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An Overview

Henry S. Rowen

One of the most dramatic changes in the world economy over the past 30 years has been the rise of Asia in the information technology (IT) industry. The numbers are impressive. In 2003, the value of final consumption of IT goods worldwide, encompassing computers, telecommunications, and components, was about $1,500 billion with Asia (including Japan) comprising about 20 percent of this total. However, Asia produced about 40 percent of these goods, exporting the difference largely to the United States and Europe. The Asian shares of both consumption and production were rising rapidly.

The numbers for China alone are striking. Although still a poor country, it is the world's largest market for cell phones, the largest market for fixed telephone line subscribers, the number two market for cable subscribers, number two for PC ownership, and the number one growth market for broadband direct subscriber lines (DSL). On human capital, China is second only to the United States in terms of number of PhDs produced annually.

This book is about the causes and some major consequences of the rise of Asia in this industry. Geographically, we focus on six regions or countries: (1) Japan, (2) Teheran Valley in Seoul and Daeduk in Korea, (3) Zhongguancun Science Park in Beijing, (4) Hsinchu Science-based Industrial Park in Taiwan, (5) Singapore, and (6) Bangalore in India. In addition, we consider the clustering (or not) of companies within them. Other themes include expressions of innovation and entrepreneurship within this industry. We also discuss the roles of governments, venture capital, and university-business connections.

2 THE QUESTIONS ADDRESSED

In 1970, IT was a far smaller and less global industry. Several European countries and Japan each had national champion computer firms; Asian countries outside of Japan played negligible roles. IBM, the leader throughout the world, was the object of hostile action by the U.S. anti-trust authorities. Today, the scene is radically changed.

We ask these questions:

- Why has Asia emerged so strongly in this industry?
- What were the similarities and the differences in the strategies used among these countries?
- What accounts for their different specializations? How did their firms and governments decide what to make and how to make it?
- Why have companies clustered in particular localities?
- What were the initiating events in each cluster, and what has enabled them to grow?
- What roles have various institutions played—governments (national and local), universities, research institutes, financial institutions, legal professions, and so forth?
- What is changing? In particular, is Asia on the brink of forging ahead in important kinds of technology? If so, what are the implications for the United States?

Today's pattern is not fixed. Companies and governments in all these regions are trying to move up the value chain while others are trying to enter the marketplace and new technologies are emerging. There will be new companies and new industries. But there is also much path dependence; where the leading regions are today depends in good part on where they were yesterday and today's investments will strongly influence where they will be tomorrow. A region with established companies and an environment favorable for creating new ones is not easily displaced.

Although Asian regions are the focus of this book, implications for Silicon Valley and for the United States as a whole are also discussed. This is for several reasons. For one, Silicon Valley is widely seen as the most successful high-tech cluster in the world and a model for comparison and emulation. Another is that the United States, with Silicon Valley as the main hub, has been the principal source of ideas that have led to IT products worldwide, and the Asian nodes in the IT value-added chain are linked in many ways to it. A third is that the rise of Asia poses a challenge to Silicon Valley's eminence.

OPPORTUNITIES SEIZED IN A RAPIDLY EXPANDING WORLD MARKET

A good place to begin is the vast expansion of the Asian economies and of world trade during the past several decades. World economic growth from 1970 through 2003 averaged 4 percent a year, and world trade growth 6 percent. Growth in much of East and South Asia was much faster. Japan's economy took off right after World War II and grew rapidly for 30 years. Next came the four "Tigers": Korea, Taiwan, Hong Kong, and Singapore, which grew at 8 percent annually for several decades. They have been followed by China's growing at 8–10 percent a year. These countries are having a large impact on the world economy, and so will India if it sustains its recently improved performance.

Essential to these excellent performances were several crucial developments: one was a large reduction in barriers to trade, both tariff and non-tariff, in the developed countries and then widely in Asia. These Asian governments decided to become engaged with the world economy, which is not to say that they thoroughly embraced free trade and investment; only Hong Kong did that. They also invested in training enough scientists and engineers to be able to exploit the excellent opportunities that came their way.

Parallel declines in transportation costs and a huge reduction in telecommunications costs have been major contributors to Asia's rise. For example, the monthly cost of leasing a telecom line between Los Angeles and Bangalore fell from $73,000 to $13,000 between January 2000 and January 2004. India's emergence as a significant player in the software and business processing sectors would not have been possible otherwise. Within China, Voice over Internet Protocol (VoIP) technology is being used. In 2004, domestic long distance calls often cost less than 5 cents per minute and those to North America 25 cents, down from $1 a few years earlier.

There has also been a shift in the composition of trade to lighter-weight goods and to services, with bits of information being the ultimate in low-weight commodities. The industries most affected by these developments—financial services, computers (hardware and software), and many kinds of business services—have created value-added chains that more easily cross national borders than ever before.

The information technology industry, including telecommunications, grew at about 10 percent a year for 25 years to comprise about 4 percent of total world output. It is well known that this growth was driven by advances in computer technology often summarized in Moore's law that states that the number of circuits on a chip doubles every 18 months to two years; it is less well known that even greater advances in storage technologies have occurred.

Thirty years ago a memory card stored 2,000 bytes; today a hard disk stores 200 billion bytes. Fiber optics and space technologies have comparably advanced communications capacities.

Although the basic technologies appear to have advanced steadily, from an industrial perspective they have been expressed in epochs—that is, discontinuities in the structures of industries associated with the production of radically new types of products and services, such as the shift from mainframes to workstations and then to PCs. Following came laptops, PDAs, cell phones, and other handheld wireless devices. The advent of the Internet marked a major new epoch resulting in enormous growth in electronic commerce. New business models have also been a striking aspect of this era, including those for search engines, auctions, business services, online games, and more. Major innovations also occurred in the distribution of products, including Dell's direct sales model.

A key change for the industry—with particularly large consequences for Asia—was the emergence of modularized standards in many goods. Modularization entails defining relatively simple interfaces among components of final products. The adoption of such standards meant that vertically integrated computer systems makers had to compete with companies whose products could be more cheaply put together from independent, specialized suppliers of hardware and software within value-added chains. This shift entailed both the dominance of some proprietary ones, especially the adoption of the Windows operating system–Intel microprocessor (Wintel) standard and Qualcom's CDMA telecom technology along with the adoption of open industry standards such as Java and Linux. Market advantages came more through supply-chain management, the creation of new business models, and the exploitation of brand names. Vertically integrated companies such as IBM and DEC disintegrated, and the industry segmented into discrete product categories such as chips, computers, operating systems, and applications software (Grove 1996). New firms entered the industry, many of them in Asia. The large resulting declines in costs and prices fostered a vast expansion in the use of computers.

U.S. government policies also created opportunities for new firms. Important early actions by it were the requirement that AT&T license transistor technology at a low price to all comers and that IBM unbundle its software from its hardware, an action that opened the way to an independent software industry. In addition, the U.S. government step-by-step fostered the development of the Internet, including financing. The ensuing dotcom boom resulted in a host of new online services and firms—many of which have survived the bust.

These developments gave openings to suppliers anywhere in the world, and U.S. firms moved fastest to fill the newly opened spaces. Of 176 semiconductor companies formed in the world between 1977 and 1989, 88 percent were formed in the United States with 55 percent of them in Silicon Valley. During this period, many companies also increased their original equipment manufacturing (OEM) purchases from Asia. The Asian companies had to compete on both cost and quality and many did so with great success. Since then, the roles of Asian firms have expanded greatly in size and in the complexity of their products.

Another factor working to expand the number of participating companies and enabling many of them to be competitive, although located far from the main markets, has been the slowing rate of innovation in some sectors. This has made the trajectory of new products more predictable. In personal computers, it became evident during the 1990s that the Pentium X would be succeeded by the Pentium X + 1, or at least by a chip whose main characteristic would be more circuits within an, at most, incrementally changed architecture. (Intel has recently signaled that this sequence has run its course.) Similarly, in the cell phone industry, independent designers and manufacturers could look ahead a few years and see that 4G will succeed 3G and so on; this enables them to anticipate the kinds of components that will be in demand, even though they can still have the challenge of correctly predicting the particular features that will be demanded by buyers.

The labor cost advantage of Asian workers over those in the developed countries was substantial, but while that advantage was necessary for their firms to enter this market it wasn't sufficient; they also had to meet quality standards. Initially, and to a large extent today, Asian companies worked to specifications set by their customers. Labor cost advantages are fleeting; as the textile and shoe industries show, they can quickly migrate to a yet lower-cost country. Growing competencies were necessary to secure an enduring role.

The IT industry is one of the most international of all. The Asian producers are connected across borders to each other and to consumers throughout the world. Companies in the smaller Asian economies produce largely for export, while those in the larger ones also have substantial or at least rapidly growing and potentially large domestic markets.

In this global marketplace, a de facto and not necessarily long lasting, division of labor emerged: the Americans, and to a lesser extent the Japanese and Europeans, conceived new *products* and offered large *markets* for them while the Asians assembled them. Their assembly/manufacturing, or *process*, function is not as simple as it might seem. Although breakthroughs in processes are less frequent than in products, they can accumulate over time to be properly regarded as revolutionary. A good example is the increase in the size and quality of flat-panel displays that in 30 years went from being digital-watch size to being

40 inches or more in size and hung on walls. This occurred largely through improvements within factories in Japan and then in Korea and Taiwan.

This leads to two different ways to view the global character of this industry up to now. One way is by the following sequence. An invention was made in the United States, perhaps in Silicon Valley; product conceptualization was done there; detailed design was also done there or, increasingly, in Taiwan or Korea; complex stages of manufacturing came to be done increasingly in Taiwan (but incorporating high-value components made by U.S. or Japanese firms) and less complex assembly in mainland China; the final product was shipped to users around the world. A similar sequence originated in Japan or Europe with, again, much of the manufacturing occurring in Asia. The software value-added chain was similar, with innovation and architecture being done in Silicon Valley or in another developed country, with application programming or services work performed in Bangalore or some other Indian region. Worldwide marketing and strategy in these sequences were managed by multinational brand-name companies in Silicon Valley, Austin, Tokyo, Helsinki, Seoul, or a few other leading centers.

An alternative representation of these global networks puts the manufacturing skills of Japanese and, increasingly, Korean and Taiwanese companies at the center of the picture. The value they add to final product has grown year by year as they have moved up various value chains for integrated circuits, flat-panel displays, computers, and mobile devices. Their efficiency drives costs down and thereby expands markets. They now outsource assembly operations to China and are reaching out to India for software and design services. Their research and development activities, as well as those of companies in other part of Asia, are advancing. It is safe to predict that Asia will move beyond manufacturing (itself important) to become a significant source of new products, although the timing for major innovations from there is uncertain.

