Beyond Late Development

Taiwan's Upgrading Policies

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Preface

Since the mid-1980s, ideology and reality have diverged in the fastest-growing latecomer countries. Global ideology for economic development has become one of open markets, increased foreign investment, a greater role for the small-scale firm, and sharply diminished market interventions by the state. The reality, however, is otherwise. In Taiwan, a stellar performer among latecomers in the last four decades, the share of foreign firms in the output of the electronics industry, the engine of growth of the 1990s, has become insignificant. Large nationally owned "second movers" rather than foreign enterprises or small, "networked" firms have pioneered high-tech industry. The dinosaurs of the traditional economy—diversified business groups—have taken the lead in building a modern service sector. Although the role of foreign firms in services has increased, even here their contribution has been minor measured by market share. Together with new groups based in electronics, conglomerates have substantially raised their share of total national income. Arguably, government intervention has been greater and more systematic in promoting high-tech industry and modern services than in promoting mid-tech industry, but the promotional policy tools have been different. Markets have become more competitive, and interventions have become more selective.

This book is dedicated to distinguishing ideology from reality in terms of theory, institutions, and policy, in the hope of improving economic growth and welfare in latecomers throughout the world.

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1 Scale

This book addresses the question of how latecomers compete in world markets at the stage in their economic development when they already have basic industry but neither operate at the world technological frontier nor still profit from low, unskilled wages. Their sustained competitiveness depends on upgrading, or improving their performance in mid-tech industries and moving into high-tech sectors. Upgrading requires exploiting a different set of competitive assets from previously, using altered organizational and institutional structures to do so, and subjecting these structures to new mechanisms of discipline and control. At this stage of a latecomer's life, a key component of upgrading is upscaling. The growth of big business is necessary for a latecomer to become a global player in mid-tech industries and to compete in those technologically advanced industries and services where skills are complex but not cutting-edge.

As latecomers become more integrated into the world economy, and as they become more exposed directly to its ups and downs, they suffer acutely from business and product cycles, which makes upgrading more of a challenge. But those countries where upgrading succeeds are likely to experience fewer, shorter, and shallower downswings. This is because at the heart of upgrading is an ability to *adjust quickly* to global demand changes and to manufacture "new" products.

The speed of adjustment is viewed differently by rival theories of the firm: some emphasize the importance for quickness of networks (which encourage flexibility among small-scale enterprises); others, the market (which allows resources to flow rapidly across borders); and still others, the hierarchically managed firm (whose chain of command, deep pocket, and hub of knowledge enable it to be the first to exploit a new business opportunity). We argue that all institutional theories of firm behavior need to be modified to understand countries whose firms lack cutting-edge skills. But the theory closest to reality is the one that emphasizes the importance of big business and the advantage of the "first mover."[1] In its modified form, this theory predicts that for latecomers to improve their performance in mid-tech sectors and enter higher-tech industries, their national business organizations must scale up, investing more in managerial and technological capabilities and expanding their production scale and scope, domestically and globally. The first latecomer firm to make a three-pronged investment—in optimal size plants, technology and management, and distribution—gains "*second-mover advantage*" in world markets. The more numerous a latecomer's second movers, the better its national economic performance is likely to be.

The phenomenon of the second mover also exists in advanced economies, under the name of "late mover" (see Lieberman and Montgomery 1988, 1998) In new high-tech sectors these are the firms that "wait and see," reaping the rewards of the free rider. But the second mover in an advanced economy differs from the second mover in a latecomer country. Second movers from advanced economies tend to compete against first movers on the basis of the timing of their entry.[2] Second movers from latecomer countries, by contrast, compete in world markets on the basis of a lower level of costs and different composition of skills.

Small-scale firms may also be the first in a latecomer country to introduce a world-class foreign technology. But typically small firms take a back seat in upgrading to national large-scale firms. Whereas small firms in advanced countries may be technological pioneers, small firms in latecomer countries do not fulfill this role because they do not yet have technology at the world frontier. Many are backward in terms of management skills. In the first generation of a "new," mature industry, firms may start small, as in the electronics sector. But to survive, they must ramp up at a very fast rate. Then, in the second generation, existing large-scale firms dominate new product cycles, utilizing their finances and project execution skills to spin off small start-ups, or to invest in independent start-ups using their own venture capital affiliates. Both small and large firms in Taiwan moved their manufacturing operations to China, but only large firms had enough resources to maintain product-development facilities in Taiwan, enabling them to upgrade recurrently. Both large and small firms in the electronics sector conduct R&D, but the content differs. Small firms dominate in the *non*electrical machinery industry, but this industry has stagnated in terms of its share in GNP. Even the small suppliers of parts and components to electronics assemblers have been subject to "one-stop shopping" rationalization, as each assembler has demanded a greater number of parts from a smaller number of suppliers, thereby pushing the importance of bigness down the supply chain. By the second or third generation of industrial development, most start-ups or promising small-scale firms are tied in one way or another to an existing large-scale firm.

By definition, no latecomer—large or small—has technology that is state-of-the-art. Therefore, even in so-called high-tech industries, and even with the support of returning expatriates ("reverse brain drain"), they manufacture products that are new to them but mature globally. From these two defining characteristics of lateness—relative technological backwardness and the maturity of high-tech products—we derive the economic patterns that govern their upgrading. Mature products typically earn declining and eventually paper-thin margins. To survive, a latecomer must exploit unique types of scale economies and manufacture in large volume. Even if a firm starts small, it must ramp up very rapidly to achieve a high output level, a process that requires building assets related to project execution, production engineering, and a form of R&D that straddles or falls somewhere in between applied research and exploratory development (integrative design in the case of electronics).

If such assets are accumulated at all, the responsible party tends to be a nationally owned organization—a private firm or a government R&D laboratory, often working together. It is more in the interests of national entities than foreign multinational firms to invest in the specific assets that are required to compete at this stage of development; the opportunity costs of the foreign-owned entity are higher than those of the nationally owned entity. We argue that unless nationally owned second movers evolve, the development of high-tech industry will be slower and there will be no "globalization" in the form of outward foreign direct investment. National ownership is a precondition for aggressive entrepreneurship in high-tech and, by definition, outward FDI (foreign direct investment), which creates the potential for greater scale economies.

Without a new set of nationally owned firms, the total number of countries with multinational enterprises worldwide will remain

Table 1.1
Leading economic indicators, 1971–2000 (average annual growth, %)

	National economy					Electronics industry	
Years	Population	GNP	Per capita income	Exports	Wages	Production	Exports
1971–1980	2.0	9.8	7.0	29.5	—	—	—
1981–1990	1.4	8.3	7.0	10.0	7.4	14.0	14.8
1991–2000	0.9	6.3	5.0	10.0	2.9	13.0	17.4
1971–2000	1.4	8.1	6.4	16.5	5.0	13.5	16.2

Sources: Taiwan, Council for Economic Planning and Development (various years) and Taiwan, Ministry of Finance (various years).
Note: Real wage rate growth: DGBAS Web site, *http://www.dgbas.gov.tw/*. A revised series on electronics production was provided by the Department of Statistics, Ministry of Economic Affairs.

unchanged, and the degree of competition characterizing world markets will remain unchanged as well. This will impede an increase in world welfare.

We draw on empirical evidence from two sectors in Taiwan: electronics and newly liberalized services. The evidence derives from heretofore unpublished data and firm-level interviews. Given the outstanding performance of Taiwan's economy at least until global depression struck in 2001, other latecomers should find the nature of its upgraded firms and the character of its revamped industrial policies of general interest. Taiwan's GNP grew at an average annual rate of 8.3 and 6.3 percent in the 1980s and 1990s respectively (see table 1.1). Its electronics industry and modern service sector grew much faster, while its political system democratized.

The Trend toward Large-Scale Firms

Market theory correctly predicts a convergence in the industrial structures of early and late industrializers, but says little about how a latecomer's graduation to higher-tech industries is accomplished *at the level of the firm*. It leaves unspecified whether or not the agent of upgrading is the large or small firm, the new or established firm, the specialized, vertically integrated, or diversified firm, or the national or foreign firm. This vacuum has been filled by institutional theories that have addressed the firm-level issue, but mostly from the perspective of advanced industrial economies. Two classic approaches offer conflicting answers about the agent of industrial change. One may be characterized as *Jeffersonian* and the other as *Hamiltonian* in perspective.

The former, with antecedents dating back to Pierre Joseph Proudhon (1809–1865), emphasizes collectivity and cooperation.[3] The relatively small, highly specialized firm is the agent of progressive change. It is able to cut bureaucratic costs through individual initiative and achieve speed and flexibility in entering new industries by being networked. What it lacks internally it overcomes by being part of a cluster of firms that mutually create "external economies" (as analyzed by Alfred Marshall; see Marshall 1949, vol. 4, chs. 9–13). Such economies promote innovation and the efficiency needed to compete abroad.

Hamiltonianism, on the other hand, attributes modern manufacturing success to big business and internal economies, with Joseph Schumpeter as one of its most prominent partisans (Schumpeter 1942).[4] It posits that in the course of economic development, as more and more physical and human capital is applied to manufacturing, the agent of change becomes the firm that makes a "three-pronged" investment in plants with minimum efficient scale, in managerial hierarchies and proprietary knowledge-based assets, and in global systems of marketing and distribution. The "first mover" to do so enjoys advantages in the form of entrepreneurial rents that arise from scale economies, novel products and processes, and the managerial skills and capital to diversify into still newer industries.[5]

By far, Jeffersonianism has proved to be the more attractive of the two theories. It champions individualism, cooperation, and democracy. In especially the United States, whose economic theories tend to dominate in the global marketplace of ideas, the ideology of the small entrepreneur is supreme. This hero is imbued with the attributes of innovativeness, efficiency, and flexibility. Arguably, however, Hamiltonianism has in fact ruled the modern industrial world. The visible hand and internal economies may be said to predominate in most modern industries over the invisible hand and external economies (Chandler 1977). Whatever the tendencies toward disintegration and greater specialization, firm-level expansion has increasingly taken the mode of diversification, merger, and acquisition.

As an industry matures, it tends to become concentrated. Many first movers fall by the wayside. But those that survive continue to enjoy relatively low costs and large increases in knowledge-based assets. Hence they retain their first-mover advantage despite "gales of creative destruction" (Schumpeter 1942). Long-term oligopolistic survivors—that remain formidable competitors to latecomers—include Hoechst, Bayer, Dow, and DuPont in chemicals; Dunlop, Pirelli, Goodyear, and Firestone in tires; Ford, Fiat, General Motors, and Mercedes in automobiles; Siemens, Philips, Westinghouse, and General Electric in electronics; John Deere, DEMAG, Escher-Wyss, and Olivetti in machinery; Anaconda, Arbed, Krupp, and Nippon Steel in primary metals; IBM, Tosihiba, Apple, and Dell in computers, and so on.

The Proudhonian view has also gained popularity in explaining the success of late industrializers. Economic development in Taiwan especially has been attributed to networks, small-scale firms, and Chinese Americans returning to Taiwan from California's Silicon Valley.[6] We argue, however, that even in Taiwan reality is otherwise. Small-scale firms (with 100 or fewer workers) are not notably innovative, and between 1986 and 1996 the rate of entry of new firms declined. In electronics—the chief example offered as evidence in favor of network theory—and in newly liberalized modern services—which tend to be neglected altogether in such theory—the relatively big business has grown from small to large in a very short time period and has acted as the most progressive and developmental force. Local assemblers in Taiwan have benefited from buying parts and components from local subassemblers, most of them small or medium in size. But these transactions have been arm's-length in nature. There is virtually no subcontracting *within* the electronics industry in Taiwan, although Taiwan assemblers are typically the subcontractors of foreign buyers.

Given ease of entry, there will always be small start-ups in Taiwan exploring new avenues of business. Soon, some start-ups may be expected to create a path-breaking technology at the world frontier. But today's start-ups are much more likely than in the past to have links with large-scale firms, either as their affiliate or as a client of their venture capital subsidiary.

High-tech industries in latecomers begin by importing their key peripherals, parts, and components. Their import dependence is much greater than that of their counterparts from advanced economies, even in import-intensive industries such as electronics (Langlois 1992). Latecomer governments like Taiwan's, therefore, selectively and systematically promote import-substitution to ensure timely access to such inputs and to create domestic high-wage industries. This process is comparable to their import substitution of mid-tech industries in the past. What differs are the policy tools used at the two stages of development. Instead of state-owned enterprises, the catalyst in high-tech sectors are spin-offs from government R&D laboratories and science parks. Instead of tariff protection, the government promotes the research and development that is necessary for the private sector to climb the ladder of technological complexity and compete in world markets. Despite a global ethos of liberalization, the Taiwan government has systematically planned and promoted the growth poles around which networks and high-paid jobs have emerged. Thus local networks have been "state-led" rather than autonomously driven.

Second-Mover Advantage

Product Maturity and Scale Economies

High-tech products and services are already technologically "*mature*" by world standards when a latecomer economy begins to supply them. The first latecomer entrant into such an industry earns above-normal profits because margins are still high when production of a mature product begins overseas. But profit rates tend to decline steeply once mass production commences, so the capture of second-mover advantage is critical.

Declining profit margins and standardization are incentives to exploit *economies of scale*. Three types of scale economies may be distinguished: (1) production-related economies (learning-by-doing), (2) diminishing unit design costs, and (3) economies in information, signaling, and transactions costs (which are unique to latecomers).

