From Brain Drain to Brain Circulation:
Transnational Communities and Regional Upgrading in India and China

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Abstract

By 2000, over one-third of Silicon Valley's high-skilled workers were foreign-born, and overwhelmingly from Asia. These U.S.-educated engineers are transforming developmental opportunities for formerly peripheral regions as they build professional and business connections to their home countries. In a process more akin to "brain circulation" than "brain drain," these engineers and entrepreneurs, aided by the lowered transaction costs associated with digitization, are transferring technical and institutional know-how between distant regional economies faster and more flexibly than most large corporations. This article examines how Chinese- and Indian-born engineers are accelerating the development of the information technology industries in their home countries—initially by tapping the low-cost skill in their home countries, and over time by contributing to highly localized processes of entrepreneurial experimentation and upgrading, while maintain close ties to the technology and markets in Silicon Valley. However, these successful models also raise several questions about the broader relevance of brain circulation outside of several key countries, and regions of those countries, within the global South.

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Global labor markets are being transformed as the falling costs of transportation and communications facilitate greater mobility and as digital technologies support the formalization and long-distance exchange of large amounts of information. International migration, historically a one-way process, has become a reversible choice, particularly for those with scarce technical skills, and it is now possible to collaborate in real time, even on complex tasks, with counterparts located at great distances. As a result, scientists and engineers from developing countries—once forced to choose between settling abroad and returning home to far less attractive professional opportunities—are contributing to their home economies while maintaining professional and economic ties in more technologically advanced economies. Some become "transnational" as they work, and even maintain residences and citizenship in more than one nation.

The migration of talented youth from developing to advanced countries was viewed in the postwar decades as a "brain drain" that exacerbated international inequality by enriching already wealthy economies at the expense of their poor counterparts. According to a classic textbook on economic development,

> The people who migrate legally from poorer to richer lands are the very ones that Third World countries can least afford to lose, the highly educated and skilled. Since the great majority of these migrants move on a permanent basis, this perverse brain drain not only represents a loss of valuable human resources but could also prove to be a serious constraint on the future economic progress of Third World nations." (Todaro, 1985)

Data on these trends are hard to find, but the UN has estimated a total of three hundred thousand highly skilled emigrants from all developing countries to the West during the 1960s (Rapaport, 2002); the 1990 U.S. Census showed 2.5 million highly skilled immigrants, excluding students.

Much of the movement of skilled individuals from developing to advanced countries during the latter part of the twentieth century has involved migration to the United States, specifically Silicon Valley. The region's technology producers grew very rapidly from the 1970s through the 1990s, absorbing scientists and engineers voraciously and irrespective of national origin. Tens of thousands of immigrants from developing countries, who had initially come to the U.S. for graduate engineering education, accepted jobs in Silicon Valley rather than return to their home countries, where professional opportunities were limited.[1] By 2000, over half (53%) of Silicon Valley's scientists and engineers were foreign-born. Indian and Chinese immigrants alone accounted for over one-quarter of the region's scientists and engineers, or approximately 20,000 Indian and 20,000 Chinese (5,000 Taiwan- and 15,000 Mainland-born) engineers.[2]

This paper argues that the same individuals who left their home countries for better lifestyles abroad are now reversing the brain drain, transforming it into "brain circulation" as they return home to establish business relationships or to start new companies while maintaining their social and professional ties to the United States. When foreign-educated venture capitalists invest in their home countries, they transfer first-hand knowledge of the financial institutions of the new economy to peripheral regions. These individuals, often among the earliest returnees, also typically serve as advisers to domestic policymakers who are anxious to promote technology growth. As experienced engineers and managers return home, either temporarily or permanently, they bring the worldviews and identities that grow out of their shared professional and educational experiences. These cross-regional technical communities have the potential to jump-start local entrepreneurship, and they succeed over the long term to the extent that they build alliances with technical professionals, businesses, and policymakers in their home countries.

The spread of venture capital financing provides a window into this process. In the early 1980s, returning immigrants began to transfer the Silicon Valley model of early-stage high-risk investing to Taiwan and Israel, locations that U.S. venture capitalists typically had neither interest in nor the ability to serve. Native-born investors provided the cultural and linguistic know-how needed to operate profitably in these markets. In addition to capital, they brought technical and operating experience, knowledge of new business models, and networks of contacts in the United States. Israel and Taiwan today boast the largest venture capital industries outside North America, and both have high rates of new firm formation and growth. Israel is now known for software and Internet firms like Mirablis (an instant-messaging program developer) and Checkpoint (security software); Taiwan has become a center of leading edge personal computer (PC) and integrated circuit (IC) manufacturing with firms like Acer Technology Ventures (PCs and components) and TSMC (semiconductor foundry.) All have relied on returning scientists and engineers as well as a new breed of transnational venture investors.

Building upon the experience of Israel and Taiwan, this article explores the developmental consequences of the heightened mobility of highly skilled workers in two of the world's largest developing economies: India and China. Specifically, it examines how Indian and Chinese immigrants to Silicon Valley are influencing economic development in their home countries directly, by transferring technology and know-how when they return home to work or start businesses, as well as indirectly, by influencing the formation of policy and other aspects of the institutional environment. Not surprisingly, this has proven to be a significantly easier process in Israel and Taiwan than in the complex political economies of China and India. Nonetheless, the long-term impacts of returning entrepreneurs and their communities may well be more far-reaching in the latter countries.

The article focuses on the creation of venture capital industries with close links to Silicon Valley—a process that entails extensive institutional change, particularly in domestic capital markets, and in turn has important consequences for the pattern of economic development. By 2004, venture capital and private equity firms were investing more than $1 billion annually in enterprises located in China and a comparable amount in India. While this is a fraction of the venture capital invested annually in the United States or even the amount of FDI in these economies, it supports indigenous entrepreneurship and has created an alternative, increasingly competitive, trajectory to the development opportunities provided by both the established domestic firms and the multinational corporations in these nations.

The first section of this paper discusses the limits of traditional core-periphery understandings of the relation between developed and developing economies in an era of global labor mobility and "brain circulation," and particularly the failure to anticipate the development of independent technological capabilities in the periphery. The following section traces the transfer of the Silicon Valley model of venture capital to Taiwan during the 1980s by networks of U.S.-educated Chinese engineers. In this case the transfer of institutional and policy know-how was arguably as important as the later transfer of skills and technical knowledge. The third and fourth sections detail more recent processes of policy reform and institutional learning in China and India. The venture capital industries in these two countries have grown rapidly, with close connections to their Silicon Valley and U.S. counterparts, and in both countries, economic development in certain regions is characterized by high rates of entrepreneurship and experimentation. The article concludes with thoughts about the extent to which it is possible to generalize from these cases of peripheral entrepreneurship to other late-developing economies.

Economic Development in an Era of Global Labor Mobility

Traditional accounts of economic development assume that new products and technologies emerge in industrialized nations that combine sophisticated skill and research capabilities with large, high-income markets—and that mass manufacturing is shifted to less costly locations once the product is standardized and the process stabilized. Success in this view builds on success in advanced economies, while peripheral economies remain followers. This divide is perpetuated by both the strategies of multinational corporations and the tendencies toward agglomeration created by the economics of increasing returns.

This model leaves little room for the development of independent technological capabilities in the periphery. At best, foreign investment from the core might contribute to the incremental mastery of manufacturing techniques and upgrading of local suppliers. Even the most successful newly industrializing countries are destined to remain imitators as long as leading-edge skill and technology reside in the corporate research labs and universities in the core. The primary route to development in the periphery, in this view, is the mobilization by the state, in conjunction with local banks and industry, of the resources to either develop or import the mass manufacturing capabilities that were perfected in the core.

Transformations in the world economy have undermined the power of this core-periphery model, however. The increasing mobility of highly skilled workers and information on the one hand, and the fragmentation of production in information and communication technology sectors on the other, provide unprecedented opportunities for formerly peripheral economies. Regions that missed the postwar economic boom, in particular, have provided fertile environments for a decentralized growth based on entrepreneurship and experimentation. The key actors in this process are neither policymakers nor multinational corporations in isolation, although both certainly play a role, but rather communities of technically skilled immigrants with work experience and connections to Silicon Valley and related technology centers.