A caution on this point is suggested by the common practice of reporting of gross revenues of production or of exports. Almost always missing in such reporting is the value created domestically associated with these large and growing exports. This is often modest. Thus, in Singapore, 25 percent of the value of its exports of disk drives in the mid-1990s was added domestically and China's domestic value added to its electronics and telecommunications exports in 1995 was also about 25 percent (and might not have grown much since for Singapore, Wong 2000; for China, Chen et al. 2003). These numbers imply that China's exports of $160 billion of high-tech products in 2004 probably required imports of $120 billion in goods and services.

Another caution is the changing nature of supply chains. Increasingly, they are not supplying standard products produced in vast numbers. Rather, more consumer products are being tailored for the often unpredictable changes in consumer tastes. Thus, Dell assembles its computers in the United States, close to the point of sale, in order to minimize the time between a specific customer order and delivery. Of course, as Asian consumers grow in importance its producers will have a locational advantage (Curry and Kenney 2004).

What has determined the different specialties of countries and regions? Historical legacies have been important. Given the combination of India's English-language skills, government policies that blocked the formation of manufacturing skills, and the fact that bits of information did not go through the (dreaded) customs system, it seems inevitable that India would specialize in software services. And Japan's high quality of manufactured goods stems from a long tradition of excellence in crafts.

However, one shouldn't push this line of argument too far. For example, it has often been argued that the near absence of new high-tech companies in Japan is the result of something basic in Japanese culture. We suggest that this view is mistaken. Rather, it is the consequence of actions taken by long ago governments, actions that more recent governments have been trying to change.

NATIONAL STRATEGIES

National technology strategies are the result of the aggregation of the institutions and policies that strongly influence and sometimes determine the role of the country in a range of industries, in our case the information technology ones.[1] These strategies have varied substantially among nations.

The label "national strategies" can be misunderstood. It encompasses not only the policies adopted by governments to promote this industry but also types of behavior that are embedded in society and not quickly changed. An example is the resistance of managers of Chinese companies to accepting control by investors or to merging with other companies.

Here are several key components of these strategies.

Education, Especially of Scientists and Engineers

All our countries did this, although educational opportunities in some were decidedly uneven. In India, education of a small elite to a high level was combined with massive neglect of elementary and secondary education for much of the population. In China, the Cultural Revolution disrupted education for over a decade, and even now many youths in rural areas have poor schooling opportunities. Nevertheless, the absolute numbers of people in these two countries with science and engineering education is large. India has 0.3 scientists and technicians per 1,000 population, 42 out of 62 countries ranked by the World Bank in 1998; it was China at 1.3 per 1,000 (ranked 25th), but that small Indian proportion still came to 300,000 people. Taiwan, with a population of 22 million, graduates 80,000 physical scientists and engineers a year compared with 100,000 in the United States (National Science Foundation 2004, Table 2-36).

In Hsinchu Science-based Industrial Park in Taiwan, the number of returned experts and scholars (as they are called locally), many with advanced degrees, rose from 27 in 1983 to 4300 in 2001, by which time they constituted 4.5 percent of the workforce. In Zhongguancun Science Park in Beijing, in 2002, of 400,000 high tech workers 5,800 had doctorates, 29,000 had master's degrees, and 155,000 had bachelor's degrees.

A pattern that emerged strongly and early in Taiwan was for graduates in science and engineering to go to the United States for advanced degrees, stay to work, and then, for some, to return home, encouraged by government-supplied benefits.[2] (Some "returnees" had not originated in Taiwan but in other parts of Greater China.) This pattern spread to other places, notably India and China. Japan, notably, did not participate strongly in this process. Significantly, not only did the flow of students from Taiwan to U.S. universities peak in the mid-1990s, so did the flow from Korea and China as well (Hicks 2004).

In all of these countries, improvements in the universities are causing more students to stay at home for advanced training. The number of people graduating with PhDs in Korea increased three-fold from 1986 to 1999, in Taiwan it went up four-fold, and in China it increased by forty times (National Science Foundation 2002, Tables 2-29, 2-36).

Acquiring and Developing Technologies

Asian governments had also to decide on technology strategies. Crucial was building the capacity to absorb foreign technologies and, in due course, go beyond them. This entailed acquiring skills in engineering and science including computer science, solid-state physics, integrated circuits, optics, software-related algorithms, robotics, advanced manufacturing, and more. The emphasis was on industrial applications, although Japan invested in a wide swath of sciences, as did China and India on a smaller scale. Korea (centered on the companies) and Taiwan (centered on government research labs) also invested substantially in technology development—investments that have recently produced a remarkable rise in patents registered in the United States.

Governments also had to decide where to have such research done: at universities, research institutes, or companies? The mix varied. Outside of Japan and then Korea in the 1990s, few Asian companies were capable of doing technically advanced research; in all these regions there was a preference for using separate institutes rather than universities because it was easier to focus them on commercially relevant projects. Thus, the Industrial Technology Research Institute (ITRI) in Hsinchu became the major research center of Taiwan, and Korea set up the Korean Institute for Science and Technology (KIST), although much research came to be done in Korea's big companies, notably Samsung and LG. In China, the Chinese Academy of Sciences has been the preeminent institution for scientific and technical research, and major companies have spun out of it after liberalization of the economy began in 1978. Its universities have also assumed commercial roles with, for instance, Tsinghua and Beijing Universities each owning around 200 companies.

In the model in which most research is done in separate institutes, universities focus on teaching. This has been especially true in India. The Indian Institutes of Technology (IITs), the source of many excellent bachelor-level engineers, until very recently have not been research centers; hence, many IIT graduates have come to the United States for advanced degrees.

Trade and Foreign Direct Investment

The main task in Asia was that of catching up. "For most countries, foreign sources of technology account for 90 percent or more of domestic productivity growth." The G-7 countries have carried out 84 percent of world research and development spending (Keller 2004).

Engaging in trade and having foreign companies invest are the two of the most prominent and effective ways to acquire technologies. At one extreme, none of our six countries or regions has come close to adopting a laissez-faire strategy on trade and investment. At the other extreme, until the early 1980s, China's trade was modest and until the mid-1980s, India was almost economically autarkic. Singapore was unusual in adopting a policy of free trade and relative openness to foreign investment—although being selective in the companies it allowed in. In general, in Asia as widely elsewhere, domestic products were widely substituted for imports, a preference that was only gradually reduced over time. Exports were promoted with success but this policy meant having a large flow of imports to enable the exports to occur. (Recall the previous observation on low domestic values-added.) Much learning accompanied trade, especially from importing (Keller 2004).

There was a trade-off. Some industries were seen as strategic for reasons of national security, or because their technologies were advancing rapidly and there might be opportunities to jump in, or because there were perceived export opportunities. The computer industry in the latter part of the 20th century was the quintessential example; it met all of these criteria. Recently, the biotechnology industry is widely seen as strategic, as is the nascent nanotechnology industry. The perceived disadvantage of openness was that foreign competition would keep local industries from developing and cause loss of control to outsiders of industries deemed strategic. The policy response was sometimes to protect them at the price of forgoing learning advantages by restricting imports and, even more, by restricting direct investment.

All our Asian governments favored electronics early. Consumer electronics products were good fits because they involved labor-intensive manufacturing in which they had a cost advantage and, being light in weight, they were cheap to transport. Computers had similar advantages. Demand was growing rapidly in the advanced countries, transport costs were low, and the modularization of supply chains enabled their companies to find segments in which to compete.

Governments found many ways to promote chosen industries: supporting research, favoring local producers in their purchases, erecting tariff and nontariff barriers against imports, directing banks to lend to designated firms, excluding investments by foreign companies, supplying land at cheap rates, financing companies spun out of government laboratories, and more.

Faced with the choice of protection versus allowing foreign direct investment, Singapore made inviting multinational companies (MNCs) central to its strategy. Taiwan encouraged them early (but then became less inviting), with some early arrivals from Japan and the United States plus Philips from Europe. India was long hostile to all foreign firms. Notably, in the 1960s it drove IBM out of the country. However, Texas Instruments got established in Bangalore in the 1970s and helped seed that high tech cluster. Japan and Korea remained hostile to MNC investment well into the 1990s; they favored the alternative of licensing foreign technology. During the 1990s, China allowed MNCs in on a large scale, usually on condition that they bring technology. Acquiring technology and business know-how from abroad via direct investment has become a key part of its strategy. This pattern shows the error of any assertion that MNC investment is necessary for high-tech development—but it surely helps.

Telecommunications Investments

As mentioned previously, advances in telecommunications technologies have greatly helped the geographical diffusion of the IT industry. It is hard to imagine India's software services sector progressing so much without the large decline in international telecommunications prices. The adoption of cell phone technology in China, now with 350 million users, is having profound economic and social consequences; there are corresponding large investments in fixed lines. Korea is the most broadband "wired" country in the world, and Japan is fast catching up.

This surge in telecommunications positions some Asian countries to lead in new services and technologies. Korea and Japan lead in online gaming. China has been trying to establish its own Internet security standard — a move that has been deferred because of objections by foreign firms and governments — but this story is not over. With growth in its markets and, especially, if China brings new technologies to the table, its influence will grow in the setting of global standards.

Finance and Industry Structure

In Chapter 10 (on venture capital in Asia), Kenney, Han, and Tanaka assert that this institution as known in the United States has barely existed in Asia outside of Taiwan. Asian financial institutions, predominantly banks, have favored well-connected and established companies. Thus, Japan created the keiretsu, the main banking system; Korea the chaebol conglomerates; under government instruction, banks in China supported companies spun out of the Academy of Sciences and leading universities; Taiwanese banks supported companies with links to government research institutes; and in Singapore, government-linked companies received preferential treatment.

There wasn't much room in these systems for young, high tech firms whose founders lacked personal connections. Risk capital of the type needed by such companies — equity — was in short supply. Some companies got started when established ones invested in the new field of computers. Others started in a traditional way by using entrepreneurs' savings and support by family and friends. Governments, national and local, often met this need through directing that banks make loans on favorable terms or by supplying real estate. Taiwan was an early mover in recognizing the need for organized risk capital and others followed during the 1990s, but even now the venture capital sector is widely under-developed. Its most developed part consists of venture capital arms of established companies that make strategic investments in start-ups.

Different financial policies and institutions were associated with — and reinforced — different industrial structures. Japan already had large and medium-sized companies, some of which moved into IT, and its financial system was oriented toward supporting them. (Sony was unusual in being a new entrant after World War II.) Korea's path was similar. In contrast, Taiwan's IT industry was long dominated by small, agile firms, and it developed the most advanced venture capital system in Asia. With the main exception of Tata Consulting

Services (TCS), India's software industry consists mostly of companies created during the past 20 years. Not coincidentally, India had a relatively advanced stock market.

Creating High-Tech Regional Clusters

Regional clusters are a ubiquitous economic phenomenon. They are driven by agglomeration economics, a term that denotes the several kinds of benefits that firms in similar lines of work can derive from proximity. The pioneer economist on this topic, Alfred Marshall, and more recent scholars, Paul Krugman and Michael Porter among them, have examined this phenomenon (Porter 1990; Krugman 1991). Broadly, there are effects external to a given firm such that actions by one firm spill over to the benefit of others. There can be learning benefits when specialists move from one firm to another or even talk informally. Having common suppliers is another mechanism, and having a local venture capital industry helps with the financing of new companies. (Venture capitalists, who supply expertise along with their money, tend not to be in the advance guard for they arrive when there is business, but their arrival strengthens a region.)