Type 1 concerns the usual production-related economies with respect to learning-by-doing from longer production runs, cost savings from fuller capacity utilization and bulk purchases of inputs. *Type 2* also concerns fixed cost, but with respect to design. This generic scale economy is not unique to latecomers, although latecomers in electronics mastered a unique design skill—the integration of the many parts and components that comprise mass-produced devices such as handheld calculators, notebooks, and cell phones. Given fixed costs of design and prototyping, and design modularities for different customers, unit design costs tend to be lower the greater output. *Type 3* scale economies concern *information, signaling, and* *transactions costs*, and are unique to latecomers. To become a subcontractor for a big foreign firm, a latecomer enterprise must itself be large. First movers in advanced countries use size to identify potential foreign subcontractors (or joint venture partners in the case of services) in order to reduce their own risk and monitoring costs. In the personal computer industry, for instance, a subcontractor in Taiwan must typically meet a minimum percentage of a first mover's total volume of business, and a maximum percentage of its own business for any single foreign buyer. These conditions entail annual production runs in the millions. Thus scale signals a potential subcontractor's eligibility for an OEM or ODM contract.[7] The larger the contract is, the lower are the average costs. Similarly in the case of foreign vendors, the bigger a buyer is, the better is a vendor's service. When global demand for a high-tech product surges, key parts and components may be in short supply, and bigger buyers are served first. In normal times bigger buyers are given greater technical assistance by vendors, who typically are the agent to provide a road map for where an industry's technology is going. Access to leading foreign vendors is critical for latecomers, given their high initial dependence on imported inputs and the technology transfers inherent in vendor relations.

As first movers around the year 2000 began to demand more products and after-sales service from a single subcontractor (*one-stop shopping*), and as the supply chain became more rationalized (fewer transactions in the sequential supply of parts and components to an ultimate final buyer), the scale and scope demanded of international subcontractors further increased. By the same token, consolidation among service providers in the advanced economies raised the minimum acceptable scale for foreign joint venture partners. The larger firms became, and the more concentrated markets became in advanced economies, the larger and more concentrated they became in latecomer economies. In this regard global tendencies converged (as discussed in chapter 2).

Skills

Two kinds of skills are required for latecomers to become second movers in mature, high-tech industries. First, they need technological knowledge about a new product such that once it matures, they can produce it commercially. Second, they need project execution and production capabilities in order to be quick-to-market at the lowest cost. In Taiwan, the first skill was "statized" and the second was "privatized." The government invested in the R&D and ancillary institutions necessary for nationally owned firms to enter promising high-tech sectors. It spun off second movers from government R&D labs, it nurtured start-ups in science parks, and it import-substituted high-tech parts and components to relieve scarcities and create well-paying jobs (as discussed further below and in chapter 3). For its part, nationally owned firms invested in professional management and engineering talent. They hired experienced managers and engineers from overseas, created large in-house automation departments, and poured money into quality control, global logistics, and improving integrative design (which is part of R&D). Thus highly specific skills are needed to upgrade.[8]

Ramping up and Increasing Concentration

The growth path of a second mover may start with either a large or small investment. In the latter case, the ramp-up in the face of potential scale economies must be extremely fast. Aside from project execution skills, the rapidity of ramp-up will depend on the availability of capital, human resources and de-bugged technology (a function of product maturity and government-sponsored research). If these resources are available, then a firm can grow from small to large quickly (even ignoring mergers and acquisitions, which became more prevalent in Taiwan despite legal restrictions).

The type of firm that is the agent of such expansion will differ in early and late industrializers. In the former, a path-breaking innovation is typically the origin of a new company (the assembly line in the case of Ford Motor Company, the telephone in the case of Ericsson, the integrated circuit in the case of Intel, etc.). Among latecomers, where there are as yet no path-breaking innovations to attract capital and other resources, an existing firm is likely to be the agent of diversification, including diversification into a new segment within the same industry. The small, inexperienced firm is disadvantaged in accumulating the requisite human and physical capital compared with an existing enterprise, unless it allies with it.

A consequence of diversification by existing firms is a rise in aggregate economic concentration. Even at the industrywide level, a shakeout among firms competing for market share and lower costs occurs after a period of intense competition. Upscaling therefore entails a rise in the concentration and centralization of a latecomer's capital. National competition then takes the form of a struggle among established second movers for supremacy in still "newer" mature product markets.

Globalization and Foreign Exit

"Globalization" enables latecomers to achieve greater scale economies in production than what they could achieve domestically, if faced with a fixed supply of any input (e.g., land, low-cost labor, and qualified managers and engineers).[9] If globalization abroad by national firms is coupled with exit by foreign firms at home, due to rising wages, then there is a fall in the ratio of inward to outward foreign direct investment, FDI_{Ii}/FDI_{Oi} (defined for the *i*th industry). The nationally owned firm becomes increasingly dominant in a latecomer.[10]

Given an advanced economy's frontier technology, its leading enterprises tend to exploit the advantages they derive from innovative products in the richest countries; it is a stylized fact that the most popular venue for US outward FDI has been Canada and Europe, and vice versa. Upscaled latecomers, by contrast, exploit their competitive advantage in manufacturing by shifting production to lower-wage countries in order to cut manufacturing costs.[11] On both counts, the locus of outward FDI by leading enterprises from latecomers occurs mainly in countries with low per-capita income. Firms from advanced economies also cut costs by relocating production to low per-capita-income countries. But their outward FDI will, on net, tend to be dominated by new product development, and may be hypothesized to concentrate in countries with high incomes per head. Upscaled latecomers that lose their low-wage advantage, therefore, are likely to experience a relative decline in inward FDI unless foreign investors regard them as a new market worthy of FDI, or invest in the same skills necessary to compete against second movers in world markets. The nationally owned firm becomes a latecomer's dominant form of business enterprise by crowding out inward FDI and serving as the agent for outward FDI.

By 2000, Taiwan's total accumulated amount of approved inward and outward FDI were both estimated to be around US$44 billion (see table 1.2). This ratio is almost certain to be overstated given the understatement in official statistics of approved outward FDI to China.[12] As services began to be liberalized in 1986, inward FDI rose as a share of sales. But in industry, the share of foreign investors in

Table 1.2
Globalization, 1952–2000

Year	Inward FDI: Number of cases	Inward FDI: US$mil	Inward FDI: Average value per case, $mil	Outward FDI: Number of cases	Outward FDI: US$mil	Outward FDI: Average value per case, $mil
1952–1983				—	134	—
1984	175	558.7	3.2	22	39	1.8
1985	174	702.5	4.0	23	41	1.8
1986	286	770.4	2.7	32	57	1.8
1987	480	1,418.8	3.0	45	103	2.3
1988	527	1,182.5	2.2	110	219	2.0
1989	547	2,418.3	4.4	153	931	6.1
1990	461	2,301.8	5.0	315	1,552	4.9
1991	389	1,778.4	4.6	601	1,830	3.0
1992	411	1,461.4	3.6	564	1,134	2.0
1993	324	1,213.5	3.8	9655	4,829	0.5
1994	389	1,630.7	4.2	1258	2,579	2.1
1995	414	2,925.3	7.1	829	2,450	3.0
1996	500	2,460.8	4.9	853	3,395	4.0
1997	683	4,266.6	6.3	9484	7,228	0.8
1998	1140	3,738.8	3.3	2181	5,331	2.4
1999	1089	4,231.4	3.9	1262	4,522	3.6
2000	1410	7,607.8	5.4	2231	7,684	3.4
1952–2000	12,521	**44,566**	3.6	29618	**44,059**	1.5
1989–1995	2,935	13,729	4.7	13375	15,306	1.1
1996–2000	4,822	22,305	4.6	16011	28,160	1.8

Source: Adapted from Taiwan, Ministry of Economic Affairs (various years [e]).
Note: FDI = foreign direct investment.

the sales of Taiwan's top 500 firms declined. FDI became virtually insignificant in the output and exports of the electronics sector.

Electronics manufacturers were responsible for Taiwan's largest share of outward FDI (and domestic manufacturing output). Only as electronics firms began to compete on the basis of technology did the United States become an important locus for their investments, in the form of listening posts and distribution channels. Instead, outward FDI was concentrated in Asia, first the Southeast and then China. As in Taiwan, profitability from Asian operations outside Taiwan depended on big-volume and high-capacity utilization. Parts suppliers only followed Taiwan's assemblers overseas when volume was large enough to warrant it. Taiwan companies in China reported that they operated their plants 24 hours a day, 7 days a week, making use of young Chinese female labor that earned extremely low wages and allegedly welcomed overtime work.

Foreign production may assume different *modes*: foreign *direct* investment (equity), foreign *indirect* investment (debt), or subcontracting. The preferred mode may be predicted to depend on the *product immaturity* and *asset specificity* of the foreign investor, and on the *production and project execution skills* of the host country.[13] The United States may be subcontracting to a latecomer (Taiwan) when Taiwan is making a foreign direct investment in a still lower-wage country (China). As the United States shifts its mode of operation in Taiwan from equity to debt or international subcontracting, ownership in Taiwan changes from foreign to national. The exit of foreign firms operating in Taiwan due to rising wages may thus be occurring at the same time as Taiwan firms are themselves "globalizing" in China (FDI_{Ii}/FDI_{Oi} falls). Generally, as first movers in advanced economies get leaner through international subcontracting or FDI, second movers in latecomer economies get fatter through integration. *The international division of labor is not necessarily reproduced domestically.*

In traditional models of economic development, the foreign investor from an advanced economy is the agent of transformation and growth. The skills it brings to an underdeveloped country supposedly diffuse through various means, and through diffusion and the local procurement of parts and components, nationally owned enterprises evolve.[14] These nationally owned enterprises then mature and invest in other countries, and so economic development is predicted to spread globally.

As we will see in the case of Taiwan, the progression from the arrival of foreign investment to the emergence of nationally owned firms did not occur spontaneously, by dint of market forces only, as the market model suggests. It was mediated by the government and by other nonmarket institutions. Even the first instance of a major inward foreign investment in the electronics industry—televisions—did not approximate laissez-faire. Technology transfer was most intense not from American companies operating in export enclaves but from Japanese TV joint ventures that were subject to tariff protection and local content requirements, and served primarily the domestic market. The transition in Taiwan from inward foreign investment, to national ownership, to outward foreign investment by nationally owned firms was systematically planned and institutionally driven, as examined in chapter 3.

Services

In the newly liberalized service sector of a latecomer, comprising such specializations as telecommunications, finance, retailing, and fast foods, most of the assumptions and hypotheses that apply in electronics also apply here. There is a general absence of cutting-edge skills in national enterprises, foreign technology is mature and hence subject to standardization, and economies of scale are important (especially regarding brand name). The major difference between a mature high-tech industry and a modern service is that there is no international (or intranational) subcontracting. Foreign firms cannot out-source the provision of many services in the same way that they can out-source the manufacture of certain products. Therefore, national firms tend to compete head-on in services with foreign firms, which can exploit their long-standing advantages with respect to technology, scale, global logistical experience and brand-name recognition. The survival of nationally owned firms in newly liberalized services, therefore, partly depends on a government's regulatory policies. In Taiwan the government restricted foreign entry in the immediate period following market opening of services ranging from banking and insurance to telecommunications and transportation.

For a latecomer firm to enter a modern service industry typically requires a large capital outlay and advanced project execution skills. Therefore, newly liberalized services, like new high-tech industries, are likely to be dominated by extant enterprises rather than new start-ups. In the case of nationally owned firms, a diversified group tends to have the most expertise in diversifying and thus may be expected to dominate among national service providers, as they have done in Taiwan.

Given entry into newly liberalized services by multiple groups, the immediate result is overcapacity. Then follow consolidation and rising concentration at the industry level coupled with rising aggregate economic concentration. As Taiwan's old business groups diversified into services, and as new business groups emerged in electronics, the share in GNP of its top 100 groups jumped from less than 30 percent in 1986, when liberalization began in earnest, to 54 percent in little over a decade (as discussed in chapter 4).

State-Led Networking

A network is a locus of transactions among firms that are mediated *personally* rather than *anonymously*, as they supposedly are in market theory. A network's strength may be measured conceptually by its number of transactions, their value, and the degree to which they are mediated personally (i.e., based on "trust"). By these criteria (number, value, and degree of personal interface), networking is likely to vary by industry—it is supposedly strong in the electronics sector. Even in the electronics sector, however, networking is likely to be relatively weak *within* a latecomer, even if it is strong between a latecomer and an advanced economy in the form of international subcontracting.

In terms of value of transactions, an electronics network tends to be weak within a latecomer due to a heavy reliance on imports for "active" components and parts (active in terms of relatively advanced technology and customization). Instead of buying from each other, latecomer firms initially buy their critical inputs from foreign vendors.

In terms of personal interface, network activity may be divided into four overlapping types, all of which involve some personal element: the *subcontracting* of parts or components; the *customization* of inputs that require close inter-firm cooperation (e.g., tools and prototypes); "*in-processing*," or the processing of materials supplied by one firm to another firm that specializes in such a process (e.g., paper for printing or fabrics for dyeing); and the *local procurement* of peripherals (equipment), parts or components from known suppliers. Local procurement is the weakest form of networking because the personal element may be superficial; parties to a transaction may know one another personally but may act strictly opportunistically, neutrally (at arm's-length) and in response only to existing market signals. Subcontracting is the strongest form of networking because it is premised on a contract, implicit or explicit. It may not necessarily involve a long-term commitment; contracts between computer companies in high-wage and low-wage countries—say, Dell and Quanta—are typically negotiated on a yearly basis. Still subcontracting is the most personal form of networking yet the least likely to exist *within* a latecomer. Within the electronics sector of Taiwan, subcontracting is virtually nil.