U.S.-educated and trained engineers are increasingly transferring up-to-date technology and market information and helping to jump-start local entrepreneurship, allowing their home economies to participate in the information technology revolution. Because of their experience and professional networks, these cross-regional entrepreneurs can quickly identify promising new market opportunities, raise capital, build management teams, and establish partnerships with other specialist producers—even those located far away. The ease of communication and information exchange within ethnic professional networks accelerates learning about new sources of skill, technology, and capital as well as about potential collaborators. It also facilitates the timely responses that are essential in a highly competitive environment. This decentralized responsiveness is an advantage that few multinationals can claim.

This is not a one-way process. As recently as the 1970s, only large, established corporations had the resources and capabilities to grow internationally, and they did so primarily by establishing marketing offices or manufacturing branch plants overseas. Today the fragmentation of production and the falling costs of transportation and communication allow even small firms to build partnerships with foreign producers to tap overseas expertise, cost savings, and markets. Start-ups in Silicon Valley today are often global actors from their first day of operations; many raise capital, subcontract manufacturing or software development, and market their products or services outside the United States.

The scarce resource in this environment is the ability to locate foreign partners quickly and to manage complex business relationships and teamwork across cultural and linguistic barriers. This is particularly challenging in high-tech industries in which products, markets, and technologies are continually redefined—and where product cycles are often nine months or less. First-generation immigrants like the Chinese and Indian engineers in Silicon Valley who have the language, cultural, and technical skill to function well in the United States as well as in their home markets have a commanding advantage here. They have created institutions and social structures that enable even the smallest producers to locate and maintain mutually beneficial collaborations across long distances and that facilitate access to distant sources of capital, skill, and markets.

Late-developing economies typically face two major disadvantages: they are remote from the sources of leading-edge technology, and they are distant from developed markets and the interactions with users that are crucial for innovation (Hobday, 1995). Firms in peripheral locations use a variety of mechanisms to overcome these disadvantages, from joint ventures and technology licensing to foreign investment and overseas acquisitions. However, a network of technologists with strong ties to global markets and the linguistic and cultural skills to work in their home country is arguably the most efficient and compelling way to overcome these limitations. Cross-regional entrepreneurs and their communities can facilitate the diffusion of technical and institutional know-how, provide access to potential customers and partners, and help to overcome reputational as well as informational trade barriers for isolated economies.

The increasing sophistication of information and communication technologies and the liberalization of global markets have accelerated this process. It is now quick, simple, and inexpensive to communicate internationally and to transfer information between distant locations. Information systems that facilitate the formalization of knowledge are dramatically expanding the volume as well as the variety of possible forms of information exchange. However, information technology alone cannot ensure successful coordination or efficient transfers of technical and institutional knowledge. Long-distance collaborations still depend heavily upon a shared social context and language that ensures mutual intelligibility between partners, particularly as speed and responsiveness are essential in today's technology competition.

Market liberalization has been equally important to the economic transformation of both China and India. However, the reduction of trade barriers and bureaucratic intervention alone does not create the institutional and social context, let alone the domain knowledge, required to sustain entrepreneurial success in global industries. Technology entrepreneurship remains highly localized even in the most advanced economies and it cannot be created by fiat, as evidenced by decades of failed attempts to "grow the next Silicon Valley." Efforts to jump-start entrepreneurship by mobilizing researchers, capital, and a modern infrastructure cannot replicate the shared language and trust of a technical community that permits open information exchange, collaboration, and learning (often by failure) alongside intense competition in places like Silicon Valley.

The new technology centers differ significantly from one another, and from Silicon Valley, in their technological sophistication as well as the specializations of local producers. Cross-regional entrepreneurs rarely compete head-on with established U.S. producers; instead they build on the skills and the technical and economic resources of their home countries. Israeli entrepreneurs, for example, have successfully applied the findings of the nation's advanced military research to innovations in the Internet security and telecommunications arenas. Indian entrepreneurs, by contrast, recognized the opportunity to mobilize the thousands of underemployed English-speaking Indian engineers to provide software development services for American corporations. Returning entrepreneurs are ideally positioned to identify appropriate market niches, mobilize domestic skill and knowledge, connect to international markets, and work with domestic policymakers to identify and devise strategies to overcome obstacles to further growth.

These regions are each developing their own ecosystems for entrepreneurship, as well as close connections to technology and markets in the United States. The infrastructure for entrepreneurship is best-developed in Israel and Taiwan, where technologists have returned by the thousands since the 1980s and successfully transferred both U.S.-style venture capital and the Silicon Valley model of business focus and partnering. Both regions have also completed several entrepreneurial cycles in which successful entrepreneurs have reinvested their capital and contributed accumulated know-how and contacts to a subsequent generation of technology ventures, while also serving as role models. This cycle is central to establishing the relationships and decentralized information flow that support collective experimentation and learning in a regional economy. It does not guarantee the success of any individual firm, but it provides local producers with the capacity to collectively adapt and upgrade local capabilities.

The entrepreneurial ecosystem is still in its formative stages in the technology regions of India and China. These regions have seen important early entrepreneurial successes, and both have large technically skilled workforces willing to work very hard for relatively low wages. However, few U.S.-educated emigrants returned to either India or China during the 1980s and 1990s. The technology recession triggered an upsurge in cross-regional entrepreneurship that, along with the emergence of a second generation of successful start-ups, should significantly strengthen the entrepreneurial ecosystem of each. While it may be too early to define the trajectories of the regions in these large, complex political economies, the cross-regional entrepreneurs and their communities have pursued very different strategies. Returning Chinese entrepreneurs have focused primarily on developing products to serve the domestic market, while their Indian counterparts are oriented toward providing software and other services for export.

The dynamism of these technology regions is not reducible to cost advantages. Investors in India and China may have initially been motivated by the availability of low-cost skill, but the concentration of technology production has already generated rapidly rising wages and intensifying congestion in these regional economies. Engineering salaries in both Bangalore and Shanghai, for example, are now among the highest in their nations, yet new and established producers continue to cluster there rather than seeking lower-cost locations. The experience of Silicon Valley demonstrates that decentralized economies can flourish long after their labor cost advantages disappear as long as local investors and entrepreneurs are organized to collectively learn, innovate, and upgrade local capabilities—to create and recreate their regional advantage.

The contributions of an international technical community in transferring the institutions of technology entrepreneurship should not be confused with the broader role of a diaspora in 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. Transnational networks, however, are created by a small subset of highly educated professionals whose potential contributions to economic development are disproportionately significant. These transnational entrepreneurs are not typically drawn from the traditional economic or political elites of their home countries. Rather they are often the top engineering students from middle-class households whose access to education in the United States has landed them in a very different technological and institutional environment—one that they initially master and later transfer to their home countries.

Returning migrant communities are not replicating Silicon Valley around the world. Wide variations in national economic and political institutions, themselves the products of enormously varied histories and cultures, ensure distinctive and divergent economic trajectories. It is more appropriate to see the emerging regions as hybrids, combining elements of the Silicon Valley industrial system with inherited local institutions and resources. Returning entrepreneurs typically seek (with varying success) to transfer venture capital finance, merit-based advancement, and corporate transparency to economies with traditions of elite privilege, government control, and corruption. They seek to reproduce the team-based firm with minimal hierarchy and horizontal information flows in an environment dominated by family-run businesses or state-owned enterprises. The national institutions that support the Silicon Valley system—efficient and well-developed capital markets, property rights, an independent judiciary, regulatory oversight, and sophisticated education systems, research institutions, and physical infrastructure—are rarely present in these peripheral economies.

Technology entrepreneurship is nonetheless a growing presence in each of these economies. Returning entrepreneurs have developed a variety of adaptations to the challenges created by conditions in their home countries. In India entrepreneurs rely on private telecommunications facilities and power supplies rather than on the nation's costly and unreliable infrastructure, while in China returning entrepreneurs have learned how to negotiate the complex rules that regulate private companies. Returning entrepreneurs also have the advantages of access to U.S. institutions: not only do they pursue graduate education in the

United States, but many incorporate their businesses there, establish headquarters or research labs in Silicon Valley, seek venture capital and professional services as well as managerial and technical talent from the United States, and even raise money on U.S. capital markets.