Whether or not companies in a given industry segment locate closely together depends on the net effects of several factors. Kenney and Florida identify five main ones: (1) transportation and communications technologies and networks; (2) time and speed demands in specific markets; (3) pricing pressures; (4) knowledge capabilities; and (5) proximity to customers (Kenney and Florida 2004). The resulting patterns among parts of the IT industry vary greatly and have changed over time. The enormous growth of the IT industry and changes in its technology, including the aforementioned modularization, fostered much specialization at the level of the firm. For many products, the logistic supply chain from R&D and design at one end to sales and after-market services at the other became distributed globally among specialist firms. At the same time, many firms at similar stages in these supply chains became concentrated geographically. Silicon Valley is the outstanding example. Although it began by doing everything from innovating, designing, manufacturing, marketing, and managing globally, its scope has narrowed to doing research, global marketing, and other headquarters functions, as manufacturing and much design work moved elsewhere. This has led to the saying (only a little exaggerated): "There is no more silicon in Silicon Valley."

In Asia, Taiwan has created a major cluster of computer manufacturing and design companies; Shanghai is developing a silicon foundry and design complex, and Beijing (in Zhongguancun Science Park) a software cluster. Singapore has become the center of a Southeast Asia hard disk drive production complex, most of whose companies are U.S. based and do their design work in Silicon Valley (McKendrick 2004).

A cluster has workers with the right skills and a supporting infrastructure of suppliers; upstream and downstream companies locate there; and specialists in finance and accounting arrive. The local government learns the needs of its companies, creates favorable conditions for them, and lobbies for support from the central government. Such interactions entail feedback processes in which strength begets more strength, with the result that products are brought to market more quickly and more cheaply than otherwise would happen.

Sometimes universities or major research institutes are foci for a knowledge cluster (as distinct from a production cluster) and help create and sustain it, as MIT and Harvard have done in Boston, Stanford and UC Berkeley in Silicon Valley, KAIST in Daeduk in Korea, ITRI in Hsinchu, and the Academy of Sciences and major universities in Beijing. Universities benefit from the clusters they foster by placing graduates in local companies and getting feedback of technology and gifts from them.

After asserting the distinction between knowledge and production clusters, a qualification is needed. Technical progress in the flat-panel display industry has been driven substantially by learning by doing in factories with major contributions by equipment makers and material suppliers; the result has been a huge increase in the size and quality of products. In this case, knowledge was accumulated through production (Murtha et al. 2001).

With varying degrees of success, most of our Asian governments tried to promote their IT industries by offering incentives to companies to locate or start up in them, incentives that include real estate and tax benefits and consulting services. They often establish formal incubators. Motivating them was the marked success of several U.S. companies, notably around Boston and in Silicon Valley. Hsinchu Science-based Industrial Park in Taiwan, created by the government, was an Asian pioneer and remains the most successful in nurturing home-grown companies, some now large. It began with original equipment manufacturing (OEM) for foreign firms, progressed to doing original design manufacturing (ODM), and was the origin of Taiwan's highly successful semiconductor fabrication industry. Korea set up a science research park in Daeduk, south of Seoul. China has many such parks, both national and local; its national "Torch Program" has 53 parks throughout the country, the most famous of which is Zhongguancun Science Park (ZGC) in Beijing (a cluster already developing before it was so designated).

Incubators can be especially useful when the wider economy poses obstacles for start-ups, which is why they are so prominent in mainland China. They are favorable microenvironments, and experiments can sometimes be tried in them. In Chapter 7 on Zhongguancun Science Park, Zhao points out that it was originally named the "Beijing Experimental Zone for Development of High and New Technological Industries." New rules could be tried that, if successful, might be applied nationwide.

It is far from true that governments are responsible for the formation of all regional clusters. The Boston and Silicon Valley instances were market, not government created and among our set in Asia, the Teheran Valley software cluster in Seoul (in a district named after a sister city) is a case of spontaneous creation. The main Indian regions—Bangalore, Mumbai, Hyderabad, New Delhi, Chennai, major cities where educated workers were in ample supply—were also basically formed by the market, not by government. However, as Dossani notes in Chapter 8, it was only after the Indian government created the first software park with satellite communications that Bangalore took off.

With the exception of a group of semiconductor companies in Kyushu and media companies in Tokyo, high-tech clusters are not prominent features of the Japanese landscape. This is probably a consequence of Japan's having few young companies.

Clusters can last a long time, but there is no good reason to assume that they are eternal. Growth eventually slows as empty space is filled, land prices increase, congestion worsens, and—sometimes—changes in technology and the marketplace disfavor a region's companies. (The fate of Detroit in the auto industry is such a case.) New clusters can then arise. Dossani reports in Chapter 8 that infrastructure limitations are holding back—but clearly not yet stopping—the further growth of Bangalore. A shortage of land is limiting the growth of Hsinchu so the Taiwanese government is developing science parks elsewhere. Silicon Valley faces inherent constraints—notably high housing prices—as well as competition from increasingly skilled companies is Asia.

One might reasonably ask if the arrival of low-cost, digitized information is making clusters obsolete. Is the future likely to see companies spread out more geographically? Activities that do not have to be in high-cost localities, such as Silicon Valley, have been moving elsewhere for a long time, and no doubt this migration is aided by low-cost telecommunications. Many production activities are widely dispersed today. Perhaps the arrival of technology that virtually erases distance will change this pattern, but there is reason to doubt that clustering will soon end, especially at the high end of value chains where the creation of ideas and the making of key business decisions entails much face-to-face interaction.

These factors have led to very different patterns in our countries.

Japan entered the IT era already industrialized and with a rapidly growing economy. It had a major consumer electronics industry and went on to create formidable positions in integrated circuits, computers, flat-panel displays, and capital equipment. It spends one of the world's largest shares of GDP on R&D, about 3 percent. After a short period of new company formation after World War II, during which Sony was one of the few successful new high-tech firms, it accomplished this largely by renewing its existing companies, such as Toshiba, Fujitsu, NEC, and Hitachi. Foreign firms were largely excluded. (However, IBM was "grandfathered.") Instead, it licensed much technology from abroad. Its national universities and research institutes were of high quality, but the professors were civil servants and the universities were kept distant from industries. As Maeda points out in Chapter 3, Japan had found the right solution for catching up. However, the difficult decade of the 1990s has produced a change in strategy to one of greater openness. In addition, new companies are beginning to be formed, mostly by sponsored spin-offs from established ones.

Korea's strategy emulated that of Japan. So did its types of IT products. Its now successful companies were not as well established at the outset as the Japanese ones, but government support together with prodigious efforts, high savings, and a mercantilist impulse to export created an array of strong ones. It, too, kept foreign firms out and relied heavily on licensing. It is a remarkable fact that in the early 1990s Korean companies paid U.S. companies almost as much for technology in fees and royalties than the rest of the non-OECD (Organisation for Economic Co-operation and Development) world combined. And it was also spending an increasing share of GDP on research, an investment reflected in a sharp increase in U.S. patents. After an initial spate of company formation, Korea, too, had few start-ups. Today, however, its strategy is also shifting as a result of the traumatic financial crisis of 1997–1998. It is more open to foreign firms, has invested heavily in broadband communications, and is trying to create a more entrepreneurial system, a topic discussed by Bae et al. in Chapter 6.

Taiwan's strategy was to create a strong export-oriented manufacturing industry, initially with technology and direct investment from the United States and Japan, and with a focus on improving manufacturing processes. Its strength had long been in electronics and came to be concentrated in computers, integrated circuits, and, recently, wireless technologies and flat-panel displays. By the 1990s, foreign MNCs were switching to buying from domestic Taiwanese firms. Still later, after 2000, Taiwan has encouraged foreign firms to set up R&D operations there, with some success. Over time, there has been a large increase in R&D, also, as in Korea, reflected in a marked increase in U.S. patents making Taiwan fourth in the world after the United States, Japan, and Germany. The industrial base had initially consisted of many small firms, some of which have become large, along with companies spun off from its Industrial Technology Research Institute (ITRI). This highly entrepreneurial system created the most advanced venture capital industry in Asia. Recently, its companies have become increasingly engaged in triangular trade with, on one side the OECD countries, and, on the other, assembly operations on the mainland.

Singapore's strategy was to have foreign firms bring technology and market know-how to make goods for export. Having succeeded, its strategy has shifted to a more home-based innovation and entrepreneurial one. This change, undertaken in characteristically thorough Singaporean fashion, entails promoting entrepreneurship and attracting entrepreneurial talents from overseas, reducing government red tape, fostering a venture capital industry, and encouraging small enterprises.

China's high-tech strategy has been, as noted previously, to train many technologists, to help scientists and engineers in research institutes and universities to form companies, to make state-owned companies more market focused, and to encourage foreign firms to bring technology and management skills through direct investments. Foreign MNCs and Taiwanese companies are responsible for a large proportion of China's IT exports. Large investments in telecommunications have been a core part of the strategy. The Zhongguancun cluster in Beijing has made a remarkable transition from a set of government research institutes, state companies, and universities in a non-market system to a more dynamic, market-driven place with many new companies.

India has not had much of an IT strategy—which, given its bureaucracy, is probably a good thing. Only when liberalization gathered momentum, and with small investments in satellite communications, did the software industry take off. The opening of the telecom sector is having beneficial effects as is reform of the financial sector that has boosted the venture capital industry.

THE SIX REGIONS EXAMINED MORE CLOSELY

Hsinchu, Zhongguancun, Bangalore, Singapore, Teheran Valley, and Fukuoka illustrate the large differences among Asian high-tech clusters.

Hsinchu Science-based Industrial Park (HSIP)

The preeminent example of a successful, government-created cluster, one with little direct foreign involvement, is HSIP in Taiwan. It was set up in 1980 in a place with established universities, and since then the government has invested about $1 billion in it. As Shih, Wang, and Wei point out in Chapter 4, almost all Taiwanese IT manufacturers came to be located in the 88-kilometer-long belt from Taipei to Hsinchu.

HSIP was a key part of an economic development strategy from the 1960s centered on Taiwan's becoming engaged with the world economy (as were those of the other small Asian "Tigers"). In Taiwan, it combined government support for industries deemed to fit its potential along with reliance on markets.

The Industrial Technology Research Institute, ITRI, had been set up earlier, in 1973, as Shih et al. put it "after referring to the experience of Korea and recommendations of European and U.S. experts." It acquired CMOS technology from RCA in 1976, established a demonstration IC factory in 1977, and spun off the UMC company in 1980, the first of ITRI's spin-offs. It was followed by the Taiwan Semiconductor Manufacturing Company (TSMC) in 1987, the Taiwan Mask Corporation in 1988, and the Vanguard International Semiconductor Corporation in 1994. By the end of 2000, 31 companies had come out of ITRI.