Subcontracting is weak in a latecomer because the incentives for it are weak. Additionally foreign buyers may impose an outright ban on a subcontractor's own freedom to out-source. In terms of incentives, whereas international subcontracting is premised on a large wage differential between countries, the wage differential among firms within a latecomer is not necessarily large. Whereas the co-generation of technology in advanced economies is premised on risk-sharing, long-term planning, and a large element of trust, the incentive for firms in latecomer countries to co-generate technology is weak because no firm is at the world technological frontier (the defining characteristic of lateness), and a prerequisite for the development of genuinely new technology. Electronics assemblers in latecomer countries tend to buy "passive," standardized parts and components locally, but the procurement of such inputs can be handled without personal intermediation.

Given high import dependence and the absence of cutting-edge skills, the role of the government in promoting the growth poles around which networks flourish is likely to be greater in a latecomer than in an advanced economy. The government becomes the leading actor in promoting the import substitution of high-tech components and parts. It leads in the development of advanced technologies to the point where their commercialization is possible once they mature. In Taiwan the government targeted key sectors and directly intervened in them. The model in electronics was to create spin-offs from a government-owned research institute (ITRI).[15] Whereas import substitution of basic industries largely relied on the policy tools of tariff protection, financial subsidies and local content rules, the import substitution of high-tech industries largely relied on diverse policy tools to promote government-sponsored or government-subsidized R&D, as well as regulatory policies that limited foreign entry in services (however briefly).

In general, the government was a leading actor in Taiwan's economic development. Starting in the 1950s and continuing through the 1990s, the government accounted for roughly *half* of all gross fixed capital formation, a share that was unsurpassed by any other latecomer (Amsden 2001).[16] The government allotted resources in order to influence firm size, structure, and degree of specialization by means of its policies related to industrial licensing, bank lending, debt-to-equity ratio requirements, and constraints on mergers and acquisitions. As for discipline, when the government wielded power over the purse, discipline operated through the imposition of performance standards on subsidy recipients *and subsidy providers*—bureaucrats in state-owned banks, for example, were held personally responsible, in terms of their salaries and promotion, for the health of their loans (Wade 1990). Later globalization played the role of disciplinarian. The threat of a "hollowing out," meaning the relocation by firms of their production and other business functions overseas (especially in China), dominated government thinking. Its strategy to invest heavily in education, R&D, import substitution, and science parks was aimed deliberately at upgrading in order to keep industry in Taiwan.

Geographical Agglomerations

Taiwan's electronics assemblers benefited from a dense network of passive parts and components suppliers. Personal intermediation was insignificant, and the value of each transaction was relatively small, but the *number of total transactions* was large and highly beneficial to the electronics industry at large. In the case of personal computers, by the late 1990s assemblers of notebooks were still sourcing around 60 or 70 percent of the *value* of a notebook from abroad, but were sourcing 97 percent of the *number* of parts locally. Taiwan's electronics network thus took the form of a geographical agglomeration of firms whose transactions were arm's-length (for the general case of spatial clusters, see Fujita et al. 1999 and Neary 2001).

The emergence in latecomers of dense networks involving a large number of transactions depends on several variables. First, a network tends to arise in a latecomer with a certain composition of manufacturing output, one that comprises industries with a large number of discrete parts, each of which must be designed, prototyped, and produced (e.g., garments, transportation equipment, and machinery), rather than industries with continuous process technologies (e.g., steel, chemicals, and cement). The larger the share of manufacturing in a country's GNP, and the larger the share of such sectors in its total manufacturing (both of which are partially a function of government policy), the more likely the emergence of a network.

Second, in the case of networks in the "new economy," the greater the size of an educated elite, and the greater the engineering orientation of such an elite (both partial functions of government policy), the greater the likelihood of a network comprising learning-based firms.

Third, networking is encouraged by geographical proximity. The greater such proximity among firms due to small country size and modern transportation and communication services, the more cohesive a network is predicted to be.

Fourth, networks operate best where governments operate best. The more systematic and disciplined government policy with respect to skill formation and import substitution, the greater the success of a network is likely to be.

Among latecomers, Taiwan excelled on all four counts. The share of its manufacturing sector in GNP and the share of its machinery sector (electrical and nonelectrical) in manufacturing output were both outstanding by latecomer standards. Moreover Taiwan's educational attainments and engineering training were especially high (see chapter 3). Its relatively small total population and concentration of manufacturing activity in a small, densely populated geographical area facilitated personal communication among an educated elite. Finally, the quality of its state intervention was high because of discipline.

The origin of Taiwan's network began with its prewar and immediate postwar manufacturing history. This history is rich in foreign connections. An influx of entrepreneurs from the mainland after China's 1948 revolution created the foundation for a dense agglomeration of machinery manufacturers, including manufacturers of bicycles and machine tools (Chu 1997 and Amsden 1977 respectively). Later, when the electronics industry began to boom, machinery makers shifted to manufacturing electronic devices. A supply of small- and medium-size firms thus already existed when opportunities to export and win foreign subcontracting jobs presented themselves. Government policies that strongly promoted exports beginning in the late 1950s further encouraged international subcontracting (e.g., see Wade 1990). Japanese colonialism ended with World War II and decolonization, which had the virtue of clearing the decks for the emergence of nationally owned firms and government-controlled banks. But business connections with Japan were instrumental in winning international subcontracts. Many Taiwan and Korean firms were known personally by leading Japanese manufacturers through prewar supplier relations—examples being Tatung and Teco in the case of Taiwan, and Samsung and LG in the case of Korea. Japan itself began much of its globalization in Taiwan and Korea before investing in other Southeast Asian countries (Ozawa 1979). Japan had been the original locus for subcontracting by American multinationals in the bicycle, radio, TV, and electronic calculator industries. But as Japan's wages began to rise in the 1960s, both American and Japanese multinationals looked to Japan's neighbors for cheaper labor. Wages in Korea and Taiwan were low even by Latin American standards.[17] Thanks to foreign aid, both countries had good infrastructure. Under repressed political conditions, organized labor was weak.

By way of conclusion, and introduction to what follows, second movers and networks in latecomer countries are not incompatible, either theoretically or empirically. Nevertheless, we would argue that the dynamic behind a latecomer's upgrading, and the explanation behind the rapid growth of latecomers such as Taiwan in the 1980s and 1990s, was the garnering of *second-mover advantage*. Competition among second movers to produce mature, high-tech products acts as an incentive to exploit scale economies, domestically and globally. Large-scale firms emerge that survive by investing internally in their own proprietary knowledge-based assets, related to project execution, production engineering and integrative design (in electronics). A high level of concentration in various market segments is a consequence, and one that generates the necessary entrepreneurial rents to invest still more internally, in the capacity and especially knowledge needed to diversify into still "newer" mature product lines. Networks of parts suppliers, in the form of geographical clusters, help this process, but a latecomer network contains no internal, organic mechanism to drive it because it lacks technology at the world frontier. The role of driver must be assumed by big business and the developmental and regulatory arms of the latecomer state.

2 Second Movers: Electronics

As late as 1975 Taiwan's electronics industry was dominated by foreign firms. The national companies that existed were believed to be mainly "small" in size, with fewer than 100 workers. By 2000 this situation had been completely reversed. The share in value added of foreign-owned firms was negligible, while that of small national companies approximated only around 20 percent. Instead, the nationally owned corporation with at least 500 workers had become the dominant form of business in the electronics industry. Rapidly rising wages had induced many foreign electronics firms to exit from Taiwan, whereas national firms had invested heavily in skills in order to create new competitive advantages. Learning thus became increasingly asymmetric. The best among the national firms enjoyed "second-mover advantage"—they were the first latecomers to build plants with minimum efficient scale and managerial and technological capabilities in "new," industries, whose profit margins were declining but not yet paper thin. With their high-volume profits and project execution skills, they could then be the first to diversify into the next wave of hot, mature product markets, gaining the fastest time-to-market and enjoying the highest returns.

How upgrading in the electronics industry was accomplished is the subject of this chapter.

The Television Era

Taiwan's first mature, mid-technology export was the television. Production was dualistic and was dominated by foreign-owned firms. One type of production, enclave in nature, involved American 100 percent-owned foreign direct investments oriented toward exports. The other type involved Japanese and national joint ventures

Table 2.1
Sales of electronic devices, 1966–1971 (NT$mil)

	Telephones	Switch boards	TVs	Tape recorders	Radios	Phonographs	Components
1966	31.6	49.3	450.2	0.2	344.7	16.7	98.6
1967	36.5	115.2	464.2	1.0	670.7	11.9	403.7
1968	47.1	55.4	3,100.1	233.1	848.3	42.4	1,402.7
1969	57.5	96.0	2,901.2	207.6	861.1	46.1	2,156.2
1970	70.1	126.6	3,819.8	178.3	936.9	76.6	2,680.1
1971	52.3	196.9	5,380.4	191.9	960.8	63.2	3,188.8
Ratio 1971–1966	1.7	4.0	11.8	724.2	2.8	3.8	32.4
Number of units (1971)	66,428	43,946	1,794,499	319,644	3,815,213	115,269	—
Unit value, 1971 NT$	787	4,480	2,998	600	251	548	—

Source: Adapted from Arthur D. Little (1974).

oriented toward selling in the domestic market and utilizing local components in response to government policies of tariff protection and domestic content requirements, mainly of cathode ray tubes.

American foreign investment was led by Philco (1965), followed by Admiral (1966), RCA (1967), Motorola (1970) and Zenith (1971) (Chen et al. 1997). Additional American investors emerged after the introduction in 1965 of Taiwan's fourth Five-Year Plan, which promoted color TVs. Japanese joint ventures were led by Matsushita, Sanyo, Sharp, and Toshiba.

The star role of televisions in the electronics sector is evident from table 2.1. The production value of TVs in 1971 was greater than that of telephones, switch boards, tape recorders, transistor radios and phonographs, other major electronics products at the time, as well as all "other electronic components." Among the top 10 foreign companies (by sales) operating in Taiwan in 1975, TV producers captured at least seven positions (see table 2.2). Excluding Bristol-Myers (in pharmaceuticals), the other exceptions proved the rule: Texas Instruments and General Instrument did not produce TVs but came to Taiwan to supply key components to the TV industry. RCA, Tai-

Table 2.2
Taiwan's top 10 foreign companies ranked by sales, 1975–1999

Company	1975	1980	1985	1990	1995	1999
RCA	1	1	1			
Admiral	2		9			
Zenith	3	3				
Texas Instruments[a]	4					4
Philips Electronics	5	2	2	4	2	3
Capetronic	6	4				
General Instrument	7	10	5		7	
Sylvania-Philco	8					
Bristol-Myers	9					
Clinton	10					
Oak East		5				
Philips Video		6				
Philips Electronics Bldg		7	6	5	3	2
Uniden		8	7			
Singer Sewing Machine		9				
Wang Labs			3			
Digital Equipment[b]			4		8	
Cargill			8			
Wyse Technology[c]			10			
Ford Lio Ho[d]				1	1	10
Matsushita Electric[d]				2	5	
Nan Shan Life Insurance				3		1
China America Petrochemical				6	4	
Yamaha Motor				7	10	
IBM				8		
AT&T Telecommunications				9		
Motorola Electronics				10	6	8
NEC Electronics					9	
Aetna Life						5
Toshiba Electronics						6
Presicarre						7
Samsung Electronics						9

Source: Adapted from China Credit Information Service (1990, 2000).
a. TI-ACER, a 50-50 joint venture, was formed in 1990 to produce DRAMS. It was sold to TSMC in 2000.
b. Acquired by Inventec in 1998.
c. Wyse Technology was acquired by a consortium of Taiwan firms and the government Development Fund in 1989.
d. CCIS did not classify Matsushita or Ford Lio Ho, established in Taiwan in 1962 and 1972, respectively, as foreign companies until 1986.

wan's leading TV manufacturer, ranked first in sales among all foreign firms in 1975, 1980, and 1985.

Television production was a learning-intensive experience for Taiwan's electronics industry because of the scale involved. In the case of television receivers, scale economies in the advanced countries resided in both manufacture and design:

> Executives (in the US) were unamious in the opinion that high production volume was a crucial prerequisite for success. High volume allows the producer to: a) gain leverage with component suppliers; and b) spread overhead. Leverage with component suppliers means not only getting quantity discounts on large orders, but also making it possible to get semiconductor firms to design proprietary circuits for the set maker. Without a large order, component suppliers will not be in a position to design and produce such circuits at reasonable cost. Similar considerations apply if the circuit is to be designed in-house. Such an activity costs many person-hours of engineering time. Unless there are a lot of receivers over which to spread that fixed overhead cost, the effort will not be worthwhile. The same holds true for chassis design in general and for fixed tooling costs (Levy 1981, p. 69).

The large-scale export plants of American firms in Taiwan utilized "automated production methods *similar to those used in the United States*" (Levy 1981, pp. 69–70; emphasis added).[1]

In 1971 Taiwan was producing as many as 1.8 million TV sets annually (see table 2.1). The number of radios produced was greater, but the unit value of a TV far exceeded that of a radio. A high value signified a more complex product, in terms of number of parts and components and their technological sophistication. Television manufacture thus necessitated relatively heavy investments in managers and engineers, to assure smooth throughput and high quality.