At the same time, in all these countries, transnational entrepreneurs and their communities have devoted substantial time to efforts to transform domestic institutions by advising national governments on legal, regulatory, or capital market reforms, by working with regional governments on improving local infrastructure, universities, research, and training institutions, and by creating forums for information exchange and other forms of coordination among local producers. The outcome of these diverse strategies will differ from place to place—and while these regions may approximate the underlying principles of entrepreneurship-led growth, they do not seek to replicate the institutions or technological capabilities of Silicon Valley precisely.

A regional economic trajectory is shaped not only by local institutions but also by the range of technological and market opportunities available at the time it enters global markets. The most successful producers in Israel and Taiwan are those that have identified niches that allow them to differentiate and complement, rather than compete directly with, established producers in Silicon Valley—thus avoiding trade wars like those between U.S. and Japanese semiconductor firms in the 1980s, which reflected the old model, with vertically integrated "national champions" competing head-on for shares of a capital-intensive commodity business. And the fast-growing market for wireless communication in Asia has created opportunities for firms in China and India to contribute to the direction of the technology and its applications—even if they do not define the leading edge of the technology. Over time, producers in developing regions build independent capabilities and define entirely new specializations and markets.

Organizational and institutional innovations will also likely emerge from these new centers of technology entrepreneurship, as they did from Japan in an earlier era. Entrepreneurship-led growth, with highly competitive and sophisticated small and medium-sized technology producers in high-skill regions connecting to and collaborating with counterparts elsewhere, is only one possible future for these formerly peripheral regions. They could forgo the opportunity to upgrade local skills and capabilities, and instead remain suppliers of low-cost labor to global (or domestic) corporations. China and India have the labor supply to do this for a relatively long time. However, many transnational entrepreneurs have maintained close ties to the technology and markets of Silicon Valley, and are constructing firms committed to an alternative, high-value-added trajectory.

Taiwan: Transferring the Silicon Valley Model

The Taiwanese economy emerged in the 1970s initially as a source of low-cost skill for labor-intensive calculator and later personal computer production, just as the old model predicts. The commitment to education provided the domestic skill base required for industrial upgrading, but at the same time networks of foreign-educated engineers worked with policymakers to develop local institutions that support entrepreneurial experimentation. Eventually networks of entrepreneurs and established firms defined specialized niches that allow them to focus and shift to higher-value-added activities without competing head-on with industry leaders. Taiwan became the world's most efficient center of IT manufacturing. While this process is at an earlier stage in China and India, and these are significantly larger and more complex political economies, it appears that both are following similar trajectories of upgrading.

Faced with the slow growth of the Science Park in Hsinchu, government officials sought alternative development strategies. K.T. Li, Taiwan's finance minister (who had visited Silicon Valley regularly in the 1970s to meet with Chinese engineers) was especially impressed by the U.S. venture capital industry and saw it as a potential missing link in Taiwan. In the early 1980s—long before it was fashionable elsewhere—he convinced the Ministry of Finance of the need to provide funding for research-intensive production and promote the development of a public capital market. Once again Taiwan's policymakers studied the U.S. experience: they consulted investment professionals, organized collaborations with large U.S. banks to transfer financial and managerial expertise, and sent teams to Silicon Valley to be trained in managing a venture capital firm. Clark Su, chair of the Taipei Venture Capital Association, describes venture capital in Taiwan as a "pure transfer" from Silicon Valley.

Li spearheaded the legislation to create and regulate the venture capital industry and established a framework for enterprises to establish venture capital funds. This was challenging as the concept of venture capital was foreign to traditional Taiwanese practice, in which family members closely controlled all of a business's financial affairs. Under Li's guidance, the Ministry of Finance created significant tax incentives: 20 percent of the capital invested in strategic (technology-intensive) ventures by individual or corporate investors was tax-deductible for up to five years. Recognizing the challenge of raising capital from Taiwan's risk-averse financial and industrial communities, the government also provided substantial matching funds. The Ministry of Finance organized the initial "Seed Fund" with NT$800 million from the Executive Yuan Development Fund. This was so quickly allocated that the government committed a second fund of NT$1.6 billion.

Acer founded Taiwan's first venture capital firm, Multiventure Investment, in 1984 as a joint venture with Continental Engineering Group. Equally important, Li invited senior Chinese-American financiers to establish venture capital companies in Taiwan. Ta-lin Hsu, who had been a key senior policy adviser and STAG member since the 1970s, set up Hambrecht & Quist Asia Pacific in 1986. Hsu reports that it was not easy to raise the initial $50 million fund. In particular Li "twisted lots of arms" to raise $21 million (51 percent) from leading Taiwanese industrial groups such as Far East Textile, President Enterprises, and Mitac. The balance (49 percent) came from the government.[3]

The first general manager in H&Q Asia Pacific's Taipei office, Ding-Hua Hu, earned a doctorate in engineering at Princeton University in the 1970s and played a lead role in building Taiwan's semiconductor industry as the first general director of the Electronics Research and Service Organization (and previously an associate director of the Industrial Technology Research Institute and a professor at Chiao Tung University). His career—and connections—underscore the extent to which the social and professional networks cut across university, government, and private sector (both financial and industrial) worlds in Taiwan and the United States. H&Q Asia Pacific's early investments included Acer, United Microelectronics Corporation (UMC), Microtek, and Tai Yan. The early successes of these investments made successive rounds of fundraising easier.

Two other U.S.-educated Overseas Chinese engineers, Peter Liu and Lip-Bu Tan, responded to Li's invitation as well, establishing Taiwan's second U.S.-style venture fund, the Walden International Investment Group (WIIG) as a branch of the San Francisco–based Walden Group in 1987. Both H&Q Asia Pacific and WIIG—along with Peter Liu's spin-off firm, WI Harper, remain leading investors in Taiwan's technology industries, and increasingly in Mainland China as well.

Once the early investments began to pay off, domestic IT firms created their own venture capital funds, including Acer, D-Link, Macronix, Mosel, Taiwan Semiconductor Manufacturing Company (TSMC), SiliconWare, UMAX Data Systems, UMC, and Winbond. After that, even the old-line firms in traditional industries that had been reluctant also began investing in IT-related businesses.

The availability of venture capital transformed the Science Park from its originally envisioned role as an export processing zone into an open environment for the growth of indigenous technology firms. This was distinctive in Asia at a time when capital was available only to large corporations with ties to governments or to wealthy families. While throughout the 1980s Taiwan remained a low-value-added producer of electronics components, in the early 1990s—with the growth of entrepreneurship and accumulated production experience—local firms began to differentiate products on the basis of innovation and quality rather than simply low cost.

Building China's Venture Capital Industry

In the 1980s the Chinese government initiated creation of a domestic venture capital industry as a mechanism for supporting new technology ventures. But in contrast with Taiwan, where the venture capital industry took off in the 1990s, China's venture capital industry is constrained by the financial system and capital markets inherited from the planned economy. The China New Technology Venture Investment Corporation, which was established as a limited corporation in 1985 by the State Science and Technology Council and the Ministry of Finance as the country's first experiment with venture capital, was declared bankrupt and closed by the People's Bank of China in 1997. This and several other early failures were an indication of structural problems, but did not stop local governments, universities and state-owned companies, and other organizations from setting up venture capital funds.

By 2000 there were approximately 160 domestic venture capital firms in operation in China, primarily located in Beijing, Shanghai, and Shenzhen. The underlying problem in many of these funds is that the government remains the primary source of capital, either directly or indirectly through university or state-owned firms. (There is ample private capital in China today but it is not being invested in venture capital funds.) This problem compromises the incentive for fund managers to make high-risk investments, particularly in private enterprises (White et al., 2002).