Benefits to companies in HSIP included import duty and tax exemptions, rent subsidies, bilingual schools, preferential credit, and research support. The government supported the financing of start-ups by supplying seed money. HSIP companies paid-in capital went from NT $43 billion at the beginning of park operations (1979) to NT $910 billion in 2002.

Graduates from Hsinchu's universities became the core of the local workforce, while the government offered inducements to former students who had gone abroad for graduate studies and to work, to return. By 2003, there were 4,318 returned students and scholars; 119 companies had been founded by them.

In 1996, ITRI set up the Open Laboratories for collaborative research and incubation services. Its Incubation Center, set up in 1996, by 1999 had 33 young firms and had spun out 7. Altogether, from 1973 to May 2002, 5,000 ITRI staff had moved to the private sector in HSIP.

At the end of 2002, HSIP had 335 companies (282 domestic and 53 foreign) with total sales of NT $70 billion (U.S. $2 billion) in the IC, PC and peripherals, communications, optoelectronic, precision-machinery, and biotechnology industries. The supporting infrastructure for the IC industry in 2000 had 140 design houses, 8 wafer material suppliers, 4 mask manufacturers, 16 wafer foundries, 48 sealing enterprises, and 37 testing organizations.

Taiwan now faces, as do other countries in Asia and elsewhere (including Silicon Valley) a challenge from a mainland China that today has a modest level of industrial technology but is determined to move up the value chain and has the requisite assets for doing so. It has major assets in being Chinese and having a good knowledge of global markets. Its largest challenge is in creating more valuable intellectual property.

18 *Zhongguancun Science Park*

Zhongguancun in Beijing (ZGC for short) has the largest concentration of high-tech companies in China. It had 12,000 of them in 2002 with more than 400,000 workers and revenues of $29 billion. Sixty-four percent were in the information technology industry with the rest in advanced manufacturing, biomedical, materials, and energy sectors.

Shortly after China's reform movement started, in 1980, a researcher, Chen Chunxian, left the nuclear laboratory of the Academy of Sciences to set up the first privately funded research and technology institute in Beijing. He was followed by other entrepreneurial scientists and technicians. A striking fact is that from 1950 to 1978 the Chinese Academy of Sciences "which owned the all the technology . . . in all that time did not sell one product. Since the reforms, 40,000 products have been passed to companies and have been put on the market" (Segal 2002; Zucker and Darby 1995).

By the end of 1987, the Academy had spun out several dozen high-tech enterprises, including the computer companies Legend (now called the Lenovo Group) and China Daheng Information Technology. Most were PC related. By the end of 1987, hundreds of enterprises were crowded along a ten-kilometer long street called Zhongguancun Electronics Street.

During this period, Tsinghua University and Peking University also established their own high-tech enterprises. There were two main motives: one was to supplement low salaries and enable them to keep the best people; the other was to move technology from laboratories to the market. University-funded enterprises have played an important role in Zhongguancun's development.

In 1988, the Beijing Experimental Zone for Development of High and New Technological Industries was set up with the power to try new rules and institutions on a small scale before moving them nationwide. It became known as the Zhongguancun Science Park. It was small, with only 10,000 workers in 1989, but about to take off. Waves of start-ups in ZGC coincided with, and depended on, the rapid growth of China's IT industry. The domestic market was greatly aided by large government investments in telecommunications; paralleling this was China's rapidly growing participation in the global IT market. Essential to this strategy has been an openness to foreign goods and direct investments.

At the beginning the region had important assets and daunting liabilities. The main assets were many scientific and academic institutions, a well-educated and talented group of scientists, a willingness to experiment, and supportive governments, both at the national level and locally. The liabilities, also substantial, included poorly defined laws, including those for intellectual property rights; an array of state-owned companies; bureaucrats micromanaging state-owned enterprises; weak managerial skills; isolation from world markets; and an underdeveloped financial system, especially for risk capital.

Essential to the successes that followed were networks of relations that connected families, the new entrepreneurs, the institutes from which they had come, universities, local governments, and national ministries. The institutes supported their spun-off entrepreneurs in several ways, including financially; local officials for the most part worked to reduce regulations, arranged for finance usually in the form of loans, and did not interfere excessively in the inner workings of many enterprises; universities set up enterprises and maintained close ties to their graduates; and national ministries kept research money flowing to institutes and universities.[3]

As a result, ZGC has become the largest high-tech R&D center in China. From 1988 to 2002, the number of its companies grew from 527 to over 12,000 (of which perhaps 4,000 are not really viable) with total employment going from 10,000 to 420,000. In 2002, 55 of these companies were listed on an exchange and 33 had sales of over U.S. $12 million per year. ZGC firms have 40 percent of the market for software applications and 50 percent of the PC hardware market. It has the No.1 Chinese portal, Sina.com, and the top online game firm in China, ourgame.com. It is the leading place in biotechnology, new medicines, and new materials, but these industries are still small.

At the lower end of company sizes, 4,300 had sales of less than $120,000. This is far from an equilibrium situation. For example, 82 percent of the 4,300 small companies lost money in 2002. The number of firms in ZGC is likely soon to shrink.

Today, China gets most of its technology from overseas with multinational companies as the main source. In ZGC, they account for 43 percent of the Park's total revenues and 78 percent of its exports. Actually, what is being transferred is not only technology in a narrow sense but also design techniques, know-how, and managerial skills, including knowledge about how to solve problems and how technologies are related to each other. Investments made by multinationals are a kind of package that combines money, products, technology, talent, managerial skill, and ideas. Many are establishing research centers; for example, Intel, Microsoft, and Novozymes (a Danish enzyme company) have set up such centers there. China's poor protection of intellectual property discourages the transfer of advanced technologies, but it has not prevented a large and sustained flow of direct investment by foreign firms.

Another major source of "capital" is the human kind, embodied in returnees from overseas. It is remarkable that the total of 4,900 such people (3,500 since 1999) had started 1,800 companies in ZGC by 2002. In two years they had started two companies each working day on the average.

ZGC has both advantages from being in the capital city and disadvantages. The advantages include a large flow of money from government ministries both directly for procurement and indirectly through support of institutes and universities, and it benefits from the idea incorporated in the Beijing Experimental Technology Zone, "What is not forbidden by the law is not against the law." Two examples: one is that a venture capital limited partnership can be established, and the other is that the scope of a business need not be clearly defined. The disadvantages lie in the notion that from the vantage point of "Silicon Valley—or Shanghai or Shenzhen—there are benefits in being far from the emperor, whether he is seen as being in Washington or Beijing."

Regarding ZGC's human resources, about half the workforce has at least bachelors degrees. There are over 30 online job service web sites, and 42 percent of workers find jobs through them. The job market is a classical free market one: employment at will by both the employee and the employer. Those who don't measure up are dismissed, an especially effective measure in the early development stage when other enterprises offered lifetime employment. Worker mobility is high; two-thirds of employees working for less than three years have changed jobs. (A rate this high may be dysfunctional.)

The ZGC system has changed. Tax advantages were reduced in 1993 and the Academy of Sciences ended its support for many successful firms in order to support new ones. Competition has been encouraged among domestic firms and has intensified with the arrival of foreign ones. Corporate forms were adopted with ownership being expressed through stock issuance, appointment of general managers, and boards of directors.

Close university links to business are also under pressure for change. Universities and research institutes within ZGC run their own ventures, often holding 100 percent of their equity. Problems inherent in these connections have become evident. Lack of clarity in ownership law has been a barrier to raising capital. Efforts are underway to clear up enterprise ownership, to enable university-founded enterprises to operate independently, and to set rules so that teaching, research, and operation of university-founded enterprises can be mutually beneficial and not in conflict. This requires a separation of the teaching and research missions of universities from commercial activities that may be socially useful but that can detract from their core missions.

China's financial system, especially for risk capital, remains underdeveloped. Despite the fact that the Beijing Municipal People's Congress enacted the first local law allowing limited partnership venture capital firms, this organizational form has yet to be adopted, and a mergers and acquisition market has just begun to emerge. High-tech companies are listed in Hong Kong or, ideally, on NASDAQ. (A recently established NASDAQ-like second board at the Shenzhen exchange might provide a domestic market listing for young firms in a few years.) In 2002, 21 ZGC start-ups received RMB 830 million (U.S. $100 million) of venture investments. Foreign investors are still dominant; 12 local institutions supplied 29 percent and 7 foreign ones supplied 71 percent.

In little over 20 years ZGC has come a long way. Its future depends on that of China, which faces challenges in building institutions, including those of law and finance and those for the creation of technology. Given its record, it will overcome them.

Bangalore

Dossani reports in Chapter 8 that, contrary to a widespread belief, the Indian software industry did not originate in Bangalore. Companies in Mumbai, which had advantages in finance, labor, communications, legal, and accounting services, and marketing and sales skills, began it.

However, Bangalore's importance has grown while that of Mumbai has declined. By 2000, firms in Bangalore were responsible for 25 percent of the country's software exports. Several factors were responsible for its rise, including an agreeable climate (it is called the "Garden City"); the presence of the Indian Institute of Science, defense companies strong in electronics, aeronautics and machine tools; access to a large supply of educated engineers; few labor troubles; and, not least, being the site chosen in 1985 by Texas Instruments (TI).

The central government was long a huge obstacle to Indian modernization, notably including its near economic isolation from the world. Policies began to improve in the mid-1980s and, especially, after 1991. Contributing to Bangalore's being a late entry in the software industry was poor government planning and "an endless bureaucracy" that produced inadequate infrastructure. That began to improve only after 1999.

Despite these local deficiencies, TI was influenced by the central government's decision to undertake the Software Technology Park (STP) system, beginning in Bangalore, in 1985. It supplied satellite bandwidth to software exporters, mainly to overcome the country's poor telecommunications. In the mid-1980s Bangalore's superior telecommunications helped to attract Infosys and Wipro, now leading firms, from their original locations in Pune and Mumbai.

TI's decision not only demonstrated an MNC voting for Bangalore, it also showed the industry a new and more profitable way of doing business by pioneering offsite software development. Its satellite links to the United States allowed programmers to work in India real-time for the first time, a method quickly copied by Indian firms that moved in.

Although it necessarily competes with other regions, in a recent survey of software firms in Bangalore, almost half cited the availability of high-technology professionals and the presence of research institutes as the most important reason for their being there. It appears that agglomeration economics are finally at work.

Singapore

As described by Wong in Chapter 5, Singapore's strategy was based on the rule of law, good government services, free trade, stable macroeconomics, and attracting foreign investments in industries that would export. The government has played an active role in many sectors, both through direct ownership and through quasi-state enterprises. Its compulsory savings system (the Provident Fund) is a major source of finance. It has a strong educational system and a highly competent and honest government. It is a story of great success.