As the television industry waned in relative importance, direct foreign investment in the electronics sector also waned. Rising wages negated the major impetus for TV makers to locate their assembly operations in Taiwan.[2] Further contributing to the investment decline by American producers were their eclipse by Japanese start-ups and a more general lack of interest among American producers in exploring alternative investment opportunities in black-and-white televisions. Indeed, as has been observed, "there was not much change in machinery and equipment from the initiation of [black-and-white TV set] production to the final withdrawal of the whole operation, *since the parent company lacked the motivation to undertake improvements in Taiwan*" (Lin 1986, p. 157, emphasis added).[3] Foreign survivors, such as Philips and General Instrument, did so by diversifying out of televisions. Philips invested in monitors, cathode ray color picture tubes, and semiconductors, the latter in a joint venture with a state-owned foundry, the Taiwan Semiconductor Manufacturing Company.

Despite their closed nature, American TV manufacturers had a positive impact for experienced Taiwan engineers and managers. As they ceased working in American electronics companies, they typically started their own companies, and some came to work for existing nationally owned firms. Top executives in the Lite-On group (a major notebook peripheral manufacturer) came out of the Taiwan-based LED division of Texas Instruments. Some top executives of the GVC Corp., a manufacturer of modems as well as notebooks and later cell phones, came from RCA and Phillips.[4] A sample of 318 electronics firms in 1987 indicated that 71 nationally owned firms and 33 foreign-owned firms (or roughly one-third of the total) employed high-level managers and engineers with working experience in foreign electronics companies. Of these firms, a fair (although not overwhelming) number of the respondents thought this was positive: about 43 percent considered previous working experience helpful in raising management skills, 32 percent thought it improved product design and development, and about 30 percent thought it aided the acquisition of market information (San and Kuo 1998).

Still Japan remained the main source of technology transfer in this early period, and Japan also became the electronics industry's leading and long-abiding vendor of high-tech parts and components.[5] One cannot, therefore, say that the principal source of technological learning in Taiwan's television era emanated from exporting. Japanese TV producers contributed more to learning than American TV producers because they operated in joint ventures rather than export enclaves. Given their domestic market orientation, they were subjected to the Taiwan government's "local content" requirements. Such requirements provided them with an incentive to transfer know-how not just to their joint-venture partners but also to their local parts suppliers. Because they had to buy locally, they wanted their suppliers to be as efficient as possible. "All local firms in Taiwan acquired their technology by proprietary transfer from foreign manufacturers, especially Japanese manufacturers, through the channel of joint ventures or technological contracts. Since TV manufacturers also produced other home electrical products, they chose their TV technology suppliers based on their cooperating experiences in manufacturing other products, or as sales agents of their technology suppliers" (e.g., Sampo was sales agent in Taiwan for SHARP TVs, and when Sampo decided to make TVs itself, Sharp provided the technology). "All the foreign TV technology suppliers were Japanese manufacturers in the 1960s." Moreover, when color TV manufacturers began to export from Taiwan in the 1970s, they did so under OEM (original equipment manufacture) contracts. *These contracts were mainly with Japanese firms* (despite the popular belief that multinational firms from Japan "globalize" more slowly than American multinationals) (Lin 1986, p. 98). Given the embodiment of technology in imported parts and components, and the technical assistance package typically offered by foreign vendors, it is noteworthy that of the raw materials, parts and components used to manufacture Taiwan's $243 million electronics exports in 1971, 37 percent was from local sources, 10 percent was imported from the United States, and 53 percent was imported from Japan (Arthur D. Little 1974). This indicates both the scope for import substitution in the electronics sector and heavy reliance of Taiwan's electronics firms on Japanese inputs. From 1952 to 1979 there were 337 cases of technology licensing agreements between local electronics firms (including subsidiaries of multinationals) and foreign technology providers. Among these, 236 cases were contracted with Japanese firms, 80 with American firms and 18 with European firms (Chen et al. 1997).[6]

Japan's influence on learning is transparent in the case of electronic products closely linked technologically and commercially with TVs. When growth in the demand for TVs slowed, nationally owned joint venture partners in the first tier of the TV industry diversified into *monitors* (a TV is a combination of a monitor and a tuner) and *terminals* (a terminal is a combination of a monitor, a keyboard and a logic board) (Schive and Simon 1986). "The accumulated technological knowledge and experience from TV manufacturing . . . facilitated the technological capability of manufacturers to engage in the production of monitors and terminals" (Lin 1986, p. 86).

Large-scale production of monitors and terminals was initiated in Taiwan in 1980 by foreign subsidiaries; national participation in both industries was nil. But national firms quickly increased their production and exports. By 1983, a mere three years after start-up, nationally owned firms accounted for 63 percent of output and 60

Table 2.3
Entry of national firms into the monitor and terminal industries, 1980–1983

Year	Output[a]	National share (%)	Exports[a]	National share (%)
Monitor industry				
1980	49.4	4	49.1	3
1981	139.7	32	98.6	42
1982	340.6	58	328.4	56
1983	1,009.4	63	956.6	60
Terminal industry				
1980	25.0	1	25.0	1
1981	44.8	23	44.7	23
1982	106.3	29	103.1	30
1983	528.8	51	516.5	52

Source: Adapted from Lin (1986). Data are from ten major suppliers of each product. Together they account for about 95 percent of output and exports.
a. In thousand pieces.

percent of exports of monitors, and 51 percent of output and 52 percent of exports of terminals (see table 2.3). By 1983 total output of monitors had already reached over one million units annually.

The First Second Mover

The premier "second mover" of Taiwan's television era was Tatung. It qualifies as a second mover par excellence because it made a "three-pronged" investment in manufacturing, management and marketing.[7] It was the first in Taiwan to build modern mass production facilities (with foreign, largely Japanese, technical assistance). It also invested heavily in its own technological and managerial capabilities. Given a critical shortage of skills in the 1950s, Tatung established a companywide Institute of Technology (1956), which it upgraded into a four-year college in 1964 (with Departments of Electrical Engineering, Mechanical Engineering and Business Management). Finally, and almost unique in Taiwan, Tatung invested heavily in marketing. It lacked (and continues to lack) technology at the world frontier, but it successfully established its own brand name, first domestically and then globally, on some of its home appliances—rice cookers, fans, and refrigerators. Tatung competed on the basis of consistent quality and low price owing to its low wages, high volume, production engineering capabilities, and project execution skills. Although it was initially oriented toward selling in the domestic market, in the 1970s and 1980s it was repeatedly awarded the government's Premier Prize for export performance (as well as prize for high quality). By 2000 roughly half of Tatung's sales were domestic and half were export.

Marketing included establishing overseas facilities. In the case of electric fans, which Tatung began producing in 1949, exports to the Philippines started in 1954 and exports to Japan started in 1968. In 1974, Tatung established a plant to manufacture fans in Los Angeles. In the case of televisions, it began production of black-and-white TVs in 1964 and colored TVs in 1969. It began to manufacture colored TVs *in the* United States in 1976. In 1981, Tatung opened a TV production plant in England (the same plant began to make monitors in 1988). In 1980, TATUNG broke ground for a domestic plant to produce color picture tubes (Chung Hwa Picture Tubes, a joint venture with five other local companies in which Tatung eventually acquired 100 percent equity). In 1990, Chung Hwa began to manufacture picture tubes in Malaysia. In 1996, it broke ground to manufacture picture tubes in Scotland. In terms of market-expanding globalization, whose competitiveness does not depend on low local wages, Tatung was a pioneer in investing in production facilities in the United States and United Kingdom. It was also a pioneer in losing money in overseas ventures (mostly in the United Kingdom).

Tatung started in 1918 as a construction company under Japanese rule. In 1946 it struggled to survive amid postwar dislocation by repairing railroad trains. Then in the late 1940s it caught the boom in local demand for consumer electrical appliances—rice cookers, radios, refrigerators, and electric fans. As indicated in table 2.4, the electric fan was Taiwan's first mass-produced item, even before televisions, with a steady demand that peaked at 30.5 million units of output annually as late as 1986. In that year the number of fans produced exceeded the number produced of radios, TVs, telephones, and watches. Given this cash cow and its reputation, Tatung was able to finance its expansion at a critical turning point—1957 and 1958—by floating preferred stocks and bonds to local investors. Given its experience with large-scale production, it could enter into what proved to be a strategic joint venture in 1964 with Toshiba to manufacture television sets. With experience in TVs, Tatung diversi-

Table 2.4
Start (****) and peak output, early principal electronic products

Year	Radios (sets)	TVs (sets)	Telephones (sets)	Watches (pcs)	Fans (sets)	Calculators (sets)
1952					****	
1961		****	****			
1962	****					
1970						
1971						
1972						****
1973	14,531,000					
1974						
1975				****		
1976						
1977						
1978		7,095,000				
1979						
1980						
1981						
1982						
1983			25,989,000	14,038,000		
1984						
1985						
1986					30,508,729	
1987						
1988						
1989						69,275,980
1990						
1991						
1992						
1993						
1994					17,547,543	
1999	2,156,614	1,022,000	6,629,451	1,933,379	—	556,552

Source: Adapted from Taiwan, Council for Economic Planning and Development, *Taiwan Statistical Data Book* (2000).

fied into monitors and cathode ray tubes—which became a popular path of learning in Taiwan.

By 2000 Tatung held one-fourth of the world market for color picture tubes. It had become a highly diversified business group within the electronics industry, producing 300 products such as motors, home appliances, electronic devices, computers, telecommunication systems, heavy electrical apparatus, steel machines, electric wires, optical power cables, electronic components, chemical materials, and plastic products. In terms of its second-mover advantage, for at least 20 years, from 1975 through 1995, it consistently ranked first or second domestically in the production of electrical appliances (see table 2.5), even excluding from its total sales those of Chung Hwa Picture Tubes. For many years it was reputed to be one of the most profitable companies on the island.

The Calculator Era

The electronic calculator (handheld or desktop) was Taiwan's next mass-produced electronic export, possibly of even greater importance in creating a *path of learning* than the television. Among other virtues it started a trend away from original equipment manufacturing (OEM) toward original design manufacturing (ODM). Given the calculator industry's production and design characteristics, it was the mother of the notebook industry. In turn, notebooks nurtured cell phones. An identical set of second movers dominated in all three industries—calculators, notebooks, and cell phones.

In terms of sheer *number* (as distinct from value) of units manufactured, calculators towered over Taiwan's early principal electronic products (see table 2.4). The assembly of calculators, based almost entirely on imported components, was the most mass produced among electronic products. Alongside television it provided a laboratory for learning mass production techniques, managerial as well as technological. Production in large volume made possible the realization of economies of scale. In turn, economies of scale provided the environment for an early shakeout in the number of calculator producers. According to key managers at the time, of the 20 or so calculator companies that had begun assembly in the early 1970s, as few as five key players remained in the early 1980s, each with a particular specialization: desktop, handheld, printing calculators, and so on.

Table 2.5
Taiwan's top 10 electric appliance and electronics companies (excluding computers), ranked by sales, 1975–1999

Company		1975	1980	1985	1990	1995	1999
Tatung		1	1	1	1	2	4
Matsushita Electronics[a]	F	2	2	2	2	4	
RCA	F	3	4	4			
Sampo		4	3	3	6	10	
Sanyo		5	5	6			
Admiral	F	6		10			
Shinlee		7	7				
Zenith	F	8	8				
Texas Instruments[b]	F	9					5
Philips Electronics	F	10	6	5	3	1	3
Taiwan Telecommunication	F		9				
Capetronic	F		10				
General Instrument	F			7		9	
Philips Electronics Bldg	F			8	4	3	1
Uniden	F			9			
Chung Hwa Picture Tube					5	7	6
AT&T Telecommunications	F				7		
Kolin					8		
Motrola Electronics	F				9	8	8
Taiwan International	F				10		
TSMC						5	2
UMC						6	10
Applied Materials	F						7
Winbond							9

Source: Adapted from China Credit Information Service (1990, 2000).
Note: F = companies with more than 50 percent foreign ownership.
a. CCIS did not classify Matsushita, established in Taiwan in 1962, as a foreign company until 1986.
b. TI-Acer, a 50-50 joint venture, was formed in 1990 to produce DRAMS. It was sold to TSMC in 2000.

Table 2.6
Taiwan's top 5 notebook producers, 1999

Top five firms	Output, 1999 (1,000 sets)	Major buyers	Founding	Experience
Quanta	2,150	Dell, IBM, HP	1988	Calculators, monitors
Acer	1,900	Dell, IBM	1981	PCs
Inventec	1,200	Compaq	1975	Calculators
Compal	1,100	Dell, HP	1974	Calculators, monitors
Arima	1,000	Compaq, NEC	1989	Digital scale
Subtotal	7,350			
CR-5 (%)	78.6			

Source: Company data and Taiwan, Market Intelligence Center (various years).

The calculator industry did not create a formal association to set prices, but its major producers (and later manufacturers of notebooks) became (and remain) "close friends" (see table 2.6). Whereas Taiwan's monitor industry failed to prevent price wars, the rationalization of the calculator industry met with greater success (and probably more market concentration, as discussed above). Price regulation became a major form of cooperation among industry leaders, abetted by government urgings to present a united front to foreign vendors.