An investment in a government-owned company, by contrast, carries very little risk. Julie Yu Li, a partner in a venture capital firm started by a government-owned trading company in Shenzhen, summarizes the challenge: “I am supposed to invest in high-technology businesses, but my director once asked me if I could ‘reduce the risk to zero’!” And she points out other limits of the current system: “I never expected my job would be this difficult. We have no way to identify entrepreneurs or to evaluate risks and returns and we must get approval from the president of the company to make any investments, which takes forever because it’s so hard to get access to senior management.”[4] A Silicon Valley–based entrepreneur who has advised the Chinese government on reforming the industry notes: “Venture capital fund managers in China have little at stake in the success of their ventures. If they are honest they will take no risk at all; if not they take advantage of the opportunity to make under-the-table deals with entrepreneurs.”

The legal framework for venture capital is also not in place. For example, Company Law in China requires a minimal number of shareholders and level of investments (RMB 100,000 yuan per holder) that exceed the practice in the typical venture capital firm; likewise, it stipulates that the accumulated amount invested should not exceed 50 percent of the company’s assets, which again arbitrarily limits the role of venture capitalists. Apparently these rules are being overlooked in practice (Xiao, 2002).

Some formal adjustments are being made. In 2001 the government issued a notice announcing that foreign companies would be allowed to set up wholly owned or Sino-foreign cooperative venture capital firms in China. Foreign venture capital firms are not, however, allowed to invest in securities, futures, or other financial markets, or in real estate and other industries that are not open to foreign investment. They are also not allowed to make loans or underwrite or invest with borrowed money (CIEC, 2001). Other regulatory changes were targeted at the venture capital investments in technology firms, including reduction of minimum levels of capital invested, establishment of a preferential tax regime (10 percent) for venture capital investors, and recognition of the limited-liability partnership structure that is common to many venture capital funds in the West. Chinese Company Law also limits the amount of an enterprise’s registered capital that can be granted for the contribution of intangible technology to a maximum of 20 percent. This limit has been abandoned in practice but not yet in regulations. However, the failure to specify restrictions on the qualifications for the general partners in a limited-liability partnership makes it likely that many more venture capital firms in China will fail to earn returns.

The problem is compounded by inexperience. Fund managers typically have little technical or business understanding of the industries they are investing in; they also lack procedures for objectively evaluating potential projects and ideas, and they have limited understanding of corporate governance. Potential entrepreneurs in China rarely know how to develop a viable business plan; they lack understanding of markets or management experience, and so they frequently adopt the model of the traditional Chinese family firm with husband and wife running the business rather than the professionally managed enterprise (which leads to struggles over ownership and control of the business). The managing director of the Beijing

Venture Capital Company describes other challenges, including the information asymmetries between investors and fund managers and between venture capital firms and the companies they finance. In both cases the lack of transparency, objective performance measures, and external oversight creates incentives for concealing or falsifying information (Xiao, 2002). As a result, while the Chinese venture capital has financed thousands of high-tech enterprises, these funds have generated only minimal returns.[5] A cynical interviewee claims that most venture capital in China is simply a new form of job creation for local governments.

The only real high-risk investors in China are the approximately fifty foreign venture capital firms that have a presence in the country—including many from Taiwan and Silicon Valley. However, these firms—including Japan's Softbank, Warburg Pincus, Intel VC, WI Harper, WIIG, H&Q Asia Pacific, Acer Technology Ventures, V2V, IDG, and Vertex (Singapore)—have invested quite cautiously in China. The overriding problem for these international investors is the lack of viable exit options, since access to the Chinese stock market has been impossible. Private enterprises in China have virtually no access to public capital markets because the two main trading boards, in Shanghai and Shenzhen, are dominated by former state-owned enterprises. Equally important for foreign investors, the RMB is not convertible, so there is no legal way to get earnings out of the country. International investors have consistently pushed for reforms to improve the environment for equity investments in China.

International venture capital has not only pushed hard for institutional reform but also financed some of China's most promising new technology enterprises. The successful firms typically have experienced senior management teams who are returning from the United States with sophisticated business plans, typically with the goal of serving the fast-growing China market. These "cross-Pacific start-ups" are typically headquartered in Silicon Valley, incorporated in the Cayman Islands or the Bahamas, and structured as U.S. Delaware-style corporations. Most have a permanent research and development capability in Silicon Valley as well as higher-level design or logistics capability in Taiwan.

These entrepreneurs and their investors are primarily Mainland-born or Taiwanese, with the firsthand knowledge of the language as well as culture and institutions that are essential to doing business in China. These returnees are often advantaged by networks of former classmates, friends, and family they can tap as they undertake the challenges of growing a firm in an environment that requires personal connections to get things done. Their investors typically bring knowledge not only of technology and management but also understanding of and experience in doing business in the Chinese market.

The Chinese stock market was organized in the 1980s to provide capital for the expansion of state-controlled companies, and that bias continued during the 1990s as the exchanges were used to prop up failing state-owned enterprises. Even today, in spite of efforts at reform, the market remains poorly regulated and subject to price manipulation. The old governmental quota system, which gave each province an annual initial public offering (IPO) quota and ensured that state companies dominated the market listings regardless of their profitability, is being phased out. However, the top regulators and exchange officials for the China Securities and Regulatory

Commission are government appointees, and promotion is based more on internal politics than on performance in managing the exchange.

The main trading boards have onerous listing requirements and complex regulatory procedures for approving public share offers that tend to favor state-backed firms. It took four years of intense lobbying for UFSoft to be listed on Shanghai's main board, in spite of its market leadership in accounting software, because of Chinese regulators' reluctance to approve privately owned firms. In 2000 only a handful of the thousand-plus companies listed on the Shanghai and Shenzhen exchanges were started as private companies.

Some Chinese policymakers are actively seeking to improve the environment for venture capital, and the past few years have seen almost continuous reform. The China Securities and Regulatory Commission in the late 1990s planned a second board in Shenzhen modeled after NASDAQ for high-risk, high-return companies. However, the anticipated opening was delayed indefinitely following the U.S. technology stock collapse in early 2001. An initial step toward setting up the second trading board was taken in 2004 when small and medium-sized firms were allowed to list on the Shenzhen exchange for the first time, and the expectation was that a second step would be taken in 2005 with a lowering of the listing requirements for these smaller capitalized companies. On the other hand, when a local government issues a list of the industries that venture capital will focus on in the coming years, it shows that China is often still trying to "grow the new economy using the tools of the planned economy" (Xiao, 2002).

Sustainable Start-Ups

Acer Technology Ventures, the investment arm of Acer Computers, has played a central role in promoting cross-Pacific start-ups through investments in companies based in the United States and Asia. Its "IP Fund One" is a limited partnership incorporated in the Cayman Islands, devoting its $260 million to early-stage start-ups in the Internet protocol (enabling technology and solutions based on Internet platform) and intellectual property (software, IC design, etc.) fields. The limited partners include Acer affiliate companies (32 percent), Acer top management (6 percent), and institutional investors. With offices in Silicon Valley, Taipei, Shanghai, and Singapore, the firm markets itself as bringing "unique intangible value to portfolio companies with cross-regional business concepts." In particular, the firm provides "Cultural understanding to assist entrepreneurs in breaking new grounds cross-regionally in North America and the Asia Pacific region" (www.acervc.com). This assistance includes both communications and connections in these distant locations.

The sustainable cross-Pacific start-up, according to Acer's Ronald Chwang, is a technology-intensive business that combines Silicon Valley's new product and business vision, technology architecture, product marketing, and research and development coordination with China's research and development implementation, manufacturing and production logistics, and field engineering and local sales support. This leverages the management experience of Silicon Valley's overseas Chinese, China's low-cost engineering resources, standard and commercially available development tools, and the supply chain manufacturing infrastructure of Greater China (Taiwan and Mainland). In this vision, products like mobile appliances or new semiconductor designs can rely on the U.S. market as an early drive and then be commercialized in both China and U.S. markets.

