taiwanese IC industry initially grew out of talent and technology from the U.S., producers like TSMC contributed indigenous innovations that in turn benefited the entire industry. Likewise, while China remains at a lower technological level that both Taiwan and the U.S., it has all of the resources (skill, capital, know-how, connections) to innovate, and there is evidence that the large Chinese telecommunications market will provide local producers with the opportunity to experiment with, and ultimately innovate, in the field of wireless communication.

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