With mass production the price of each calculator began to fall dramatically, and by the 1980s it was already low compared to the price of a TV (although an exact comparison is difficult). *As a consequence of low unit value, it was possible for relatively small-scale firms to become "large-scale" producers*. Despite their small size in terms of sales, their sheer volume of production in terms of number of units became an advantage later, when it became a question of winning foreign contracts to produce notebooks, which depended on demonstrated operating scale.

Many first-generation electronics firms were founded by money from the "old economy." Nearly all of these firms soon became defunct, most likely due to their owners' lack of understanding of the new technology. But many founders of today's top producers of calculators and notebooks once worked for these now-defunct firms. With financial backing from a lumber-hotel group, founders of Compal, Quanta, and Inventec, major notebook manufacturers (see table 2.6), all helped to found Santron before setting off on their own (Inventec holds a 25 percent equity stake in Quanta). The founder of

Acer, Stan Shih, first worked in Unitron and Qualitron, which were first-generation calculator producers founded by a textile company. One electronics firm from the old economy that specialized in motors, Teco, itself diversified into calculators.

The impetus behind Taiwan's calculator industry came from a new engineering elite. Some young, Taiwan-educated engineers share credit for the industry's rise in the early 1970s. As a first step they tried to reverse-engineer foreign calculator models. They copied a design and then tried to make it a little different. They then began immediately to export, in imitation of Japan. They provided samples at exhibitions (e.g., at the Consumer Electronics show) and sold to importers known as The Broadway Businessmen. These were huge, multimillion dollar American importers. They backed Taiwan's leading calculator manufacturers because their volume was large enough and their unit selling price was low compared with that of Japan. Japan was then the world's premier manufacturer of calculators and sold directly to retail outlets.[8] Taiwan had once tried to sell calculators directly to the United States but had failed (Inventec, however, later penetrated smaller European markets without going through an importer).

By the early 1980s Japan began to produce calculators in Taiwan on an OEM basis, having started the production of calculators at home almost 15 years earlier. All three of Taiwan's leading calculator manufacturers landed large Japanese OEM contracts. With Japanese backing, exports to the large American market commenced and output of calculators soared, from around 10 million units in 1980 to a peak of 69 million units in 1989 (see table 2.4). Japan was also the major source for key parts and components (display panels, batteries, and integrated circuits). Local supplies were limited mainly to plastic housing and printed circuit boards (from Formosa Plastics, Taiwan's largest business group).

In addition to skills related to production engineering and project execution, calculator manufacturers precociously mastered the skill of *design integration*. They caught the mature phase of a wave of new products (electronic calculators, watches, digital scales, etc.) based on *large-scale integration* (LSI). They then went around the world to study LSI applications. Based on what they saw and what they learned from Japanese suppliers, they became very good at integrating into a small space a large number of parts and components sourced globally at the lowest price. The skill of integration allowed leading Taiwan calculator manufacturers to position themselves in world markets against stiff competition: neither did they compete on the basis of their own brand or design platform, nor exclusively on the basis of low wages. They competed on the basis of their detail design capabilities, which enabled them to be "first to market" (if not lowest in cost), and thus to win the most profitable "original *design* contracts" from foreign prime contractors.

Given that integration was critical to overcome low profit margins in the production of both notebooks and cellular phones, and was subject to large economies of scale, it is not surprising that leading calculator manufacturers went on to become leading notebook manufacturers and aspiring producers of cell phones.

The Notebook Era

The notebook personal computer (PC) was a far more complex machine than either the handheld calculator or the television. Even among Taiwan's other information technology (IT) indusries, it stood out for both *total production value* and *unit value* (see table 2.7). In 1999 notebook production was almost equal in value to that of all other IT products combined, except desktop PCs and monitors. A notebook's unit value in 1999 ($1,090) exceeded that of any other IT product by a wide margin, desktop PCs ($369) and monitors ($158) included. By 1999 the largest notebook manufacturer, Quanta, produced over 2 million units annually (see table 2.6). Both Inventec and Quanta each employed between 3,500 and 5,000 workers in Taiwan (see table 2.8). Thus, unlike calculators, *the mass production of notebooks required the rise of the large-scale firm*.

What is striking about the expansion of notebook manufacturers is how rapidly they "ramped up" in the face of declining margins (between 1996 and 1997, for example, the average gross margin in Taiwan of notebook production fell 40 percent, from 14.2 percent to only 8.6 percent).[9] For the notebook industry as a whole, aggregate output rose from 1.3 million sets in 1993 to 9.4 million sets in 1999, over a seven fold rise in only six years (see table 2.7). Inventec's employment (Taiwan only) rose in five years from trough to peak by a factor of 3.8. Its sales rose by a factor of nine! In the same time period, Quanta's sales rose by a slightly higher factor, 9.4! In terms of compound annual growth rate, for the period 1988 to 2000 it was 29 percent for Inventec and 42 percent for QUANTA (See tables 2.8 and 2.9).

Table 2.7
Taiwan's IT hardware products industry, 1993 and 1999

Product	Industry concentration (number of firms in parentheses), % 1998	1999	Production (sets) 1993	1999	Value of production (Taiwan and offshore), US$mil 1999	Unit value, US$ 1999	Offshore production (by Taiwan firms), % 1999	Global market share, % 1998
Video card	95 (4)	96 (4)	251	1,102	33	30	18	40
Sound card	87 (2)	90 (3)	461	8,481	78	9	65	49
Desktop PC	84 (3)	62 (5)	2,293	19,457	7,188	369	88	na
SPS	83 (5)	89 (5)	21,190	60,221	1,744	29	91	65
Notebook PC	74 (5)	79 (5)	1,291	9,355	10,198	1,090	0	39
CD ROMs	72 (5)	—	—	48,690	1,740	36	60	50[a]
Keyboard	64 (3)	77 (5)	18,830	79,445	512	6	91	65
Mouse	62 (3)	62 (4)	22,100	68,160	155	2	89	60
Scanner	57 (5)	76 (5)	953	21,901	925	42	38	85
Motherboard[b]	55 (5)	58 (5)	12,338	64,378	4,854	75	38	66
Monitor	45 (5)	47 (5)	17,485	58,729	9,330	159	71	58
Graphics card	40 (5)	53 (5)	7,140	18,583	848	46	65	na

Source: Adapted from Taiwan, Market Intelligence Center (various years).
Note: Industry concentration is measured in terms of sales. Concentration data are for the second half of 1998 and 1999. SPS = system power supply.
a. 1999 data.
b. Excluding those sold as part of a PC system.

Table 2.8
Employment growth, electronic firms interviewed, 1988–2000 (unit: persons)

Year	Acer	API	BTC	Delta	GVC	Inventec	Lite-On	Quanta	Tatung	Teco	Accton	D-Link	MTI	Realtek	TSMC
1988	2,967	626	430	3,090	na	na	1,650	na	12,386	3,647	na	na	500	na	na
1989	3,405	704	480	3,029	300	1,597	1,586	na	21,346	3,526	na	na	605	na	809
1990	3,678	590	491	3,000	340	1,300	1,345	na	21,346	2,611	na	162	739	na	1,187
1991	1,900	556	576	3,243	430	1,100	1,256	na	19,967	2,785	na	281	737	na	1,501
1992	2,800	600	645	3,243	546	1,138	990	na	11,000	2,963	230	414	660	na	1893
1993	2,800	714	757	3,600	917	1,100	986	745	10,320	3,220	315	556	749	147	2,294
1994	2,400	887	880	3,600	1,646	1,170	na	745	10,353	3,406	405	670	922	187	2,681
1995	3,788	1,478	879	3,040	1,870	1,945	1,122	900	11,105	3,593	537	835	976	217	3,412
1996	3,447	1,478	1,097	3,295	2,218	2,739	1,164	2,200	11,377	3,460	740	843	850	210	4,117
1997	7,861	1,520	1,136	3,778	2,218	na	1,238	2,303	na	3,650	1,064	982	na	223	5,593
1998	4,708	1,517	856	3,927	2,400	4,150	1,300	2,800	19,200	3,726	996	1,300	761	270	5,908
1999	5,112	1,676	720	3,928	1,900	3,922	1,155	3,475	18,633	3,213	1,218	1,550	867	305	7,460
2000	5,369	2,000	730	4,384	1,600	3,623	1,173	5,000	11,355	3,369	1,600	1,600	1,167	370	8,000
CAGR 1988–2000	5%	10%	5%	3%	16%	8%	–3%	31%	–1%	–1%	27%	26%	7%	14%	23%

Source: Adapted from *Commonwealth Magazine* (various years).
Note: CAGR (compound annual growth rate) is calculated either from 1988 or from the year data are available. API changed its name to Acer Communications and Multimedia in 2001.

Table 2.9
Sales growth, electronic firms interviewed, 1988–2000 (US$mils)

Year	Acer	API	BTC	Delta	GVC	Inventec	Lite-On	Quanta	Tatung	Teco	Accton	D-Link	MTI	Realtek	TSMC
1988	386	57	42	101	na	na	68	na	1,045	400	na	na	27	na	na
1989	496	50	41	111	46	169	84	na	1,188	459	na	na	48	na	71
1990	459	72	57	133	64	124	94	na	1,024	355	na	16	64	na	81
1991	463	101	66	182	84	180	126	133	1,180	401	na	29	84	na	179
1992	482	204	73	253	106	231	145	na	1,303	469	29	na	78	na	256
1993	726	255	111	310	230	203	170	217	1,187	535	39	67	81	23	463
1994	1,260	597	145	345	525	267	244	306	1,379	650	58	93	99	33	737
1995	2,293	965	145	449	763	468	335	321	1,499	703	75	117	96	42	1,055
1996	2,092	999	170	416	870	1,582	384	636	1,412	702	116	142	84	55	1,433
1997	2,137	889	239	397	740	1,250	406	1,071	1,018	625	169	171	71	56	1,346
1998	3,040	1,038	229	388	877	1,433	407	1,611	1,323	652	182	233	79	66	1,559
1999	4,085	1,207	261	697	584	2,032	406	2,399	1,958	675	306	328	95	102	2,329
2000	3,115	1,474	328	835	288	2,845	476	2,509	2,562	631	398	363	149	162	5,038
CAGR 1988–2000	19%	31%	19%	19%	18%	29%	18%	42%	8%	4%	39%	37%	15%	32%	47%

Sources: Adapted from *Commonwealth Magazine* (various years). Exchange rates are taken from Taiwan, Council for Economic Planning and Development (various years).
Note: CAGR (compound annual growth rate) is either calculated from 1988 or from the year data are available. API changed its name to Acer Communications and Multimedia in 2000 and then to BENQ Corporation in 2001 when it split from the Acer group.

The numbers in these tables are more reliable for evaluating each individual company over time rather than for comparing different companies at the same moment in time because the data for some companies may be more consolidated than for other companies and, in general, accounting conventions may differ. Generally, however, the ramp-up rate of the companies represented in tables 2.8 and 2.9 was both phenomenal and profitable, if nonlinear (ramp-up was concentrated in a few years rather than spread evenly over time).

The companies in these tables include not only notebook manufacturers but other types of electronics firms. They tend to be among the best companies in the electronics sector in terms of innovativeness. We selected them for study on this basis as well as for their willingness to be interviewed. Delta, Lite-On, API (Acer Peripherals), and BTC produced parts and components for notebooks. Realtek, an IC design house, and TSMC, a foundry, were in the semiconductor business. D-Link, MTI, and Accton were start-ups in the telecommunications industry. GVC produced modems, notebooks, and other products. Despite their diversity (see tables 2.10 and 2.11), they almost all succeeded in ramping up fast.[10] Therefore, even ignoring the issue of finance (discussed in chapter 3), the question addressed below is: How did these second movers manage to ramp up so quickly?

Ramping Up

The ramp-up process was something of a paradox insofar as it was both fast and slow. Once it got started, it raced ahead. But the managers of leading firms report that before it got started, they went through an intense learning period and lost money. This pattern supposedly characterized the supply of semiconductors no less than notebooks and cellular phones.

A major reason for a slow phase was that ramping up typically was *synonymous with diversification*. It involved a firm in moving from the production of one product to the production of another product, from a mature industry whose demand was spent to one whose demand was still growing worldwide. Sometimes the firm ceased producing the old product entirely, but frequently it enjoyed a cash cow and became more diversified.

First we discuss the fast cycle.

Table 2.10
Electronics firms interviewed, status in 1999

Company (year core established)	Founder[a]	Core company: Sales (US$mil)	Core company: Assets (US$mil)	Core company: Employees	Core company: Top 500 sales rank	Group: Sales (US$bil)	Group: Assets (US$bil)	Group: Employees	Group: Top 100 group rank (sales)
Acer (1981)	T	4,085	2,776	5,031	1	15.2	9.6	17,817	1
API (1984)	T	1,207	1,077	1,700	20	See above	See above	See above	See above
BTC (1982)	T	261		720	142	—	—	—	—
Delta (1971)	T	697	934	3,928	38	4.6	4.4	49,617	10
GVC (1979)	T	584	547	5,151	42	1.7	1.2	7,144	42
Inventec (1975)	T	2,032	1,162	3,922	8	2.6	1.6	10,335	27
Lite-on (1975)	T	406	513	10,760	72	2.5	2.7	34,771	29
Quanta (1988)	T	2,399	1,241	3,475	5	2.5	1.9	3,497	30
Tatung	T	1,958		11,355[c]		4.4		33,423	12
TECO	T	675		3,213		2.9		10,077	26
Umax (1987)	T	338	376	489	103	1.3	1.1	2,035	55
Accton (1988)	T	306	348	1,200	121	—	—	—	—
D-Link (1987)	T	329	326	1,300	109	—	—	—	—
MTI (1982)	R	95	167	867	362	—	—	—	—
Realtek (1987)	T	102	121	304	338	—	—	—	—
TSMC (1987)	T	2,330	5,142	7,500	6	3.2	9.6	10,887	19

Sources: Company annual reports and adapted from China Credit Information Service (various years).
Note: Dash (—) indicates not part of a group.
a. Company founder (education and major experience): T = Taiwan; R = returnee from the United States.
b. API is now BENQ. BTC is Behavior Tech Computer Corporation. MTI is Microelectronics Technology. Realtek is Realtek Semiconductor Co., Ltd. TSMC is the Taiwan Semiconductor Manufacturing Company.
c. Data for 2000.