There remain substantial challenges to these cross-regional start-ups. Venture investment in China is still in its early stages: there has not yet been a complete cycle of investments and reinvestments in a second generation of entrepreneurs. Cross-regional firms also face significant difficulties coordinating distant activities, particularly in developing organizational synergy and persistent, consistent communication. Finally, they face the challenge that all technology firms in China face, of controlling and protecting their intellectual property (Chwang, 2003).

The Acorn Campus was established in Shanghai by a team of a half-dozen experienced overseas Chinese engineers—Taiwanese as well as Mainland-born. General partner Wu-Fu Chen, for example, is one of Silicon Valley's most successful repeat entrepreneurs and a leader in the field of telecommunications and optics. The campus is an incubator in which they serve as "angel investors" and provide mentoring and connections, as well as space, for promising new ventures with Chinese founders. One of their recent investees, Newtone Communications, a telecom software firm, realized that its seed money of $500,000 would go much further in China than in the Bay Area. After moving to Shanghai, these returnees doubled their employment without increasing their budget.

This experience spurred the creation of a new Acorn Campus in Shanghai. In raising money for the Acorn Campus Asia Fund, the founders' mission is 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" (www.acorncampus.com). Like WIIG, they address returning Silicon Valley Chinese entrepreneurs with substantial experience, and their focus is on semiconductor design, wireless infrastructure, and system and software development. They talk about accessing the best resources from different locations: reserch and development, new product development, and marketing in the United States; high-end logistics, design, and manufacturing in Taiwan; and low-cost engineering and manufacturing talent in China.

The power of the overseas community is most evident in the semiconductor industry, which originated in Silicon Valley and has been transferred by Chinese entrepreneurs first to Taiwan and then from Taiwan and Silicon Valley to China. In the words of WebEx CEO Min Zhu, "Silicon Valley is the technology leader and the center for real innovation because it supports the growth of start-ups. New firms cannot grow this fast in China or India. The most powerful model is a truly international company that combines the creative ideas and architectures that are developed in the United States with the ability to quickly implement them where skill is less expensive: both need to be scaleable."[6]

Of course, these are not one-way flows. While the Taiwanese IC industry initially grew out of talent and technology from the United States, producers like TSMC contributed indigenous innovations that in turn benefited the entire industry. It took follower UMC about a decade to reduce a process-technology gap of two or three generations to one generation (by the mid-1990s); today the firm is very close to the global leaders. China remains at a lower technological level than either Taiwan or the United States but now has in place the skill, capital, know-how, and connections to learn by doing. Over time the Chinese market will provide local IC designers and manufacturers the opportunity to experiment with, and ultimately innovate in, fields like wireless communications.

It is easy to overstate the scale of the domestic Chinese market in the short term. However, the internal demand for technology products remains relatively low; the domestic fabricators are serving foreign customers primarily. For example, Semiconductor International Corporation's early customers were overwhelmingly outside of China: according to the company's 2004 10K filing, in 2003, 36.7 percent of customers were located in North America, 26.7 percent in Taiwan, 12.5 percent in South Korea, 11.2 percent in Japan, 11 percent in Europe, and 1.9 percent in the rest of the Asia-Pacific region, including China. There is substantial room for growth of the domestic semiconductor market, but China will most likely continue to consume relatively low-end chips (the type used in watches, radios, cell phones, and other consumer electronics products) for the next five to ten years. IC manufacturing technology in China continues to lag behind Taiwan, and U.S. regulations on export of the most advanced manufacturing equipment to China will likely continue to slow the adoption of leading-edge process technologies.

And while research and development expenditures have increased significantly, China's companies, universities, and researchers remain relatively isolated from the market. As Frank He, president of a Dallas-based software company, puts it, "In China, research is too far from being applied to real life. For example, we can barely find one out of five hundred Ph.D. dissertations (e.g. in Computer Science) with research findings useful for commercialization. While in the United States, one dissertation out of one hundred can be turned into a real product" (Saxenian, 2003). 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 percent of those in the United States, and the domestic market for IC design in China will reach an estimated $10 billion in 2010. According to Woetzel and Chen (2002), a senior IC design engineer with five years' experience or more earns a salary of US$14,000–$30,000 in China compared to $80,000–$150,000 in the United States; likewise a junior design engineer in China earns $9,000–$20,000 compared to $50,000–$100,000 in the United States.

The circulation of world-class engineering and entrepreneurial talent between the United States, Taiwan, and China is altering the economic trajectories of all three. The coming years pose a serious challenge to the adaptive capacities of Taiwan's industrial system. Experts claim that Taiwan has only ten years before China reaches technological parity in manufacturing of even the most advanced ICs and IT products (Clendenin, 2003). During this time, Taiwanese industry needs to establish new specializations, either as producers of higher-value-added software, content, and services or as manufacturers of distinctive systems and equipment that build on their existing strengths in designing, manufacturing, and recombining intermediate parts and components.

Semiconductor equipment maker Applied Materials predicts that by 2010 China will account for 7 percent of global semiconductor production, compared to 0.5 percent in 2000, and it will be a global center for low-cost IC manufacturing and regional distribution. Taiwan will, in this view, play a complementary role to China by transforming itself into a center for high-value-added IC design, productization, and advanced IC manufacturing. The United States (and Silicon Valley in particular) will remain the center for systems and chip architecture, capital investment, and production of IC manufacturing equipment.

The Taiwan-China connection will most likely continue to grow and deepen. Taiwan's 2001 IT investments of $2.6 billion in China are forecast to grow at compound annual rate of 32 percent and reach $10.6 billion in 2006; at that point Taiwanese IT investments in China are expected to surpass their investment in Taiwan (Chan et al., 2002), driven both by the rapid growth of China's domestic market for IT products and by the falling tariffs as a result of China's continued integration into the WTO.

The relationship between China and Taiwan, like that between the United States and Taiwan, is increasingly complementary rather than competitive, with Taiwan moving up the value chain to provide leading-edge manufacturing services and high-value-added design while China becomes a center of low-end, labor-intensive design and assembly-and-testing as well as non-leading-edge manufacturing.

Venture Capital and Entrepreneurship in India

Veteran Silicon Valley venture capitalist William H. "Bill" Draper III took U.S.-style early-stage venture investing to India in 1995. Soon after establishing a $55 million fund, Draper International, with a colleague in San Francisco and local partners in Bangalore and Bombay, he realized the many obstacles involved in working with entrepreneurs in India. The concept of venture capital was new in India, where the closely held family-centered business model dominated both small firms and the large groups like Birla and Tata. It was very difficult to coordinate activities between India and Silicon Valley, and start-ups—with far more limited resources—faced all the same frustrations experienced by multinational investors, from the frequently corrupt and restrictive bureaucracy, to the lack of Western-style stock option plans, to retain key personnel to the limits of basic infrastructure such as power and water and the very high cost of connectivity. In the words of Draper's partner, Robin Richards, in 1997:

> From a venture capitalist's perspective, it is 5–10 times slower to start up a company in India than in the U.S., mostly due to the difficulty of getting the correct infrastructure in place for production. And since most of the technology market is focused in the West, it is difficult for an India-based entrepreneur to form the necessary business partnerships, and find the right management, marketing and sales talent to join his or her company. (Kurian, 1997)

Within two years, Draper and Richards had reoriented the strategy for the fund to focus primarily on investments in U.S.-based firms with a large proportion of their activities in India. When the fund closed in 2000, only one of the India-based companies that had received funding was successful (Rediff Communications), whereas a majority of the U.S.-based firms in the portfolio had found liquidity. The timing was fortuitous, to be sure, but Draper attributes the successes as well to the combination of technology development in India and business, marketing, and sales operations "near the action" in the United States. Some of the firms in the fund were in the United States to start, but others were in India and Draper brought them to Silicon Valley. According to Richards, they learned about some of their best U.S.-based deals in India: "You could be sitting in Bangalore and hear about 10 great deals in Santa Clara that you could be a venture capital investor in, but you'd hear about them first in Bangalore" (Schram, 2001: 66).