Wong portrays Singapore's high tech industry as having undergone several transformations. First, there was an industrial take-off in the early 1960s, originally based on technology transfer from MNCs. The mid-1970s brought the rapid growth of process technologies within the MNCs and the growth of local suppliers. In the late 1980s came more applied R&D on the part of MNCs, public R&D institutions, and local firms. The fourth phase starting in the late 1990s entailed a shift to high-tech entrepreneurship, deeper R&D, and the creation of technology.

As part of the effort, as Wong puts it, "to re-make Singapore into a competitive knowledge-based, entrepreneurially driven economy," in 1999 the government created a U.S. $1 billion fund to boost the venture capital industry (much of which has been invested abroad), allowed entrepreneurs to start ventures in their homes, relaxed listing requirements on the stock exchange, and changed the bankruptcy law. The government is also encouraging professionals to learn about entrepreneurship, attracting talent from abroad, reducing government regulations, and improving start-ups' access to capital.

What has been accomplished? It is too early for definitive results, but there is more spending on R&D and measures of innovation have increased. The role of MNCs remains strong as they sustain strong export growth. A remaining obstacle is the paucity of mechanisms like the small business support schemes in the United States in which government funds match private funds or an organization like ITRI in Taiwan to help bridge the gap between R&D and seed investment by venture capitalists or angel investors. In addition, the scarcity of aggressive leading users of new technologies makes it difficult for Singaporean start-ups to have their first customers at home; they need to go abroad from the beginning.

There is now the view, beginning to be acted upon, that changing the mindset of Singaporeans toward entrepreneurship might require fundamental changes in the educational system, social security, and the public sector recruitment system, all politically sensitive matters.

Teheran Valley and Daeduk

In Chapter 6 Bae et al. report that the first attempt in Korea to develop clusters was to build industrial complexes in the early 1970s to house heavy and chemical industries. These parks did not include such functions as education and R&D.

The first science and technology park, Daeduk Science Town, was started in the early 1980s by moving existing government-sponsored research institutes from Seoul. At first it had only R&D institutions but "Daeduk Valley" (by analogy with Silicon Valley) emerged in the mid-1980s when researchers created new companies.

The other principal high-tech "valley," Teheran Valley, developed in the southern part of Seoul from the mid-1980s. Although the government helped by building physical infrastructure, Teheran Valley is essentially a market phenomenon. In the mid-1990s, about 100 IT-related companies located along Teheran Road, and by 2002, many IT firms, start-ups, venture capital firms, and corporate HQs were set up. About 2000 IT, Internet-related, mobile communications, and foreign IT companies are located there, and many financial institutions, banks, and trading companies have moved in. It is becoming the center for innovation and incubation in Korea. About half of all the software and IT ventures in Korea are there. The proportion of venture capital–funded companies there is relatively high. Its companies specialize in culturally related products such as content, multimedia, design, fashion, and service industries such as venture capital, banking, IT services, and consulting. Teheran Valley has the image of a highly innovative and knowledge-generating region and being the center of entrepreneurship in Korea.

Bae et al. list several problems:

- Entrepreneurs' poor knowledge and experience with markets, management, law, and finance. Founders are usually engineers weak in marketing.
- A small domestic market requires them to look abroad; this is a barrier but one that can have long-term advantages.

- Poor support habitats, networks and social and financial infrastructure with high costs, traffic congestion, and no major universities or R&D institutions.
- Poor understanding of the nature of ventures and entrepreneurship. These are risky ventures with high rewards for the successful. The prevailing social attitude still punishes failure, a deterrent to taking risks.
- Inefficient or heavy-handed government policies. The government has played a positive role by developing technology, transferring technology from government research institutes to small and medium-sized enterprises (SMEs) and supporting joint R&D between SMEs and institutes. However, it should abandon its system of "authenticating" venture firms, the market can handle this function.

Bae et al. conclude that the key needs are more successful entrepreneurs as role models, more education on entrepreneurship, a higher quality of ideas generated (with links to government helping), internationalization, more skillful venture capitalists, and the expansion of infrastructure.

Japan (Fukuoka and Other Clusters)

Japan is different. Its companies have a remarkable capacity for renewal and for absorbing and advancing new technologies, in contrast to the model (Taiwan and India) in which new firms have done much of this. However, Japan's success in catching up with the most advanced nations together with its economic stagnation during the 1990s has caused many people to question the appropriateness of the Japanese model for the future.

Imai describes four regional clusters in Chapter 2.

One is the Aichi-Toyota Cluster, a combination of integral type innovation and strong entrepreneurial leadership, based on just-in-time production. Toyota aggressively outsources and fosters start-ups in its group.

A second, Fukuoka's New Semiconductor Cluster, has engineers who have spun off from large companies, Sony's engineers who concentrate on "post PC" technology, and Kyushu University professors who are creating new linkages for the "Silicon Sea-Belt Project," which links the island to Taiwan and Northeast China.

A third is the Sendai cluster around Tohoku University, which is strong in material development.

Tokyo is also a major cluster, the center of a cultural phenomenon captured in the phrase "Japanese Cool," which includes pop music, electronic appliances, architecture, fashion, animation, and cooking. Exports of such products have tripled during the past decade to over $12 billion. He sees the Tama area northwest of Tokyo as the first planned industry cluster in Japan and as a guideline for clusters nationwide. Companies there, unlike many in Japan, focus on product innovation instead of process innovation. Sixty percent of their leaders have created spin-offs from larger companies. Many of these companies are in such "cool" industries as manga comics, animation, and games. It is only natural that workers for these companies tend to be in Tokyo, in the same way that lawyers, accountants, patent attorneys, programmers, and consultants have also migrated there.

Tanigawa, based on a survey by the Development Bank of Japan, puts Japanese clusters into three categories:

- The Silicon Valley model—Sapporo, Yonezawa, and Fukuoka
- The traditional Japanese cluster model—Aichi and Hiroshima
- The maverick or unique cluster model—Sendai, Kyoto, and Tokushima

He sees the key concepts in Silicon Valley–type clusters as "entrepreneurship," "organic horizontal collaboration beyond business connections," "open environment," and "international linkages." Aichi, the home of Toyota and the world's leading auto cluster, represents the traditional Japanese model with historical continuity, distinctive craftsmanship, and vertical relationships. The companies have a commitment to each other that has sustained the cluster's vitality. Its future depends on Toyota's performance. The mavericks, Kyoto, Sendai, and Tokushima, each differ. Some Kyoto start-ups, Kyocera, Omron and Rohm, became global companies within one generation. Local horizontal collaborations are rare, and the region seems closed-minded. The core of Sendai is Tohoku University, whose resources have attracted public and private research organizations. Start-ups from the university have begun to appear, but their business volume is low and networking is weak. The Tokushima region has two large companies: Otsuka Pharmaceutical (chemical products manufacturer) and Nichia (electrical manufacturer) and not many others.

Yamaguchi reports on a study of the Fukuoka area carried out by the Development Bank of Japan (DBJ) and the Fukuoka Industry, Science, and Technology Foundation (IST) with the cooperation of Kyushu University (KU). Its focus was its semiconductor cluster that now accounts for 35 percent of Japan's domestic semiconductor production. This concentration has been fostered by local universities, foundations, and research centers. It is attracting large semiconductor manufacturers and R&D and design centers. Ninety percent of these firms are local, and many are spin-offs from larger firms. They engage in much horizontal collaboration on R&D and market development. Yamaguchi reports that decision-making within the large companies is moving from Tokyo headquarters to regional branches, such as those in Fukuoka, in order to speed decisions. He asserts that Fukuoka is becoming more like Silicon Valley.

26 INNOVATION AND ENTREPRENEURSHIP

Running through this book are the themes of innovation and entrepreneurship.

Innovation

Innovation—being first to market with a new product, process or business model—is the source of gains in productivity, sustains existing firms and leads to the formation of new ones and sometimes new industries. At their root, innovations are based on wholly new physical or conceptual discoveries—for example, inventions, such as the discovery of the transistor effect by scientists at Bell Labs in 1947. The modification of desktop computers into laptops making them smaller and portable was an innovation, again an important one. Both inventions and innovations involve ideas but not all ideas are equal. Some, called "basic," such as the transistor effect, open up wholly novel, at first poorly understood, paths for development, while others, called innovations, such as the shift from desktops to laptops, are steps along more-or-less defined paths. Another type of innovation involves a different class of ideas—new business models (such as Internet auctions) or enterprise resource planning software.

Inventions and innovations are ideas, and ideas have a dual character. One aspect is that they are public goods in that one person's use of an idea does not mean less of it is left for others to use, and potential users can't be excluded, unless it is kept secret or potential users are legally prevented from doing so. Their other aspect is that ideas with potential commercial value need work to enable them to reach the market; their creators or others familiar with the idea often have an advantage in carrying this work forward. Here geography enters. For example, biotech clusters form close to where leading biologists work, usually in major universities. This is because the biotechnology industry is close to its scientific roots. In the early 21st century this is less true of the IT industry but it still holds.

Broadly, Asia has not been the source of information technology inventions (although Japan has made some). The story is very different regarding innovations in products, process, and business models. Much of the most influential process innovation has been the just-in-time production system, pioneered by the Toyota Motor Corporation, which has transformed manufacturing worldwide. Indeed, a major strength of high-tech Japanese companies, and increasingly of Korean and Taiwanese ones, is manufacturing process innovations. Japanese companies have also made important consumer electronics product and service innovations such as the Sony Walkman and NTT DoCoMo's cell phone service. The visual arts, including anime and computer games, are successfully exported innovations. An important business model innovation is TSMC's IC foundry service, in which the maker of chips is not tied to any particular design.

It is a mistake to think only in terms of breakthroughs in technology. Consider advances in manufacturing processes. The flat-panel display industry illustrates this point (Murtha et al. 2001). All the technologies in use were invented in the United States, but the industry developed in Japan (with some U.S. companies participating). Most of the innovating U.S. firms were also looking for commercial breakthroughs; they failed to discern them, and so didn't invest in manufacturing. The Japanese firms settled for incremental advances and did invest. The result was a large cumulative advance over 30 years in the size of flat-panel displays from digital watches and calculators to laptops to wall-mounted TVs. This was done largely through the accumulation of know-how in factories by skilled engineers. Rapidly growing demand and large investments by Korean and then by Taiwanese companies enabled them to break into this market in the 1990s. Murtha et al., conclude that this rapid progress was made possible through continuity of effort with incremental improvements, learning on the job, and speed of response as prices kept falling rapidly.

Imai also discusses the Japanese system of innovation in Chapter 2. It has been described as "incremental" in manufacturing with a focus on high quality. However, he sees the distinction between "product" and "information" as becoming blurred. Both express "patterns," and the difference is that when one is "expressed" on steel you get a car, but when one is expressed on a computer disk or a paper you get software. The former involves a material on which it is difficult to "write," and therefore requires complementary materials, expertise, and trained skills. Not only digital architecture and design are needed but also continuous, incremental manufacturing innovation.