Table 2.11
Business groups interviewed, status in 1999

Group (year established)	Founder[a]	Sales (US$bil)	Assets (US$bil)	Employees	Core industry	Top 100 group rank (sales)
Acer (1976)	T	15.2	9.6	17,817	IT	1
Cathay Life (1962)	T	11.3	35.2	36,518	Life insurance	2
Formosa Plastics (1954)	T	10.8	33.7	60,385	Petrochemicals	3
President (1967)	T	7.6	15.1	25,653	Food	6
Evergreen (1968)	T	6.7	11.8	13,347	Marine transportation	7
Far East (1954)	T	5.2	18.4	25,812	Textiles	8
Tatung (1918)	T	4.2	6.8	33,423	Electronics	12
China Steel (1971)	O	4.0	8.6	11,680	Steel	14
Ruentex (1953)	T	3.3	13.3	22,554	Textiles	21
Teco (1956, 1965)	T	2.9	3.9	10,077	Electronics	26
USIFE	O	1.0	1.7	3,533	Petrochemicals	63

Sources: Company annual reports and adapted from China Credit Information Service (various years).
Note: IT = information technology.
a. Group founder (higher education and major experience): T = Taiwan; O = other. China Steel was initially founded as a state-owned enterprise. USIFE was founded by an American company, National Distillers, and later sold to a Taiwan national.

Product Maturity

A*ll* Taiwan's major electronic exports in the half-century following World War II were mature. Product maturity may have meant declining and small profit margins, but it also meant the availability of core technology—basic product designs and process know-how. The availability of core technology facilitated ramping up, aided by government-led R&D to make a core technology commercially viable for Taiwan firms (see chapter 3).

The determination of a product's maturity, or age, is vexed by the uncertainty of its exact date-of-birth in an advanced country and the timing of its maiden manufacture in a latecomer. Determination of the former is usually clouded by a longish period of innovation, of different key parts and components, before a clear commercial breakthrough is achieved. Determination of the the latter is befuddled by unstable production by small, precocious firms with a high rate of mortality. Bearing these limitations in mind, the origins on a world scale of the television industry, Taiwan's first high-value electronics export, may be dated from the takeoff of commercial broadcasting in the United States in 1946 and 1947 (the first crude television systems were demonstrated in 1926 in England and 1927 in the United States, and the first regularly scheduled television broadcasting was in England in 1936). Major postwar follow-up innovations in color TV that triggered mass production were in display (the shadow mask picture tube in 1950, invented by RCA) and in tuning (the automatic fine-tuning mechanism in 1965, invented by Magnovox) (Levy 1981).

Taiwan started its black-and-white TV broadcasting in 1962, with technical assistance from Japan, about 23 years after the United States and 10 years after Japan. In 1964 black-and-white TV production commenced (the manufacture of radios by Taiwan companies had begun in the 1940s), aided by American foreign investments and Japanese joint ventures, as noted earlier. Taiwan thus began to produce color TVs around 1970, about 20 years after a critical technological breakthrough by RCA (Lin 1986).

In the case of the integrated circuit (IC) industry, which started assembly operations in Taiwan as an adjunct to TV manufacture, until the late 1950s transistors were discrete devices—each transistor had to be connected to other transistors on a circuit board, whereas an IC is a single chip that has more than one active device on it. Texas Instruments initiated a research program to repackage semiconductor products (transistors, resistors, and capacitors) as single components to reduce circuit interconnections. In 1958 it developed the first crude integrated circuit.[11]

The roots of Taiwan's semiconductor industry can be traced to the establishment by General Instrument (US) of an integrated circuit assembly plant in Taiwan's new export processing zone in 1964, followed in 1969 through 1971 by investments in similar export-oriented assembly activity by American companies such as Texas Instruments and RCA, and European companies such as Philips (Mathews and Cho 2000). This represents a shorter time lag than in TVs but a simpler production process—TV assembly in Taiwan, and soon the manufacture of cathode ray tubes for TVs, was a more complex operation than IC assembly.

The personal computer (microcomputer) industry has as its forebears the mainframe and minicomputer industries and the integrated circuit industry, especially Intel's invention of the microprocessor in 1969, a design that was improved and simplified in 1974. The microcomputer itself is conventionally dated at January 1975, when an issue of *Popular Electronics* brought attention to the PC-like devices that were being made by hobbyists. The microcomputer *industry* is usually dated at 1977, when three new (and incompatible) machines appeared on the market: the Apple II, the Commodore Pet, and the Tandy TRS-80. The industry paradigm emerged in 1981 with the production of IBM's PC. The first era of the clones was 1982 to 1987, an era marked in the United States by an intensification of competition, new entry, and an impending shakeout (Langlois 1992).

Production of PC clones in Taiwan may be traced to ACER (originally named Sertek International, a company established in 1976) and ERSO (the Electronics Research and Service Organization, part of the Industrial Technology Research Institute founded by the Taiwan government). Sertek was begun by engineers (including Stan Shih) many with MS degrees from Chiaotung University in Taiwan. In 1981, it reinvented itself as Multitech (and later as Acer, with Stan Shih as CEO), and relocated in Hsinchu Science Park. In 1984, in cooperation with ERSO, Multitech developed a 16-bit personal computer.[12] In 1988, Acer won fame by successfully developing a 32-bit PC system. Thus PC-clone manufacture in Taiwan began seven years after its paradigmatic beginning in the United States, and roughly 13 years after the PC industry in the United States got started. In some instances the prime contractor of a PC from an advanced country (Dell) and its subcontractor in Taiwan (Quanta) grew up together. The difference between them in terms of function was that the prime contractor—located near the biggest customer base and most advanced sources of technology—was responsible for basic design (bought outside or made in-house) and marketing, whereas the subcontractor—located near a large supply of low-cost engineers—was responsible for the detailed design (integration of parts and components) and production.

The maturity of the cellular handset phone as it reached Taiwan's factories may be inferred from output data. In 1999, when Taiwan first began making cell phones and achieved an output of nearly 3 million sets, the "majors" were already producing 257 million sets.[13]

The majors had begun to subcontract allegedly because their gross profit margins had tumbled below a 30 percent trigger.[14] Therefore one may infer that in the early and mature stages of a high-tech product, not only function but also profitability differed between majors and minors, or first and second movers.

From an examination of these products, maturity is a characteristic common to them all.[15] Ramping up quickly was therefore a possibility.

Entrepreneurship

Behind almost every big electronics company in Taiwan was a "big man"—the owner-entrepreneur who could make decisions quickly with respect to ramping up. The "big man" continued to wield a controlling interest even when a company (or business group affiliate) was publicly traded on the Taiwan Stock Exchange (a total of 462 firms were listed on the TSE in 1999).[16] Despite the reputation of the electronics industry for professionalism, as late as 2000 the criterion used to select the individual responsible for making strategic, long-term decisions remained "ownership" rather than "outstanding managerial skills." The two might converge, especially in the case of first-generation owners—still the typical mode in Taiwan's electronics industry in the 1990s, most of whose oldest firms were formed in the 1970s. With a big man at the top and salaried managers in the middle and bottom, leading enterprises became hierarchically managed but fast to respond. The chief liabilities of the great man syndrome were megalomania and an impending succession problem.

One of the most entrepreneurial of first-generation owners was the CEO of Quanta, Barry Lam. After finishing undergraduate studies as an engineer, he joined with money from the "old economy" and became one of the original founders of Calcomp. Under Lam's presidency, Calcomp became the world's biggest OEM maker of calculators. In 1982, Calcomp founded Compal to assemble computers. Six years later, Lam left Compal to found Quanta, with an initial workforce of 14 people, soon to become one of Taiwan's largest notebook makers. By 1996, Compal, Quanta, and Inventec all ranked among Taiwan's top ten computer and peripheral companies (see table 2.12). Short of making an investment in marketing, they were second movers par excellence.

Table 2.12
Taiwan's top 10 computer and peripheral companies, ranked by sales, 1986–1999

Company		1986	1991	1996	1999
Wang Labs[a]	F	1			
WYSE Technology[b]	F	2			
Digital Equipment[c]	F	3	5	9	
Acer Inc.[d]		4	1	1	1
ADI		5			
Zenith	F	6			
Commodore	F	7			
MITAC		8	2		10
Copam Eelectronics		9	8		
Acer Peripherals[e]		10		4	9
Datatech			3		
First International Computer			4	3	7
Chuntex Electronics			6	10	
AST	F		7		
Compal			9	7	6
Elitegroup			10		
Inventec				2	3
GVC[f]				5	
Lite-On Technology				6	
Quanta				8	2
Hon Hai Precision					4
Asustek					5
Arima					8

Source: Adapted from China Credit Information Service (1990, 2000).
Note: F = companies with more than 50 percent foreign ownership.
a. Acquired by the President group.
b. WYSE Technology acquired by a consortium of Taiwan firms and the government Development Fund in 1989.
c. Acquired by Inventec.
d. Acer Inc. named Multitech Industrial Corporation before 1986.
e. Acer peripherals (API) named Continental Systems Inc. before 1986.
f. Acquired by Lite-On group.

Who were these high-tech entrepreneurs, in terms of their country of origin and higher education?

Chinese-American engineers and scientists from Silicon Valley in California supposedly became the dominant type of entrepreneur in Taiwan in the 1990s (Saxenian and Hsu 2001). In fact, given the intricate paths of learning in the 1990s that crisscrossed Taiwan's electronics industry (we have identified one path starting from TVs and monitors and another path starting from electronic calculators), the *born-and-bred in Taiwan* model was probably still the norm.[17] A knowledge of Taiwan's business system was probably greatest among the locally bred. Barry Lam, for instance, the CEO of Quanta, was born in Shanghai and raised in Hong Kong, the son of an accountant. But he studied engineering at National Taiwan University. Stan Shih, the founder of Acer, was born and educated in Taiwan, as were the founders of Inventec and Arima.[18] Of all the electronics firms in our sample, only one (MTI) was started by returnees (see table 2.10), and ironically, had suffered from overexpansion. Business groups, many founded much earlier than electronics companies, were even more likely to have a founder who was born and educated in Taiwan. Of those we interviewed, only one (China Steel) deviated from the norm by having been started as a state-owned enterprise (see table 2.11). USIFE, a relatively small group based in petrochemicals, was established as a foreign direct investment by an American company, National Distillers, and then sold to a Taiwan national in 1981.

Even at the very end of the twentieth century, and even in Hsinchu Science Park, which was the most likely venue for returnees given its provision of high-end housing and bilingual language instruction, the majority of Park companies were not founded by Taiwanese educated in the United States, let alone by expatriates or "returnees" holding US residency or citizenship. Out of a total of 284 Park companies in 1999, 110 were started by US-educated engineers, who may or may not have been born in Taiwan (Saxenian and Hsu 2001). Even if most new start-ups were Chinese-American, Taiwan nationals provided the funds, and not vice versa. In the case of Hsinchu Science Park, the foreign share of its paid-in capital *fell* in the 1990s from over 20 percent to less than ten percent. The share of overseas Chinese *fell* from a high of 6.9 percent in 1988 to a low of 0.5 percent ten years later (see table 2.13). Thus, starting from the late 1950s when Taiwan's electronics industry first began to be built,

Table 2.13
Hsinchu Science Park: Source of paid-in capital, 1986–1998

Year	Total, NT$mil	Overseas Chinese, %	Foreign, %
1986	5707		32.7
1987	10560	3.6	26.4
1988	15832	6.9	24.2
1989	28223	5.7	23.7
1990	42692	4.6	20.7
1991	55112	4.7	20.7
1992	62827	4.4	19.9
1993	66890	4.5	17.0
1994	93498	2.6	10.3
1995	147698	1.7	10.4
1996	258353	1.0	11.7
1997	375647	0.7	11.6
1998	510628	0.5	9.4

Source: Adapted from Taiwan, National Science Council (various years).

the historical record is one of nationally owned companies taking the lead and displacing foreign direct investors (discussed below).

The danger of the "great leader" was reduced in Taiwan owing to various forms of discipline. One was intense market competition, both at home and overseas. Another was the ability—or inability—to attract top talent. The less personal and capricious was the "big man's" management, the easier it was for his company to attract and retain professionals with an interest in challenging work, career advancement, and stock bonuses (stock options in Taiwan in 2000 were not yet legal).

Skills

Fast ramp-up was facilitated by a large supply of experienced, skilled managers and engineers. Reverse brain drain was critical in terms of skill formation, whether from Silicon Valley or any of the other foreign locales where Taiwan engineers and managers studied and worked (e.g., the New York/New Jersey conurbation near Bell Labs, the Austin/Houston region near Texas Instruments, and the Hudson Valley in upstate New York near IBM). Returnees helped to raise the level of R&D and the quality of professional management in Taiwan.