Draper International discovered that the ecosystem for Silicon Valley–style entrepreneurship was absent in India in the 1990s. Successful Indian and multinational software services and business-process firms had created facilities that allowed them to draw on local skill, but they remained externally oriented and isolated from the local environment. Labor mobility in regions like Bangalore was 20–30 percent in the 1990s as workers sought to maximize their earnings in a tight market, but it was not associated with the experimentation of a technical community as in Silicon Valley or Hsinchu. As a result, it simply contributed to annual wage increases on the order of 25–40 percent, as well as the increasing tendency for firms to expand to other areas (Parthasarathy, 2000).

Learning in the Indian software industry occurred primarily within the firm and through long-distance relationships, not through interactions with local customers or institutions such as universities or research laboratories—in spite of the fact that Bangalore is home to India's leading university and government research centers, including the elite Indian Institute of Science, the Center for the Development of Advanced Computing, and a range of telecommunications and defense-oriented research facilities. The public and private technology sectors, as well as industry and universities, in India remained separate spheres, with minimal professional or commercial interaction.

A study of Northern Telecom's research and development alliances with four Indian firms during the 1990s documents this pattern. These alliances were formally defined as between Nortel (as the director) and the individual firms (as software subcontractors and developers); they did not encourage interaction among the Indian partners or with local universities, and they developed products for foreign markets. Once again, these relationships were established largely through the active efforts of two senior Indian-born employees, both in the conceptualization and in the implementation. Scholars Basant and Chandra (2004) contrast this with Nortel's collaboration with the Beijing University of Post and Telecom, which involved joint research and development based at the university and was oriented toward developing products for the domestic market. They conclude that the Indian model, while benefiting the four Indian firms, had a more limited long-term impact on the domestic skills and technological capabilities than the Chinese model.

A domestic venture capital industry emerged in India in the 1990s, but much of it was large public sector funds or banks and multilateral institutions. Organizations like Union Trust of India Ventures or Small Industries Development Bank of India Venture Capital lacked domain knowledge or experience in software or technology-related industries. The funds, typically run by conservative financiers concerned with tangible assets and unwilling to take risks, were overwhelmingly late-stage investors in software services. In the words of A. V. Sridhar, former senior manager at Wipro: "The Indian venture capitalist will not take risks in new areas, as opposed to a risk-free definitive software services market, where he is assured of quick returns and profits" (Biswas, 1998).

The supply of venture capital in India remained very small by international standards, in part because of a multiplicity of conflicting, often cumbersome and anachronistic regulations and a variety of other forms of discrimination against the industry. In 1998 only 21 companies were registered with the Indian Venture Capital Industry Association, and they had approximately $700 million available for investment. This compared to Israel's 100 funds with $4 billion available for investment in 1999 and Taiwan's 110 funds with $1.32 billion investments.

A few domestic technology start-ups survived the environment of the 1990s, as well, but none experienced the successes of start-ups in Taiwan or Israel at the time, although most were started by returnees from the United States (Desai, 2003). For example, Silicon Automation Systems (SAS) was started in Silicon Valley in 1989 by four U.S.-educated Indian engineers. They bootstrapped the venture, and in 1991 they moved part of the operation to Bangalore while seeking to maintain a strong research and software and hardware design (as opposed to software services) orientation. In 1997 SAS was a small, privately held firm with about three hundred employees and $10 million in exports. Another returnee, Pradeep Singh, started the software services firm Aditi in Bangalore in 1994, after nine years at Microsoft. With headquarters in Seattle, Aditi relied on Microsoft as a stable client while also seeking to grow the business. During the 1990s most of the other returnee start-ups in Bangalore and elsewhere in India—a small number, to be sure—either failed or stagnated.

Growth and Constraint

The boom in the U.S. technology sector in the late 1990s had contradictory consequences for India. On one hand, labor shortages resulted in an increase in the quota for temporary visas granted on the basis of skill, with 124,697 Indian nationals gaining approvals of H1-B status in 2000 alone, representing nearly half (48 percent) of all visa approvals. The next largest sending country was China, accounting for only 9 percent of H-1B recipients (22,570). Desai (2003) estimates that at least a half-million Indian programmers received U.S. visas (of all sorts) between 1996 and 2001.

Labor shortages also contributed to the growing numbers of cross-regional start-ups between Silicon Valley and India. Rakesh Mathur, who worked for Intel in Silicon Valley for many years before starting three successive successful technology companies—Armedia, Junglee, and Stratify, explains: "The key constraint to starting a business in Silicon Valley in the late 1990s was the shortage of software developers. I realized that I could go to India. All three of my start-ups had design centers in Bangalore but were registered as American technology companies" (Mathur, 2002). Mathur made six trips to India in 1999, and in 2000 his firm Stratify established a hundred-person operation in Bangalore.

Mahesh Veerina, who started self-financed Internet technology firm Ramp Networks in 1993 with two friends, reports that they were quickly running out of money and couldn't afford to pay for local engineers, so they hired programmers in India for one-quarter of the Silicon

Valley rate. The firm's engineers reported that they were able to cut development time in half because Indian team worked while the U.S. team slept. By 1998 the firm had sixty-five employees in Santa Clara and twenty-five in India—and required that every engineer spend at least a couple of weeks working in the other country (Thurm, 1998). While data are not available, it appears that this cross-regional business model was increasingly common in the late 1990s.

While firms like Ramp Networks and Stratify represent the standard model for building a cross-regional company, starting in the United States and tapping talent in India, Draper International pioneered the reverse strategy. In 1997 the venture capital firm identified and recruited A. V. Sridhar, a senior manager at Wipro who had never worked outside India, to Silicon Valley to start a company in the data mining field. Sridhar quickly identified a marketing team, including Sanjay Anandaram, who was already working for Wipro in Silicon Valley, and senior managers with experience at Oracle India and IBM Research. The start-up, Neta Inc., developed Internet personalization software and was acquired two years later by Internet portal Infoseek (now Go.com). Sridhar explains why he moved to Silicon Valley to start the business: "To create a successful company, one has to be real close to the market. One has to be in a place which supports the creation of new technologies as a daily affair" (Biswas, 1998).

Permanent returnees to India from Silicon Valley remained few and far between throughout the 1990s, but the professional and personal networks linking Indians in Silicon Valley to family members, friends, and colleagues at home combined with access to e-mail and low-cost travel and phones to generate an unprecedented rate of information exchange between the United States and India. In the words of a Silicon Valley engineer:

> I go back to India two or three times a year because of my work and there are parts of India where you take a train and go over there and they don't even have a rickshaw or a cab to take you to your destination. You have to walk. But everybody in the small town knows exactly what the job situation is in Silicon Valley. They know the H-1B quota level, when it is filled, when it is open again. They know exactly what kinds of skills are required in Silicon Valley, not even in California, just Silicon Valley. (Santa Clara County Office of Human Relations, 2000)

Web sites like www.return2india.com, Non-Resident Indians Online (www.nriol.com), and www.siliconindia.com became increasingly popular among U.S.-educated Indians. They traveled home frequently, some returning home to get married (often following the traditional practice of arranged marriage), and seemed torn between the familial and cultural pull of home and what they regarded as superior professional and economic opportunities in the United States.

The potential for substantial returns has attracted a new generation of venture capitalists. A group of new $50 million to $100 million funds, typically from established markets such as Walden International and E-Ventures (Softbank), targeted early-stage investments in India. Corporate venture capital also became active in Indian technology regions. Intel Capital committed to invest $100 million in Indian IT start-ups during 2000, and Computer Associates began investing actively as well. Traditional sectors that had earlier shunned the software industry became interested in investing because of the high valuations. Fund managers began to tap India's high-net-worth individuals and family firms for capital. Total venture capital investments in India reached $1,160 million in 2000. The level declined to $937 million in 2001 and dropped off further in 2002 and 2003.

A new generation of cross-border investors with accumulated experience in both India and Silicon Valley has emerged, as well. The JumpStartUp Venture Fund was established in Bangalore in July 2000 by three veterans of the IT industry: Kiran Nadkarni had fourteen years of experience with venture capital in India, serving most recently as the Draper International partner in Bangalore; K. Ganapathy Subramanian came from ICICI Venture, a leading venture capital firm in India; and Sanjay Anandaram, who had worked at Wipro in both Bangalore and Silicon Valley and then at start-up Neta Inc. The $45 million fund was targeted at early-stage information technology start-ups and had funding from both institutional investors (including Silicon Valley Bank) and individuals, including Bill Draper and successful Indian executives in the United States (contributing 20 percent of the fund).