The architecture for automobiles, cameras, printers and other consumer electronic products is of the "integral type," which differs from the "module type" architecture of Silicon Valley. "Integral" architecture requires a delicate coordination among interdependent parts and devices whereas in the modular type, as described previously, the parts work independently. The modular system leads to an open industrial network, while the integral system, dominant in Japan, is found in closed networks among a few companies. Both types coexist, depending on the degree of industrial maturity and the prevailing technological and market structures. Japan is moving toward modular systems and is opening its markets, but the integral system core will remain because it is vital for Japan's ability to innovate. Integral systems do not quickly respond to rapid change, but have an advantage in sectors where the rate of change is moderate.

Japan's strategy has been to invest heavily in R&D, develop excellent technologists, become a master of manufacturing, and learn how to market successfully to the world. Its mercantilist drive to export and to keep most foreign firms out led it instead to license technologies that its good engineers then improved. Its brands acquired worldwide reputations. Its large domestic market, second in the world to that of the United States, makes it unique in Asia—although China's market is catching up fast. However, government efforts to make breakthroughs in technology, including creating a distinctive computer operating system, did not go well. Altogether, it was a successful strategy for rapidly catching up; Japan became dominant in consumer electronics, but not in computers. This was—and is—an effective system for industries whose technologies are changing at a moderate rate, not too fast and not too slow, not a characteristic of the IT industry between 1970 and 2000. Now, with the rapid spread of broadband and with the convergence of consumer electronics and computers, Japan has forged ahead in some sectors.

Its main challenge, similar to that facing the United States, is how to respond to rapidly growing China (and India) and one of its responses is also similar: offshoring of manufacturing to Taiwan, Southeast Asia, and, increasingly, China. Japan's so far unmatched competency in manufacturing is being challenged by the rapid rise of manufacturing competency at low costs in other Asian nations, notably in Korea and Taiwan and, recently, in China. There is a wide under-appreciation (at least in the United States) of the importance of such competencies. They are less visible than those in products that consumers can inspect, but they determine their cost and quality.

Almost all non-Japanese Asian companies have been technology and business followers. The development patterns of the software industry in Ireland and India clearly show both the "advantages and disadvantages of being a follower" (Arora et al. 2000). One can grow without a broad set of technical abilities and many markets, and technical and business model uncertainties are reduced. The negatives can include many followers competing with consumers reaping most of the benefits while leading firms can block the way up the value chain. Nonetheless, followers can create a basis for moving up the value chain to creating innovations.

As Dossani writes in Chapter 8, "From its origins and until about 1990, India's software firms played the role of a follower of the U.S. software industry, competing for the same work that similar U.S. firms were doing—though they mostly obtained work lower down in the value chain relative to comparably sized U.S. firms and moved up the chain more slowly than U.S. firms. When compared across a time scale, it appears that there is a follower-leader relationship between American and Indian software services firms, with a lag of about a decade."

An important measure of innovative capacity is patenting, especially in the United States, the global patenting standard. Japan has been consistently second only to the United States in the number of total patents and is among the top countries in IT ones. It leads the world in R&D spending as a share of GDP; this ratio has consistently been higher than in the United States or Germany.

The rise in patents from Taiwan and Korea is striking. In 2001, Taiwan was fourth in the world, ahead of Britain and France, and South Korea was eighth. According to Fuller, "three Taiwanese firms have ranked among the top 30 worldwide holders of U.S. high technology utility patents in recent years" (Fuller 2005). [However, patents vary in importance, and a recent ranking of countries by "influential" patents puts Taiwan at 11th and Korea at 12th (Narin 2003).] Hu and Jaffe conclude, "Korea and Taiwan are graduating from imitation to innovation. The number of patents granted in the U.S. to these two economies has been growing rapidly. On per capita patent count terms, Korea and Taiwan are catching up with the lower-tier developed economies. Anecdotal evidence suggests that knowledge diffusion from the advanced economies, particularly U.S. and Japan, played an important role in this catching up process" (Hu and Jaffe 2001). Using patent citation data, they found that Korea is closer to Japan while Taiwan draws for ideas about equally between Japan and the United States. This difference correlates with the high incidence of direct investment and capital goods flow from Japan to Korea and the high incidence of people flows between Taiwan and the United States.

Another indicator is the output of scientific publications. This is growing rapidly in Asia. In Chapter 5 Wong shows growth rates for Korea, Singapore, and Taiwan during the 1990s ranging from 12 to 20 percent annually. Citations of scientific papers originating in non-Japanese Asia have also been growing rapidly. The starting point was low, but they grew by six times between 1995 and 2002 (National Science Foundation 2004, Table 5-52).

Another innovation indicator is the flow of money for technologies as measured by fees paid for licenses and royalties among unaffiliated entities. In 2001, Japanese firms paid American firms $1.8 billion, and the reverse flow was $400 million. In that year, Koreans paid Americans $740 million while receiving from them $18 million; Taiwanese firms paid U.S. firms $230 million while receiving $2 million in return (National Science Foundation 2004). However, the pattern of net payments is shifting markedly in the direction of a more equal balance.

The main strategic challenge faced by companies in non-Japanese Asia, especially Taiwanese and Korean companies, is becoming more innovative. They are being squeezed from below in costs and increasingly in skills by China and above by the United States and Japan in technology. Their strengths are substantial: for Taiwan, being ethnically Chinese gives them an edge in the world's lowest-cost manufacturing place and its largest future market; its firms are adaptable, and they have close links with their Japanese and U.S. counterparts. Companies are doing more research, and ITRI is doing more advanced work. There may be a larger role for its universities in the overall innovation system. As for Korea, its large firms already support high levels of R&D.

According to Wong, in the early 1990s the Singapore government began shifting from promoting the acquisition of technology to supporting its diffusion and innovation. It also increased public spending on research and development, especially on the life sciences, and increased tax incentives for MNCs to do R&D in Singapore. There are several indicators of results from these efforts. Singapore's ratio of R&D spending to GDP went from 0.2 percent in 1978 to 2.2 percent in 2002, a ratio higher than shown by the U.K. and the Netherlands. The number of research scientists and engineers per 10,000 workers went from less than 30 in 1990 to 74 in 2002. Its publications per capita in 1998 exceeded those of Japan and came close to those of France and Germany. By 2001, Singapore's level of patents per capita was higher than those of France and the U.K., although behind Taiwan, Germany, Japan, and the United States. Although foreign firms received over half of Singapore-origin patents during the 1990s, the share of those held by individuals and domestic firms had grown.

A major technology decision was to make Singapore into a life science hub. A U.S. $1 billion fund was created for several new life science research institutes, to co-fund R&D projects by global pharmaceutical firms, and the building of a new life science park, Biopolis. This move implies reduced dependence on the IT industry, in part because of the rise of China and India in that sector.

Wong writes: "The key challenges to sustaining the development of the innovation system appear to be finding ways to augment the small absolute size of the talent base, greater investment in basic research capabilities of local universities, and improving policy support for technology commercialization activities through new programs such as the SBIR and STTR program in the United States. The need to intensify investment in precompetitive basic research and infrastructures is especially important for the biotech cluster as well as certain ICT subsectors, such as wireless and broadband applications."

Entrepreneurship

Entrepreneurship is an elusive topic. It can be defined broadly to encompass people who take initiatives within companies, but we prefer to identify it with those who create new companies. In Joseph Schumpeter's view, innovations always involve the building of new plants and equipment and are introduced by new firms and by new men (Schumpeter 1939).

Not all companies start in the proverbial garage as Bill Hewlett and David Packard did. Some of today's large IT firms, such as Tata Consulting Services (TCS) in India and Hynix and Samsung Electronics in Korea, were founded by established companies. Others have come out of government laboratories, such as Legend computer (now Lenovo), which came from the Chinese Academy of Sciences and the Taiwan Semiconductor Manufacturing Company (TSMC) which came from Taiwan's ITRI.

Entrepreneurship is found in all societies and business sectors. This is how a large part of the world's peoples—farmers, shopkeepers, artisans, peddlers—earn a living. So if entrepreneurship is ubiquitous, how can one explain the fact that in high-tech industries there are wide variations in its incidence among regions? In Asia, Taiwan led the high-tech entrepreneurial procession. and then, with a lag, followed China and India. Japan and Korea were different; they did not create many high-tech companies. Nor has Singapore yet created many successful ones.

The best answer seems to be that these large differences come from established institutions being reinforced by government policies. Thus, in Japan the overarching goal of its postwar leaders was catching up with the United States, and it chose to guide its enterprises "administratively" to this end by preserving in modified form the economic control system introduced during World War II. Finance, labor laws and practices, foreign trade, and investment were all oriented to their support. The result was an internally consistent system of education, finance, labor, trade, foreign investment policy, and tax laws that enabled its established companies to renew themselves. There was little room in this system for new companies.

Korea also established a successful system of large firms that the financial sector, labor system, policies on trade and foreign investment, and an array of regulations sustained. Taiwan's small to medium-sized firm structure is also relatively stable. Successful systems tend not to change; why should they?

But some countries have undergone large systemic changes. China's has been most dramatic, from state/collective ownership and extreme autarky to a system with rapidly growing private ownership and huge foreign direct investment. This shift came from the dramatic failure of the original model along with a compulsion to develop quickly. India, less dramatically, is also undergoing large changes—partly motivated by the example of China. Poor performance during the 1990s and the financial crisis of 1997–1998 brought significant policy changes in Japan and Korea, respectively. Singapore's shift toward promoting home-grown entrepreneurship is less derived from a crisis than from a concern about long-term dependence on MNCs.

One can reasonably ask how much difference it makes that a country does or does not have many new high-tech firms. The effects are hard to estimate. Acknowledging the limits to our understanding, we can identify three mechanisms by which entrepreneurship provides social benefits. One is that new firms reallocate resources, especially human resources, from old sectors to new ones. A competitive market causes the shrinkage and disappearance of existing firms and the creation and growth of new ones. (For example, there has been high turnover in the leading U.S. companies, including those in the Fortune 500, during the past 50 years.) Of course, established companies can reinvent themselves, as they have in Japan.

Start-ups also speed the entry of new technologies to the market. This is especially important in rapidly changing industries—"high-tech" ones—where there can be large first-mover advantages. While large firms are the wellsprings of technological advance, they are often faced with more opportunities than they can or want to exploit. Established firms have older physical and human capital, and their workers may lack the skills to take quick advantage of a new technology. Since their managements are often focused on meeting the expressed needs of current customers, they usually select opportunities that fit those needs (Christensen 2003). Many start-ups have their beginnings in exploiting large firms' unused ideas, sometimes sponsored or founded by the originating firm but often by people who leave to build new ones—with occasional disputes over the ownership of intellectual capital. Because there is always uncertainty about which ideas will be winners, the best way to select them is for many firms to be started and for the market to choose.