The degree of professional management in Taiwan's electronics industry varied according to type of national ownership. In the case of the business groups that historically had a core competency in electronics—Tatung, Teco,[19] and Lite-On—the head office responsible for strategic business decisions tended to be *very* small.[20] Such size suggests only minimal input of professionals in top management. In the case of Teco, with sales of over $2 billion in 2000 (making it Taiwan's 26th ranking group, as shown in table 2.11), decisions related to diversification were handled by a task force comprised of only six people! With slightly higher sales, there were only 12 people in the head office of Lite-On. Major notebook manufacturers—Quanta, Compal, and Inventec—were all personally managed at the top, as was FIC (part of the Formosa Plastics group). At the other extreme were Taiwan Semiconductor Manufacturing Company (TSMC) and United Microelectroncs (UMC), two of the world's leading foundries and both professionally managed. The ACER group possibly lay closer to the TSMC and UMC model than to the typical family-owned firm.[21] TSMC and UMC, however, were the exceptions that proved the rule; they were professionally managed even at the top but they were not privately owned. TSMC was a joint venture between the government and Philips (Holland). Although the government had invited private investors to hold equity, no "great man" had come to power through private ownership. Even so, TSMC's management, like that of a private company, was characterized by an able and charaismatic CEO (Mr. Morris Chang, a Chinese-American), as was UMC's top manager (Robert Tsao).

Besides serving as professional managers, overseas talent helped to teach national electronics companies the latest applications of mature technology. In the case of Delta Electronics, for example, a diversified components manufacturer specializing in switching power supplies (SPS), its entry into telecommunications involved hiring a key Taiwanese-American scientist. Delta's high-resolution, big-screen LCD project was structured around three pieces of specialized silicon that were under the Sony Corporation's control and in short supply. Delta became Sony's ODM manufacturer and so was able to access the silicon. Delta's asset in wining Sony's support was its large design team headed by Dr. Harry Chen, whom Delta had lured away from US-based Hughes Display. To shift to telecommunications from computers in its main power-supply business, Delta enlisted the support of Dr. Fred Lee, the head of the Electrical Engineering Department at Virginia Polytechnic Institute. Lee helped Delta establish an R&D lab in Plattsburgh, Virgina (later moved to the R&D triangle in North Carolina). Although this R&D lab did no 'R' and only 'D,' it was a big plus in building Delta's know-how in telecom power supply, which made possible a $70 million initial contract with the American-based Cisco Corp. Additionally Delta owned R&D labs in Boston and Portland.

Electronics firms in Taiwan, however, acquired their most advanced know-how through various means, not just reverse brain drain, or reverse engineering, or outward foreign investments in "listening posts" or overseas research labs (many of which failed). No one channel predominated over time, although government-owned R&D labs became increasingly important (see chapter 3). In the case of televisions, know-how came embodied in direct foreign investment. In the case of electronic calculators and telephone sets, it started with copying. In the case of notebooks, it came mainly from government labs and foreign vendors. In the case of monitors and TFT-liquid crystal displays (LCDs), it was acquired through joint ventures or technology licenses. The electronics industry in Taiwan accounted for more technology purchases than any other industry: around 57 percent of the total in 1990 and 1992, and roughly 75 percent of the total in 1997 and 1998 (see table 2.14). In the 1990s the value of technology purchases rose by a factor of 4.5, although Taiwan's wholesale prices barely rose and its GDP deflator increased by only around 25 percent.[22]

Thus the electronics industry in the 1990s could ramp up rapidly because most companies were tightly controlled from the top, which presumably facilitated fast (if not always smart) decision

Table 2.14
Technology purchases, 1988–1998 (unit: NT$mil)

Industry	1988	1990	1992	1995	1997	1998
Electronics (A)	2,033	6,970	7,781	11,673	26,162	31,605
All Industries (B)	7,772	12,298	13,733	19,119	34,699	41,651
A/B (%)	26	57	57	61	75	76

Source: Adapted from Taiwan, Ministry of Economic Affairs (various years [c]).

making. Their chief executives tended to be born or bred in Taiwan, which helped them navigate in Taiwan's business world. They were aided and abetted by various sources of advanced managerial and technological capabilities, including Chinese-American professional managers and high-level scientists and engineers, not just from Silicon Valley but from all over the United States (and the rest of the world).

Manufacturing Process

Electronics companies could ramp up fast given the availability of factory space from the old economy and departing direct foreign investors. In-house production engineering skills enabled renovated facilities to be automated. Project execution experience from ramping up in Taiwan later provided the know-how for globalization in Southeast Asia and China.

In the case of Arima, the owner bought a large existing plant in order to expand capacity in the shortest possible time and qualify for an order from Compaq; monthly output rose from 9,000 units to 80,000 in a matter of months (Lu 1998). In the case of Inventec's diversification into notebooks, it downsized its own calculator production lines. It also leased or bought factory space from contracting industries such as consumer appliances and textiles. The re-design of factory space or new construction was done by Inventec's own engineers, who also designed and built the equipment that was moved into expanding facilities. As a strategic decision, both equipment and industrial engineering staff was always "kept in reserve," in order to stay "one step ahead of time." Like most major notebook assemblers, Inventec even maintained an in-house construction company to ensure rapid plant erection and maintenance. By doing this repeatedly, and investing in training, Inventec acquired project execution skills and became good at diversifying.

Automation in the electronics industry began with the assembly of televisions, as noted earlier. It accelerated as volume production increased in importance. In the case of Delta Electronics, which employed around 50,000 people worldwide (see table 2.10), it established an independent automation department early in its history. By 2000 a team of 50 manufacturing automation professionals was dedicated to the design and development of automated manufacturing equipment for Delta's operations worldwide.[23] In terms of results, "The automated equipment developed by our automation department has made much contribution to our fast business growth in the past. Now, the capability to build automated equipment in-house allows us to *expand production capacity promptly* to fulfill customers' rising demand more effectively" (Delta 1999 *Annual Report*, emphasis added).

In the case of D-Link, which employed 3,300 people worldwide and manufactured network adapters, hubs, switches, and other telecommunications equipment for the small home and office, it emphasized production engineering to compete:

> Achieving economies of scale is important in bringing down costs and improving competitiveness. As D-Link production goes global, the Company has not only invested heavily to exploit economies of scale; it has also placed manufacturing skills at strategic points to maximize results. (D-Link 1999 *Company Profile*)

D-Link's Taiwan facilities included a fully automated plant in Hsinchu Science Park at the heart of which were five surface mount technology (SMT) lines. Based on experience in running these lines, D-Link opened a large new plant in Dongguan, South China. The plant began operating in 1998 with three SMT lines running at full capacity with overtime shifts. Expansion was carried out in China on a phase-by-phase basis, which encouraged learning-by-doing. Two to three more SMT lines were added when demand warranted, with a total capacity of 14 lines in the future for mass production.

The rise in automation *as a response to economies of scale* rather than escalating wages is suggested by data on average net value of fixed assets and average wages by firm size. Beginning in 1991, the average net value of fixed assets for firms in the electronics industry with over 500 workers accelerated at a faster rate than the average for firms with fewer than 100 workers (see figure 2.1). *Big firms in the electronics industry became relatively capital intensive* (measured by fixed assets per worker). That this was a response to relative scale rather than relative wages (just as it had been in the television industry) is suggested by the behavior of average wages by firm size. Beginning in 1991, the rise in wages was not much different in electronics firms with fewer than 100 workers and more than 500 workers, certainly not as different as the rise in fixed assets (see figure 2.2). Thus large firms may be said to have become relatively more capital intensive not because their wages were rising faster

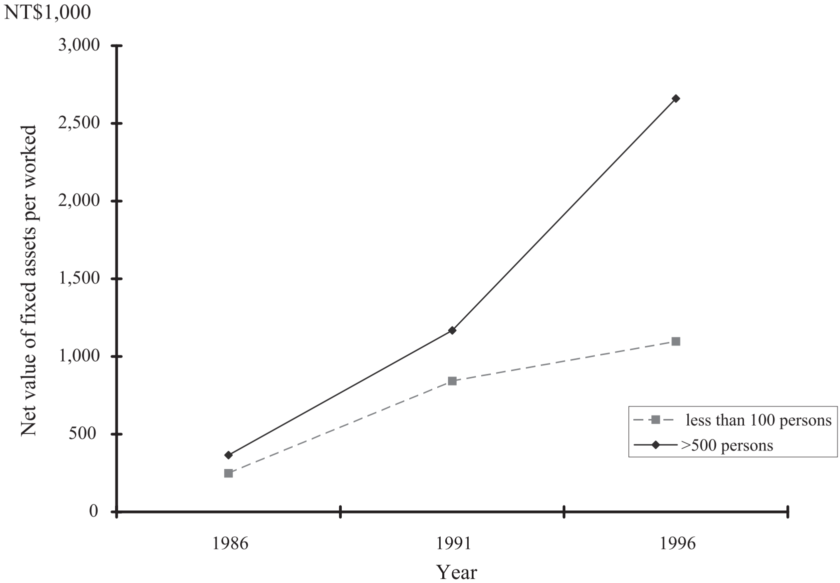

Figure 2.1
Net value of fixed assets per worker by firm size in Taiwan's electronics industry

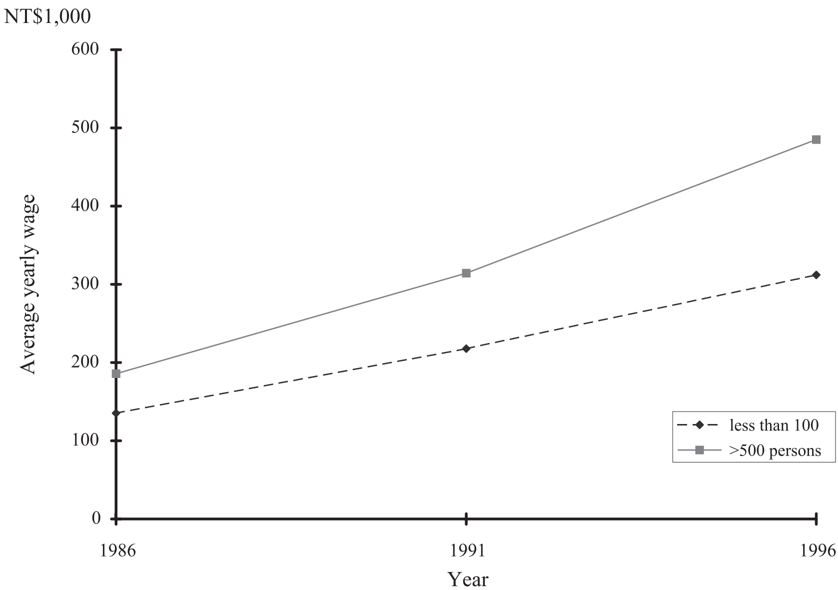

Figure 2.2
Average wage level by firm size in Taiwan's electronics industry. Source: Adapted from data provided by the Directorate General of Budget, Accounting, and Statistics.

than those of small firms but rather because their volume was rising faster, and so the introduction of automated production equipment made more sense.

In general, firms faced two generic process choices that potentially influenced their rate of ramp-up: they could assemble various purchased parts and components in-house, or they could outsource such work to another firm; they could produce automated equipment in-house or buy it outside.

In the case of small start-ups, sometimes they began simply as design and marketing companies. They thus needed someone to do their manufacturing for them until they got a major order, which might then enable them to raise the money to invest in their own production facilities. This characterized BTC, a manufacturer of keyboards and optical equipment founded in 1987. Z-Com, a small start-up founded in the late 1990s that specialized in wireless networking, had to ally itself with an existing company, GVC, to get *both* an order and manufacturing capacity. GVC acquired a 25 percent stake in Z-Com in exchange for which it gave it the dedicated lines needed to meet its production goals. According to an estimate of Z-Com's founder, John Shieh (one of Bell Lab's 250 alumni in Taiwan and a veteran of Taiwan's venture capital industry), about 75 percent of Taiwan's "late-stage," high-tech start-ups in the 1990s were "significantly controlled" by bigger businesses.

Inventec was probably representative of industry leaders in its decision to bring as much process-related activity in-house: "Subcontracting is a step that is to be avoided, if possible." The reasons cited were the high costs of overhead, coordination, control, and verification. Therefore "how to increase capacity is always on top management's mind." The BTC company only resorted to outprocessing if a good customer suddenly needed extra quantity. In terms of automation equipment, leading notebook manufacturers such as Acer, Compal, Inventec, and Quanta all manufactured such equipment in-house. The same was true of smaller companies such as D-Link and BTC.

Thus electronics firms appear to have outsourced their local processing jobs only under extenuating circumstances. But this did not slow them down. Because they automated their new production facilities and accumulated project execution experience along the way, they could ramp up fast.

Integration

Electronic companies integrated *selectively*—both vertically and horizontally—their equipment (parts and components) and services (integrative design and "supply chain management," or support to the final consumer). Their integration in-house of design services (which they classified as R&D) contributed to a substantial gross increase in the employment of electronics firms. Selectivity in vertical and horizontal integration was yet another key to rapid ramp-up.[24]

Integrative Design

The computer industry has in general, a reputation for low-level vertical integration in comparison with fabrication/asssembly industries of the "old economy" (Langlois 1992). So a latecomer country like Taiwan made a major vertical integration when it moved beyond mere assembly to the design, integration, and testing of parts and components. The investment was large in terms of numbers of engineers. As in TV manufacture, many engineers working on notebooks and cell phones were employed in-house with the aim of reducing both manufacturing costs and *time-to-market*, and increasing product differentiation.