In 2002 JumpStartUp moved its headquarters from Bangalore to Santa Clara, California, in order to shift its investment strategy from an India-focused fund toward "U.S.-India cross-border investments." The partners realized that their small fund was not sufficient to support early stage start-ups from the ground up in the environment of the early 2000s, when outside investors were reluctant to contribute to cash-poor companies. The new strategy recognizes that Silicon Valley's cash-strapped new ventures must increasingly set up engineering centers in India. JumpStartUp envisions a role as co-investor with established venture capital firms in order to help portfolio companies set up engineering teams as well as design, deployment, and support functions in India. In the worlds of Nadkarni: "It is very hard for companies started by non-Indians to think of working out of India, unless they have done it in the past. Unless the founders have intent to do things out of India. . . . When a startup decides to establish a development center in India, invariably you will see that one of the founders is an Indian" (Shankar and Sundaram, 2003).

Most venture capital in India remains focused on later-stage investments in software services firms, but venture capital firms with Indian fund managers who bring technology investment and entrepreneurial expertise have targeted the early-stage U.S.-India connection as well, including WestBridge Capital Partners and Artiman Ventures. The economic logic for this structure appears compelling: a company that would need $10 million to $15 million in its first round of funding in Silicon Valley might hire a comparable engineering workforce in India for only $2 million to $3 million.

Conclusion

The old pattern of one-way flows of technology and capital from the core to the periphery is being replaced by a far more complex and decentralized two-way flow of skill, capital, and technology between differently specialized regional economies. Silicon Valley is now at the core of this rapidly diversifying network of economies because it is the largest and most sophisticated market as well as a leading source of new technologies. However, this too could change: the relationships between these emerging technology regions are multiplying and new markets are opening up in China and India that promise to further transform the dynamics of the world economy.

Regions like Hsinchu, Bangalore, and Shanghai are not replicas of Silicon Valley—although institutions and professional service providers from that region are fast expanding into these new environments. These new regional economies have co-evolved with the Silicon Valley economy. Firms in these regions do not typically seek to compete directly with Silicon Valley producers. They focus instead on developing capabilities in areas that U.S. producers are not pursuing; and over time they have transformed activities once regarded as mundane and low-tech into more efficient and dynamic sectors. So while producers in these regions entered the global market by providing low-cost skill, each has developed specializations that add distinctive new value to electronic products and systems. Taiwan was known in the 1980s for its cheap PC clones and components; today it is recognized for the flexibility and efficiency of its IC and electronic systems producers. China was known in the 1990s for me-too Internet ventures; today Chinese producers are poised to play a lead role in developing wireless technology. In the 1990s India was a provider of labor-intensive software coding and maintenance; today local companies are managing large-scale software services projects for leading global corporations. Israel was a low-cost location for research in the 1980s; since then local entrepreneurs have pioneered sophisticated Internet and security technologies.

These developments explain why Silicon Valley–based firms are active participants in all of these regions as investors and as partners, not simply as competitors. An established firm like Cisco designs and sources critical parts of its operating system software from India and application-specific integrated circuits from Israel for its high-end routers, and the manufacturing of most of its hardware from Taiwan and China. It also invests in start-ups with promising technologies in these locations. On the other hand, a start-up (or "micro-multinational") like July Systems obtained venture capital from firms based in the United States, Taiwan and China, and India, and its products will likely incorporate components from all these locations as well as being targeted at all their markets.

The new technology regions have all become high-wage, high-cost locations in their national economies, yet they continue to spawn start-ups and attract new firms, and most existing producers continue expanding locally. This growth is reminiscent of the continued clustering of computer and communications-related firms in Silicon Valley during the 1980s and 1990s; these areas now boast a regional advantage that compensates for their high costs. Silicon Valley producers no longer view locating or sourcing from India or China as an efficient way to reduce costs; rather, they argue that the only reason to work with producers in those locations is to gain access to the talent.

U.S. technology producers benefit directly from the development of these specialized technology regions. They now look to their counterparts in Taiwan and China, India, and Israel not simply for low-level implementation but increasingly for co-development and co-architecting of products and components. In addition, firms in the new technology regions are increasingly partnering with one another as well as with firms from Silicon Valley, as when a Taiwanese semiconductor firm invests in Israeli start-ups specialized in digital speech processing chips, or when an Israeli company contributes intellectual property components to a chip design firm based in India. These collaborations deepen the capabilities of each of the partners and over time can support a process of reciprocal innovation and upgrading in the respective regions.

The nature of the firm is being redefined through this process as start-ups and investors as well as established enterprises move across geographies and open their boundaries in new and different ways. The corporate hierarchies and vertical integration of the twentieth-century mass production corporation are being replaced by horizontal networked organizations that flexibly recombine resources by drawing on the specialized and complementary capabilities of producers located in distant regions. This often involves extensive information exchange and collaboration between customers and suppliers who are located at great distances. This suggests that the region and its distinctive capabilities and resources, rather than the firm, are increasingly defining the contours of the global production.

A Model for Others?

This is not to suggest that all developing economies are positioned to reap the benefits of brain circulation and peripheral entrepreneurship. This opportunity is benefiting countries that have invested heavily in higher education, typically technical education, and are politically and economically stable enough that immigrants will consider returning home. Some of the largest technically skilled immigrant groups in Silicon Valley have not built business or professional connections to their home countries for political reasons. Most of the region's Iranian and Vietnamese immigrants, for example, are political refugees and hence not inclined to return to countries that, in any case, lack the economic stability needed for technology investment or entrepreneurship. This criterion applies in varying degrees to many of the developing economies that have technically skilled communities in the United States and at home, including Russia, parts of Eastern Europe, and Latin America. It is possible that urban areas like Saint Petersburg or Buenos Aires will become more attractive to returning entrepreneurs in the future as their economies develop and eventually provide greater professional opportunities for returnees. However, large parts of Africa and Latin America lack the skill base or political openness to become attractive environments for technology entrepreneurship.

Industrialized economies in Europe and Asia face different challenges. While they typically boast well-developed skill bases, research capabilities, and sophisticated infrastructure, technical skill is significantly more costly in these economies, particularly relative to recently developed economies like Taiwan and Israel. The financial and corporate structures in industrialized economies often discourage technology entrepreneurship, as well. In Japan and France, for example, the privileged relationship of large corporations, banks, and the state limit the opportunities for outsiders (returning entrepreneurs) to raise capital or develop domestic markets. Continuing discussions in Europe of creating industrial champions suggests that policy there may continue to reinforce, rather than dismantle, these relationships.

The structure of labor markets mirrors this configuration: the technical elite in countries like Korea and France move automatically into high-status positions at the top of the large corporations and banks or the civil service. They have little incentive to study or work abroad, and face significant opportunity costs if they do. This disincentive helps explain why relatively few pursue graduate education in the United States, and why those who do frequently return home directly upon graduation. Those who end up in Silicon Valley are less likely to be the top of their class, and they gain little respect, let alone access to capital, by returning home.

In many Asian countries, government support for large-scale, capital-intensive investments in the 1970s and 1980s, either by domestic corporations (Korea) or by multinationals (Singapore), have created inhospitable environments for entrepreneurial experimentation. One indication of this is data on the sources of innovation. South Korea's *chaebol*, or large business groups, accounted for 81 percent of all U.S. patents earned in Korea in the 1990s compared to only 3.5 percent earned by business groups in Taiwan (Trajtenberg, 2000). Likewise, in South Korea the top fifty assignees accounted for 85 percent of all U.S. patents, with Samsung alone accounting for 30 percent, while Taiwan's top fifty assignees accounted for only 26 percent of all U.S. patents. This decentralization of innovative capabilities was reflected in a substantially higher rate of patenting in the late 1990s, with Taiwan earning 17.7 patents per US$ billion exports compared to 11.6 in Korea (Mahmood and Singh, 2003).