Viewed broadly, there is a two-way interaction between large and small firms; not only do small firms emerge from large ones, through sponsorship, through people with the relevant know-how leaving large firms for smaller ones, or through ideas getting into the air (Brown and Duguid 2000). A famous example of the last of these mechanisms is the set of innovations made at Xerox Park that ended up being exploited by others, such as the young Apple Computer Corporation. Things also work the other way, with large companies buying small ones to get their technology and talent.

A third function of new firms is motivational. They give entrepreneurs opportunities to demonstrate their skills as well as opportunities to make more money than as employees of large firms. This motivation helps to account for the high incidence of new company formation by scholars who returned to ZGC. There are, of course, risks. They can be reduced if a person can return to the firm she has left, or readily join another one; in short, an open labor market supports entrepreneurship.

Indian IT Entrepreneurship

As noted in Chapter 8, the environment for entrepreneurship for many years was unfavorable. The government favored state-owned enterprises (SOEs) and it was unwilling to give out downstream contracts to the private sector. By design it stifled the private sector. For example, CMC's legally sanctioned monopoly on the maintenance of all IBM's machines in India after IBM's withdrawal in 1978 meant that private firms could not obtain this business.

The pioneering software firms were branches of existing companies. Tata Consulting Services (TCS), long the leader, was part of the Tata empire. IT firms that have grown large dominate the Indian market (the top 10 have a 70 percent market share), and they inhabit their own domains: TCS in Mumbai, HCL in Delhi, Satyam in Hyderabad, Infosys and Wipro in Bangalore. Small firms and the diaspora were not important initially and so were unable to help in the flow of information.

Bangalore was not a uniquely friendly place for entrepreneurs but it had a large pool of engineers and the legacy of the learning derived from the early presence of Texas Instruments. Returning nonresidents prefer Bangalore, and they have become conveyors of new ideas and capital. Foreign firms also prefer it, partly because they do not need local venture capital and partly for its climate and its labor pool.

India's system of finance had positives and negatives. Positive was the ease with which small firms could get listed on the Bombay exchange. Negative was the existence of restrictive rules on venture capital until 1999; the firms that became leaders were financed by their parents. After the 1999 reforms and along with their increasing wealth during the Internet boom, nonresident Indians (NRIs) in the United States began to invest in start-ups. Dossani reports that a high proportion of the founders of the eight largest IT firms received some of their education in the United States. He argues that the importance of NRIs is likely to grow—although it is unlikely to be as important as that of the overseas Chinese to China.

Before the 1990s, after several decades of excellent performance by the Japanese industry, any observer noting that Japan had few new high-tech companies would probably have met with indifference. Success spoke for itself. (Rowen and Toyoda 2003). Large firms had thrived under the keiretsu system of interlocking relationships among suppliers, manufacturers, distributors, and financiers, along with associated phenomena of low labor mobility and an emphasis on bank rather than equity financing. This system's strengths include lower transaction costs and more company investment in training from stable relationships. Its virtues are strongest in industries where technical change occurs at a moderate rate and there is a long development time horizon, as in automobile manufacturing. This has not been characteristic of the IT industry.

As Maeda writes in Chapter 3, "For the past three decades, almost no technology-oriented start-ups, like Sony, Honda and Kyocera, have succeeded. The reason is clear: high-tech start-ups were not needed in the catch-up phase. It was better not having them for the total effectiveness of the economy. Even if some start-ups were born, they died." He goes on to say: " 'What to make' is becoming more important than 'how to make' and start-ups are needed for this."

Financial and legal barriers have impeded start-ups that could help unleash the economic gains from innovation. In particular, small businesses have had difficulty in securing funds. Firms that rely on such intangibles as intellectual property—as necessarily do most high-tech firms—are handicapped by banks' biases toward firms with more employees, fixed assets, and loyal main bank relationships.

Telecommunications policies, reflecting the Japanese preference for established institutions, were long an obstacle. NTT used its monopoly power to charge high access fees, thus discouraging demand for networked computers and use of the Internet. With less regulation, increased competition had a galvanizing effect, including the introduction of broadband capacity and Internet usage. NTT's DoCoMo's i-mode, introduced in 1999, gave rise to several successful new ventures, such as Rakuten and Access, which provide content, applications, and services through cell phones. In 2000, nearly half of all people using the Internet in Japan (a total of 47 million) did so through cell phones. In short, when the rules changed, so did behavior.

Kenney et al. report in Chapter 10 that several initiatives over the years to create a venture capital industry failed to fund many new companies. The government tried to help. In 1995, small and medium-sized enterprises became eligible for money as well as data from the government; it was made easier to form venture capital firms, regional banks and corporations set up venture capital affiliates, and some independent venture capital firms also were formed. At that time, Softbank attracted much attention. It had made a lot of money from investments in U.S. start-ups and then invested heavily in more than 600 Japanese start-ups. In response to the arrival of the Internet, two new stock markets were founded: Mothers, in 1999, and NASDAQ Japan in June 2000. Both attracted more high tech-related companies as a percentage of listings, but the numbers were small and NASDAQ Japan stopped operating in August 2002. As Kenney et al. report in Chapter 10, "In the collapse of the tech bubble, Japanese venture capitalists such as Softbank experienced enormous losses. Since then, there has been little investment in start-ups." Potential entrepreneurs in big firms are unwilling to risk resigning to establish smaller firms. "The difficulties venture capital has had in taking root in both Korea and, especially, Japan seem to be intimately linked to the overall configuration of those societies and their political economies." They conclude that the start-up firms lacked deep technical expertise and did not attract the best young engineers; that few Japanese venture capitalists were technically savvy former entrepreneurs or experienced managers; that other needed parts of an entrepreneurial habitat, such as experienced lawyers, accountants, and other network constituents, never existed in Japan. As a result, "when the downturn came, few start-ups were able to survive and like the New York phenomenon of 'Silicon Alley,' the 'Bit Valley' habitat simply disbanded."

How deeply embedded is this low incidence of entrepreneurship? Imai writes that the people who led the industrialization during the Meiji Restoration became known as the zaibatsu entrepreneurs. They read the state of the world, foresaw the path to capitalist industrial development. and ensured that information and capital flowed to the necessary places. "Entrepreneurs riding the wave of change can reap huge profits, and these 'hero entrepreneurs' have indeed existed in Japan . . . the inflation-adjusted income of the zaibatsu leader Yataro Iwasaki is thought to be greater than that of Bill Gates today."

After World War II, the new, young business leaders aggressively exchanged information among companies. Lacking experience, they found that obtaining information on other companies allowed them to anticipate developments, decrease uncertainty, and ward off dangers. There was also a surge of company listings on the Tokyo Stock Exchange. There were many people in established companies alert to Schumpeter's "new combinations." They enabled Japan to catch up to the more advanced countries in a few decades.

Imai contests the customary definition of entrepreneurship (that used by the editors of this book) that holds it to mean the creation of new organizations, by reference to a Neo-Shumpeterian school that defines it to be alertness to new opportunities — that is, discovering new combination of goods and services — and argues that this takes place within established Japanese companies. Indeed, it is evident that this happens to an impressive extent. He writes that the middle-ranks of large Japanese companies have many people with an entrepreneurial spirit that serve as reserves for spin-off ventures. A major reason that so few such ventures have been created is that Japanese human capital had high opportunity costs in alternative uses. Elite engineers and managers became embedded in the traditional system and helped make the Japanese system rigid. However, he sees Japan's hierarchical system, centered on politicians and bureaucrats, as losing its hold on power. The traditional system centering on "Nagata-cho" (politicians) and "Kasumigaseki" (bureaucrats) is weakening. Networks of experts, including young politicians and knowledgeable bureaucrats, have begun to operate at the intersection of public and private domains. Imai asserts that "Japanese entrepreneurship is now ready for the next stage."

With MITI (now METI) in the lead, there have been many actions since the mid-1990s to remove the obstacles to entrepreneurship inadvertently created in earlier years, including making it easier to start firms, increasing labor mobility, deregulating capital markets, creating stock markets with less restrictive listing requirements, being more open to foreign firms, and reducing barriers to university-business connections.

Maeda reports that "something new and important is happening. In the so-called lost decade, tens of spin-off companies grew fast, with some going to IPO." This is a corporate "spin-off" phenomenon rather than a new, independent, "start-up" one. He writes that in Sony, for example, if an outstanding performer wants to spin-off, the management will support him and seek to ally with him. Of course, spin-offs occur in all clusters, but in Japan it appears that they are more likely to be sponsored by the originating company than elsewhere. The new high-tech entrepreneurs are elite engineers who are good at strategic collaboration with big companies. They are producing profits from the first year and use government funds cleverly. They aim at early stage IPOs, have close relations with professors, and seek global collaborations from an early stage.

There are still less than 50 of these companies, not enough to change the structure of industry. Maeda finds that that their founders' primary interest is not getting rich via stock options but to be specialists free from lay-offs. Some of their employees may leave in five years to set up their own companies. Moreover, young professionals with MBA degrees, many with experience in the United States, are starting to leave big corporations and government offices like METI. In Maeda's simulation, by the year 2010, about 450 R&D-focused start-ups will have had IPOs and about 80,000 engineers will be working in them. This number of new firms would be about 10 percent of the total listed, which Maeda asserts would be a critical mass.

In sum, although it is evident that Japan has found it difficult to move from a successful catch-up strategy to a moving-out-in-front strategy in the IT industry, it is undergoing significant changes, which, if sustained, might restore Japanese entrepreneurship to the heights reached in the Meiji era.

Entrepreneurship in Taiwan

Taiwan has arguably demonstrated the most successful entrepreneurial activity among our regions. Until the 1990s its IT industry was dominated by a large number of small firms. For instance, in the Hsinchu Science-based Industrial Park the average number of workers per company was 37 in 1991. They were fast followers of technology, making components and assembling products for foreign companies on an OEM basis. They developed close relations with Japanese and U.S. companies, in which the U.S. companies would supply product specifications and some technologies and would take the resulting products. This sector developed a flexible, adaptable structure with a fine division of tasks among companies.

Taiwan got into the electronics business in the 1950s by making radios, TV sets, and calculators. Many of these companies were financed from profits made in traditional industries (textiles, chemicals, hotels, lumber), and many failed. However, skills developed in producing calculators were valuable in making the transition to computer making, often done by new firms.

The movement of skilled professionals has long been an important part of Taiwan's rise. It led the way in inviting engineers with work experience in the United States to help build its computer industry. That phenomenon peaked in the mid-1990s, and since then the number of students going to the United States for study and work experience has declined sharply—so much so that the Taiwanese government is introducing a scholarship program to increase the number. There has also been a large-scale movement of business people between Taiwan and mainland China. An often-cited number is about 300,000 Taiwanese working in the Yangzte River Delta region alone, largely for Taiwanese companies.

Although the electronics industry got well underway without benefit of a venture capital industry, as noted in Chapter 10, the IT industry received a boost from 1983 legislation providing a tax rebate of up to 20 percent for individuals who maintained an approved venture capital investment for at least two years (an advantage that ended in 2000).

The dynamism of the Taiwanese electronics industry is shown by the turnover in companies. The annual entry rate of electronics firms averaged 1,100 and an exit rate of 300 from 1986 to 1991, with entries of 900 and exits of 450 per year from 1991 to 1996 (Amsden and Chu 2003).

In the 1980s, the IT industrial structure changed with the spinning off of integrated circuit companies from ITRI as reported previously. TSMC went on to develop the world's most successful pure foundry model. The success of foundries led to the creation of an IC design industry, including such design houses as MediaTek and NovaTek that spun out from UMC. An industry that consisted of 51 companies in 1991 grew to 225 companies in 2002, thus making it one of the three biggest IC design industries in the world, together with the United States and Israel, with sales of the largest 10 IC design firms totaling U.S. $3 billion in 2003.

According to Kenney et al., Taiwan is the Asian leader in funding new high-tech companies. It "is a textbook case for the ways in which the government can alter the risk-reward calculation. The 20 percent tax rebate created a powerful incentive, but it did not eliminate risk. Moreover, the government created relatively simple and transparent rules that aligned the incentives for the fledgling venture capitalists with the government's objectives."

THE IMPORTANCE OF CROSS-BORDER LINKAGES

It is hard to miss the high proportion of scientific and technical papers published in the leading scientific and technical journals that have Chinese- and Indian-born authors, many of them at U.S. universities. Increasing numbers are returning home. This was a major source of talent for Taiwan in the 1980s and 1990s, and now there is a growing flow back to China and India. They return not only with scientific and technical skills but also with know-how about organizing and conducting research projects and building companies. The contributions of returnees to Hsinchu and ZGC have been described above. Foreign nationalities constituted over one-fourth of Singapore's professional IT manpower in 1995–1997 and is likely to have increased since then.

Whether among Silicon Valley, Hsinchu, ZGC, or Bangalore, linkages have been critical. Some of these places have become hubs, such as Silicon Valley, linked through flows of goods, people, capital, and technology into a global network.

Kenney et al. describe three types of people links between Silicon Valley and Asia. The first was the human linkage provided by Asian students who stayed in the United States and worked in Valley firms and elsewhere in the United States, such as at Bell Labs. They soon began launching their own start-ups while they kept close relationships with friends and families in Asia. The second link consisted of Asian students and seasoned managers who returned to their various nations, either joining the Asian operations of Silicon Valley firms or setting up companies that contracted with Silicon Valley ones. The third link was Asians trained at home who then joined the overseas operations of Silicon Valley firms. Each link was a conduit for information transfer and learning. The repeated interactions that occurred on many levels created awareness of what was occurring in Silicon Valley, not only in terms of the technical and managerial skills but also of its entrepreneurial character.

A recent international network example is the Semiconductor Manufacturing International Corporation (SMIC), a silicon foundry whose headquarters are in Shanghai. It has three chip fabrication plants (fabs) in Shanghai, one in Tianjin, and three being built in Beijing. Ninety percent of its output is exported. Almost all of its early management team were veterans of the semiconductor industry and had spent most of their professional careers in leading semiconductor companies worldwide before they joined SMIC. Chief operating officer Marco Mora, for example, had more than 18 years of management experience at STMicroelectronics N.V., Texas Instrument Italia S.p.A, Micron Technology Italia S.p.A., and WSMC (a Taiwanese foundry). Of its 4,400 workers, 500 came from Taiwan, 300 from the United States, and 200 from other places outside of China. Significantly, all but one of its initial management team started out in Shanghai. Its funding was also global: from H&Q Asia Pacific, Walden International, New Enterprise Associates, Oak Investment Partners, Vertex, Goldman Sachs, and four Chinese state banks.

In sum, it is hard to imagine anything like the present global IT industry without these many kinds of connections. In the present post-bubble era, it is common, almost a rule enforced by venture capitalists, that Silicon Valley start-ups establish a part of their operations from the outset in some place in Asia. Costs are lower, and able people can be recruited.

This process is a win-win-win one in that the individuals who have moved have benefited from good educations and valuable work experiences. Silicon Valley firms have gained from having superior talent, and the places from which these people have come are gaining from returnees bearing valuable human capital. However, this system is in jeopardy. The number of students from (at least) China, South Korea, and Taiwan who have come to the United States for doctoral studies peaked in the mid-1990s and has markedly declined thereafter. Worse, since the disaster of September 11, 2001, the U.S. government's restrictions on issuing visas has discouraged many students and scholars from going there for study and work while, at the same time, non-U.S. countries are vigorously marketing their universities. By late 2005, many of these restrictions were eased. Unless this happens decisively there will be a large deterioration in this beneficial set of linkages.

MAIN THEMES OF THE BOOK

This book shows that there were several paths to developing a significant place in the global IT industry. By the 1990s, all six countries or regions had adopted some strategies—or exhibited patterns of behavior—that were similar, even though they differed markedly in others.

Similarities

Eventually all adopted growth-positive development policies. This was crucial. No country that failed to adopt at least a minimum set of policies to promote development—including substantial reliance on the private sector, some degrees of openness to the outside world, encouragement to capital formation, and investment in education—has succeeded in the IT industry. India and China were late entrants, but by the 1990s they had both done so and have flourished thereafter.

All these regions invested in educating enough scientists and engineers to be able to participate significantly in this sector. This does not mean that all had good general educational policies. That of India has been notoriously inadequate, and the distribution of education in China has been very uneven.

All had to acquire these technologies. At the beginning of the period examined in this book (circa 1970), only Japan among the six had a substantial technological base, and in the following decades even it had to acquire many technologies from abroad (while also advancing them). The need for technology from abroad was much stronger for the other five.

All these governments actively promoted their IT industries. They all saw this as a key set of industries. Telecommunications has widely been seen as "strategic" throughout the world, and computers came to be seen as a leading-edge sector in which they could establish market positions. The products were light and hence cheap to move; the adoption of universal standards enabled new firms to enter; demand for products was growing rapidly; and the largest market, the United States, was relatively open.

All had some kinds of openness to the outside world. No successful country or region can be isolated. Our six were engaged with the world, not only through trade but also through other mechanisms as well. These mechanisms—licensing, investments by MNCs, flows of people to and from other countries—enabled them to acquire foreign technology and know-how.

In particular, all had linkages with the United States. These were of several kinds and the mix of them varied among countries.

In none were universities important sources of technology. The role of universities was to produce trained people; for most of this period this was especially true at the undergraduate level.

The financial systems of all changed. These changes affected their IT industries. The role of banks diminished and that of stock markets increased. All sought to develop venture capital industries, but the results were mixed.

Differences

Legal rules were established and reasonably effective in all the regions except for China.

Openness was expressed in different ways:

- Japan, Korea, and India long held off foreign direct investment while Singapore, Taiwan, and China welcomed it—but selectively.
- Japan, Korea, and Taiwan became major acquirers of technology through licensing.
- Flows abroad of students (many of whom stayed to work) and the inmigration of people skilled in technology and management were important for Taiwan, India, Singapore, and China but much less so for Japan and Korea.

Promotion of their IT industries. This was done in different ways, some effectively and some less so. A wide array of instruments was used. These included the training of computer scientists and engineers; trade protection; inviting MNCs or, on the contrary, denying direct investment by foreign firms (preferring other instruments such as licensing) ; incentives for private R&D; government spending on R&D; creation of dedicated research institutes; recruiting of experts with foreign experience; supplying cheap real estate, tax breaks; and more.

Linkages with the United States. Although all had strong links with the United States, the mixture of ways differed in regard to trade, foreign direct investment, licensing, and movements of people. There were also widespread connections between Japan and East Asia. Dense business connections have been established between Taiwan and mainland China.

Entrepreneurship. Some regions had active entrepreneurship expressed through the formation of new firms (Taiwan, India, China) while there was little in others. Singapore, Japan, and Korea have been making legal and policy changes to encourage it.

Innovation. Only Japan among the six displayed technical innovativeness throughout the period. Taiwan, Korea, and Singapore, especially, began to develop it during the 1990s (measured, for example, by U.S. patents).

Regional clusters. These became prominent in all these countries except Japan. They were mostly government-created except for Teheran Valley in Korea, the Indian clusters, and the nascent IC one in Fukuoka, Japan.

Mobility of labor. All had mobile labor markets except Japan and Korea. Their governments recently have taken actions to encourage it.

Financial systems. These evolved during this period, but only Taiwan had a well-developed venture capital system by 2000.

Research institutes. Research institutes specializing in IT became ubiquitous, but their significance varied. In particular, they were significant sources of new companies in Taiwan and mainland China but not in the others.

A LOOK AHEAD

There is a growing belief in scientific and technical circles worldwide that Asia is becoming not only a place for making things but also — perhaps soon — a creator of technology. All our countries or regions that have not already done so are establishing a base for being innovators. They have able, well-trained people, have or are developing needed institutions, and are connected to the world of ideas.

Previously we discussed important indicators of progress. One is the large and growing numbers of well-educated scientists and engineers. The number of PhDs granted in Korea from 1986 to 1999 increased four times, in Taiwan five times, and in China about 50 times (from 100 to 200 to more than 7,000) (Hicks 2004). Others are increased spending on research and development; the high and rising level of patents of Japan, Korea, and Taiwan; growth in scientific publications and in their quality measured by citations; and the shift toward neutrality in the balance of royalty and license fees with the United States. Still others are the stellar group of biologists Singapore has recruited and the setting up by foreign firms of R&D centers in China—about 150 in number. Today, these centers seem to be doing much more "D" than "R," but that mix will surely shift toward doing more research.

China has great ambitions in science and technology, and, given its accomplishments, they are likely to be realized, although the timing is uncertain. Between 1995 and 2000 China's spending on R&D more than doubled. It was still only 1 percent of GDP, but it was growing at 10 percent a year and the government says it want to increase that share (Walsh 2003). By the year 2000 China ranked eighth in the world in scientific papers contributed by

Chinese authors (3 percent of the world total) compared with its being 15th in the world five years earlier. This is not to assert that China's capacities are up to those of the industrialized countries. This will not likely happen soon, but China is on the move.

The rise of Asia in innovativeness will have mixed impacts on others. The generation of new ideas can benefit everyone. It also gives their creator an advantage — as Silicon Valley has demonstrated. What should not be in doubt is that the United States and every other country will face a large challenge coping with the rise of an innovative Asia.

NOTES

1. There is a connection between the justly popular topic of national systems of innovation and this label of national technology strategies. The difference is that, Japan excepted, for most of the period covered in this book the focus of governments and companies was less on innovation and more on acquiring already developed technologies. A seminal publication on innovation systems is Nelson and Rosenberg (1993).

2. This flow diminished during the 1990s as better employment and educational opportunities emerged in Taiwan. The Taiwanese government is now undertaking a scholarship program to reinvigorate the flow of students to the United States.

3. These and some of the following points are emphasized by Segal.

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