Evidence from the Korean and Japanese communities in Silicon Valley suggests that even when entrepreneurs are successful in the United States, they often lack opportunities for alliances and partnerships at home. It is very difficult for these small firms to collaborate on equal terms with the giant *chaebol* and *keiretsu* (industrial groupings in Japan). This contrasts to the Taiwanese technology entrepreneurs in Silicon Valley whose firms have grown up through partnerships with their counterparts, often also entrepreneurs, at home. And as with European cases, Japanese and Korean graduate students earning degrees in the U.S. are typically lured back home immediately by attractive opportunities in government, large corporations, or universities.

Another group of developing economies has grown since the 1970s as recipients of manufacturing investments by United States, Japanese, and European technology corporations. These investments, which were targeted at low-wage locations including Singapore, Malaysia, Scotland, and Ireland, have contributed to the development of the supplier infrastructures and skill base needed to master high-volume manufacturing of electronic components (McKendrick et al., 2000; Rasiah, 2001). They have also contributed to substantial improvements in standards of living. However the leading recipients of foreign direct investment remain technological laggards. The rate of patenting, normalized by either population (Trajtenberg, 2000) or exports (Mahmood and Singh, 2003) in Singapore, Malaysia, Hong Kong, and Ireland since 1970 remains a small fraction of that observed in Taiwan and Israel. Seven of the top ten patent recipients in Singapore, for example, were foreign multinationals or organizations, accounting for 46 percent of all U.S. patents between 1970 and 2000 (Mahmood and Singh, 2003).

Recent policy changes, such public support of venture capital, have not been sufficient to transform domestic institutions and capital and labor markets. In these nations, skilled workers prefer stable, corporate employment, and start-ups lack access to financial and technical resources as well as markets. The 2000 *Global Entrepreneurship Monitor,* for example, found that in spite of higher than average GDP growth, Singapore had "one of the lowest rates of entrepreneurial activity" of more than twenty countries it studied (Reynolds et al., 2000). Returning engineers to these nations have not made a significant impact on their home countries.

The creation of a transnational community is a two-way process. While policymakers and planners can encourage cross-regional connections, they cannot create or substitute for transnational entrepreneurs and their decentralized networks. Government agencies from Singapore, Hong Kong, and Japan regularly sponsor networking events for their expatriates in the Bay Area as a way to recruit return entrepreneurs and investments. However, the absence of entrepreneurial collaborators at home means that these agencies can provide incentives and information but not access to partners with an interest in jointly transforming the home environment. Governments cannot by themselves insure the preconditions for return entrepreneurship; this is inherently a process of collaborative institution building that takes both local knowledge and understanding of global technology markets and networks.

Cross-regional networks develop only when skilled immigrants are both willing and able to return to their home countries for business in large enough numbers to create close links to the technical community in the home country. The receptiveness of the home country depends upon factors such as political stability, economic openness, and level of economic development. It often builds on multinational investments in research and development that have contributed to a developing local skill base and infrastructure that supports entrepreneurship. The critical variable is the possession of political leaders willing to collaborate with returning entrepreneurs to develop a shared vision and remove institutional and political obstacles to entrepreneurship-led technology growth.

The Future of China and India

India and China, both very large developing countries that opened their markets to the global economy in the last two decades, have less-defined trajectories. The political and economic environment in these countries is complex, multilayered, regionally differentiated, and continually in flux. Both countries have attracted substantial foreign investments based on the combination of large technically skilled workforces and low wages. For both, brain circulation with an overseas community in Silicon Valley has been an important factor in attracting foreign investment. Policymakers from both countries have established ties to their large technical communities in Silicon Valley. Local and regional governments in both countries compete intensely for technology activity, and in each technology investment and entrepreneurship remain concentrated in a handful of urban centers.

The leading Indian technology firms today specialize in exporting software services to American and European corporations and are concentrated in a handful of large urban centers in southern India. The leading Chinese information technology businesses focus primarily on manufacturing for the domestic market, and are concentrated in the leading urban areas along the east coast of China—where the export products are overwhelmingly produced by foreign companies, mainly from Taiwan. China has benefited as well from growing ties to Taiwanese businesses, in spite of the political tensions across the Straits. Both cases show signs of the dynamic growth of cross-regional start-ups that will become competitive in global markets or grow sizable new markets. These firms are primarily started by returnees from Silicon Valley, and they have the potential to provide the basis for a decentralized entrepreneurial industrial system. However, it is still very early in the process: neither country has seen a full cycle of entrepreneurial success and reinvestment.

Some differences can be traced to institutional factors. In China, governments at all levels have channeled substantial investment into developing an urban infrastructure and growing the domestic market. The selection of information technology industries as a national priority has also triggered vastly increased investments for research and development, technical education, the adoption of information technology in both public and private sectors, and the construction of a seemingly unlimited number of science parks. Political control by the Communist Party, ongoing corruption, and chronic weaknesses in financial markets continue to create uncertainties about China's future.

India, by contrast, made expansion of export earnings a top priority in order to improve its balance of payments at a time when distrust of bureaucratic intervention (based primarily on the failures of the postwar "license Raj") led to the gradual embrace of liberalization and a largely hands-off approach to industrial development. Nonetheless, bureaucratic obstacles remain significant and have limited efforts to improve the domestic infrastructure—from roads and airports to energy supply and telecommunications. The risk of enclave-like development is quite real in India, where thriving technology districts like Bangalore appear better connected to Silicon Valley than to their impoverished domestic hinterlands. Unlike in China, where the government has used its resources actively to insure that investment and growth continue in the west as well as the wealthy eastern regions, the distrust of the public sector in India constrains the educational and infrastructural investments needed to spread the benefits of growth.

Both India and China are increasingly important actors in the global economy and particularly in technology industries. There are, however, many unanswered questions about their developmental trajectories. The technology sectors remain a small proportion of overall economic activity in both countries, and remain highly geographically concentrated. However, either could have a disproportionate impact over the long term. We can only speculate here based on the experiences of other countries and the initial experience of each over the past two decades.

Technology markets are shifting quickly, however, with demand growing rapidly outside the United States. While the Asia Pacific region (excluding Japan) accounted for only 6 percent of semiconductor consumption in 1985, in 2000 it accounted for 25 percent, and is predicted to grow to 46 percent by 2010 (with China accounting for 16 percent). China and India are now the fastest-growing markets for wireless technologies. In 2001, 400 million mobile handsets were sold in China. This is creating new opportunities for producers in these economies to develop products for their domestic markets. These markets are also likely to provide product and design inputs for the United States. SMS messaging on cell phones, for example, originated in Asia and Europe but has become increasingly popular with American youth. Likewise, the fuel cells developed for low-cost, long-lasting energy solutions for China and India could also change the economics of similar products in the United States.

Today the West and Japan produce more than half of global output but account for less than 15 percent of the world's population. This will change decisively in the next fifty years;

some observers predict that customer demand from India and China will dominate global markets within a decade, and that the Chinese and Indian economies will be bigger than the U.S. economy by 2050 (Wilson and Purushothaman, 2003). New regional economies will certainly develop sufficient technology capabilities to participate in global networks, as well. They will likely share with their predecessors a history of long-term investments in education and research, as well as the institutional openness that derives from the absence of organized interests from an earlier industrial era. Silicon Valley's role as the dominant technology center will continue to diminish. This does not mean that the region will decline, only that it will become one of many nodes in an open and distributed global network of differently specialized and complementary regional economies.

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Notes

[1] NSF data shows that over 95% of foreign-born engineering and science doctorate holders from India and China planned to stay in the United States after graduation.

[2] Indians accounted for 13% and Chinese for 14% of the region's engineers and scientists.

[3] Interview with Ta-lin Hsu, San Francisco, Ca. USA, June 1, 1997.

[4] Interview with Julie Yu Li, Shenzhen, China., January 11, 2001.

[5] Interview with Tang Hui-hao, Berkeley, Ca. USA, September 10, 2004.

[6] Interview with Min Zhu, San Jose, Ca. USA, April 16, 2001.