Quanta, one of the leading notebook manufacturers, employed 700 design engineers in 2000, or 14 percent of its total workforce of 5,000 people. A year earlier it had employed 420 design engineers (plus 182 engineers in manufacturing sites) out of 3,400 workers, amounting to 12 percent of its total employment.[25] Quanta's designs won kudos indirectly, through awards to its clients' products, for their lightness, portability, excellent configuration, and so forth. But according to Quanta's President, Barry Lam, R&D was *time* effective rather than *cost* effective. It enabled Quanta to be first to market rather than lowest in price.

In the case of Inventec, Taiwan's third largest notebook producer in 2000 (see tables 2.6 and 2.12), of its worldwide employment of 10,300 (4,000 in Taiwan), approximately 3,300 were engineers and 1,500 were engineers dedicated to design. The ratio of design engineers to total employment, about 16 percent, was roughly the same as in Quanta. Inventec's design activity was not considered to be cost effective either because, to verify its own engineering designs, Inventec had to incur large expenses for testing. But design gave Inventec access to final customers.

Table 2.15
Proportion of engineers in total employment, selected manufacturing industries, 1988–1997

Industry	1988	1991	1994	1997
Food	1.6	2.2	2.3	2.7
Textile	1.8	2.3	2.8	3.4
Apparel	0.2	0.2	0.2	0.3
Chemical material	3.5	3.9	3.8	4.2
Chemical products	1.9	1.8	2.1	2.3
Petroleum	10.2	10.9	9.9	8.3
Plastic products	0.9	2.1	2.6	2.6
Nonmetallic products	0.8	1.5	3.0	3.5
Basic metals	1.8	2.2	2.3	2.4
Fabricated metals	0.7	1.1	1.5	1.7
Machinery	1.8	2.9	3.0	3.2
Transportation	3.2	4.9	5.1	5.8
Elecctronics	3.2	5.3	5.6	6.3
All manufacturing	1.7	2.7	3.1	3.5

Source: Adapted from Taiwan, Directorate General of Budgets and Statistics (various years [b]).

Table 2.15 presents information over time on the proportion of engineers in Taiwan employed by different industries. Between 1988 and 1997, this proportion almost doubled in the electronics industry. The proportion in the electronics industry in 1997 was higher than in any other industry with the exception of petroleum refining (whose proportion was falling over time). The same pattern applied to technicians. By 1997, around 15 percent of total employment in the electronics sector was comprised of engineers and technicians (Taiwan Director General of Budgets and Statistics, various years [b]). Their share was high and rising for many reasons, but heavy investments in integrative design was one of them. Design integration was a major contributor to PC manufacturers' large size (in terms of employment) *and flexibility* (in terms of first to market). A first-class integrative design capability had a direct and large bearing on Taiwan's ramp-up speed in electronics.

One-Stop Shopping

Notebook manufacturers began to integrate vertically into customer services in response to a rationalization of the supply chain and declining profit margins for hardware. The led to a rise in mergers and acquisitions as well as faster ramp-up. Ramp-up was faster because as the supply chain was rationalized, the number of transactions fell due to a smaller number of suppliers.

A trend in the electronics industry by the year 2000 was "one-stop shopping": each foreign contractor demanded that more stages in the production process—including after-sales service—be performed by the same subcontractor. Customers wanted a package and searched for subcontractors that could provide it. This *rationalization of the supply chain* (the sequential supply of parts, components, and related services to an ultimate final buyer) tended to favor integration at each step of the production process.[26] A case in point was the Yageo Corp., a manufacturer of passive components that began to provide its customers with one-stop shopping. It had acquired two factories for passive components formerly owned by Philips. Beginning in 1996, it had also acquired a capacitor manufacturer (Teapo) and an inductor manufacturer (Chilisin). With these acquisitions, and with the support of its just-in-time warehouse, it had created a single channel for all three components, thereby reducing transations costs. By 2001 it held a 70 percent market share of resistors in Taiwan, had become the world's largest manufacturer of resistors, and had won a large order from Flextronics that enabled it to lower unit costs and raise its profit margins even further (*Taipei Times* 2001).[27]

Delta Electronics made over a dozen acquisitions in less than three years to provide its clients with one-stop shopping for power supplies. Therefore many smaller and weaker SPS companies were expected to be acquired or go under. "As a result of consolidation and mergers, larger companies typically have the advantage of high-volume component purchasing as well as the economies of scale to achieve low-cost production to compete more effectively" (Ong 2000, p. 73).

In general, Taiwan's notebook companies were underinvested in services (including software) with relation to world computer companies and had a long way to go before they could offer one-stop shopping. In the case of Quanta, it considered itself a computer company that excelled in design and manufacturing, with the provision of after-sales services its next challenge. In 1999 Quanta's total revenues were divided between notebook PCs (95.3 percent), peripherals and components, excluding LCDs (3.5 percent), and

Table 2.16
Breakdown of revenues, desktop PCs, peripherals and services, top 100 computer companies, 1995–96

Company, global revenue rank	Desktop revenue: Total revenue	Peripheral revenue: Desktop revenue	Peripheral revenue: Total revenue	Service revenue: Desktop revenue
Taiwan companies				
19 Acer	0.48	0.58	0.28	0.50
72 MITAC	0.75	0.33	0.25	0.00
75 Tatung	0.44	0.73	0.32	0.23
86 FIC	0.74	0.34	0.25	0.01
World average	0.52	1.1	0.2	1.9

Source: Adapted from *Computer Industry Almanac* (1996).
Note: Services include software, server, and service and support revenues. World average includes only the 25 (out of 100) top computer companies with minimal revenues from large systems. It also excludes Oki Corporation, whose ratio of peripheral revenue to desktop revenue was out of line (higher) with that of other companies. FIC refers to First International Corporation, a member of the Formosa Plastics diversified group.

services (only 1.2 percent). Table 2.16 examines a small sample of the world's top 100 computer companies, those with postitive desktop revenues but minimal large-system revenues for 1995 to 1996. Four Taiwan companies in those years ranked in this subgroup: Acer, Mitac, Tatung and First International Computer.[28] On average, the ratio of desktop revenues to total revenues for world companies was 0.6 compared with 0.52 for the four Taiwan companies; the difference was minimal. By contrast, the ratio of service revenues (software, plus server, plus service and support revenues) to desktop revenues for world companies was 1.9 compared with only 0.19 for the four Taiwan companies; the difference was substantial.

By 2000, therefore, Taiwan's computer companies were becoming more integrated by investing as fast as possible in services, for them a relatively new area that promised higher profit margins than the manufacture of hardware. Integration tended to lag rather than lead ramp-up, so the effect was not to slow it down.

Vertical Integration into Parts and Components

Notebook manufacturers and other electronics companies were very selective in their vertical integration into the production of parts and components. Among large, diversified companies that were themselves suppliers of parts and components, vertical integration appeared to be great. The key components for Delta Electronics' power supply products, for example, were magnetic transformers and brushless DC fans. These components were produced in-house and were used for internal consumption "in order to reduce dependence on external suppliers" (Ong 2000, p. 71). The Lite-On group, another large and diverse components producer (with 35,000 workers worldwide), "was formed through years of horizontal and vertical integration based on its strong manufacturing base" (Company Report 1999).

Yet, just as Taiwan's suppliers of components engaged in only a little systems assembly, so too its large notebook system's assemblers (with the exception of Acer) produced only a select few of their own components. This made sense on the part of assemblers insofar as the PC industry worldwide tended to have a relatively low level of integration (Langlois 1992). Moreover low-tech parts, components, and peripherals were widely available in Taiwan from specialist suppliers, with whom an assembler could maintain a "neutral" relation and bargain hard for the best price (discussed in chapter 3). On the other hand, relatively high-tech parts, components, and peripherals that ensured high-profit margins had to be imported. Both phenomena promoted a low level of integration on the part of assemblers.

Predictably, vertical integration by notebook manufacturers occurred, if at all, in the form of import substitution, at the juncture where a high-tech imported component was in scarce supply and could begin to be produced locally at a profit. In the year 2000 the chief component that fell into this category was the thin film transistor-liquid crystal display (TFT-LCD). If produced efficiently (see chapter 3), this component typically accounted for about one-third of the value of a notebook. Of the six major entrants into the TFT-LCD industry, three were notebook producers: Quanta (with technology from Sharp), Tatung (with technology from Mitsubishi) and Acer (with technology from IBM, in collaboration with Acer's peripheral manufacturing arm, API). Acer and another entrant, UMC (through its subsidiary, Unipac Optoelectronics), soon merged to form AU Optronics, with an expected 6,000 employees and $913 million in capital. According to the head of the UMC group, Robert Tsao, "The competition is very fierce in this line of business as there are 24 TFT-LCD display makers already operational in Korea, Japan and Taiwan. . . . I believe there will be less than five companies that gradually become dominant in this industry over the long run" (Chen 2001, p. 17).

Thus ramp-up was fast because vertical integration on the part of notebook manufacturers was selective. As indicated in table 2.16, of Taiwan's four firms that ranked among the world's top 100 computer companies in 1996 (Acer, MITAC, Tatung, and FIC), the ratio of revenues from peripherals to total revenues was roughly equal to that of the world average—20 percent. Based on this sample (limited to those computer companies in the top 100 with only small or zero revenues from mainframes), it appears that Taiwan's large computer companies were neither more nor less inegrated than the large-firm average, although the degree of integration varied substantially among the top 100 worldwide.

The internalization of integrative design skills reduced time-to-market. The procurement locally of low-tech parts and components reduced the capital and simplified the logistics necessary to ramp up. Access to key, high-tech components was facilitated either by import substitution, as in TFT-LCDs, or by imports. Being at the front of the queue for imports was made possible by ramping up to high volume, as discussed later.

Pre-entry Planning

Despite the reputation of Taiwan firms for being flexible and fast-moving, their entry into "new" industries involved lengthy and costly pre-entry planning and preparation. In addition to diversification by existing firms in the form of creating a new organic subsidiary, mergers and acquisitions were a medium often used to enter a new industry. But diversification was a path strewn with difficulties and dangers. However rapid, ramp-up in new sectors was hardly effortless, as a few examples show.

In the case of GVC, whose profile appears in table 2.10, it invested four or five years of R&D in the wireless phone. Its investments included hiring experts with experience in telecommunications (a former researcher at Bell Labs, David Su, became president of GVC). GVC, however, also diversified broadly out of modems, its traditional product, into fields other than cell phones, such as monitors, notebooks, and systems PCs. It overexpanded and fell into debt. The Lite-On group, a diversified components supplier, with manufacturing experience from TI and Dell, acquired 25 percent of GVC's shares and control of its board of directors. Over night, Lite-On obtained a core competency in communications and the internet. Indirectly, it also acquired an interest in Z-Com. Z-Com, a wireless packaging company, started with 20 people. Its first five years proved to be very difficult given its overoptimism and the big knowledge gap between its engineers and those at the world frontier. The future direction of telecommunications technology was hard to predict. Z-Com started its wireless LAN project in 1995, but the standard for wireless LAN only got set in 1997. According to Z-Com's CEO, John Shieh, his company "almost got killed" finding people and training them. It could only sell locally. Finally it raised $25 million by giving part of its equity to GVC. Soon its net worth rose to $300 million. Thus Z-Com became a part of the Lite-On group through its affiliation with GVC. Like many small firms starting in the 1990s, Z-Com was unable to ramp up independently.

In the case of Realtek, one of Taiwan's many IC design houses, it was established by four engineers who had studied at ChiaoTung University in Taiwan and then gained experience working for UMC, Taiwan's second largest, state-initiated foundry. From 1987 to 1991, Realtek just produced low-end consumer products. Then in 1992–93 it started R&D in the communications segment of the market, which was growing at 50 percent a year (compared with a stable 20 percent growth in consumer products). Ramp-up took four to five years. Realtek, however, missed the PC market entirely. The technology changed, and the sound card that Realtek had been making was integrated with other parts, so the market was lost.

Microelectronics Technology Inc. was established in 1983 by eight Chinese-Americans working in Silicon Valley, and gained fame when CNN reporters in the Gulf War were able to provide exclusive coverage even after traditional communication links were cut by using a portable satellite telephone designed and produced by MTI. By 1995 MTI had overexpanded. Its 22 projects were spread too thin. It had tried to get into telecommunications but encountered a resource constraint: experienced talent. It began losing money. It restructured under the direction of one of its board members, "an HP guy."

BTC was first in Taiwan to produce a silent switch for keyboards, whose unit price was $20. Soon, however, the price of a keyboard plummeted to $4. Therefore, BTC tried to diversify into optical storage (CD ROM, DVD ROM, and CD RW drive). This jump was not so easy (see the discussion in chapter 3). Therefore BTC bought a 40 percent stake in one of its own shareholders, a Singaporean company, that gave BTC technical assistance—a subsidiary of this shareholder was already producing optoelectronic products for Philips. BTC also *re-invested* (bought noncontrolling shares) in several small local companies in order to “jump into new technology faster.” In terms of acquisitions, it bought a company with 15 to 20 people that operated like a lab, in order to gain expertise quicker in hard wire drive design. Another small acquisition gained it radio frequency know-how.

Inventec diversified successfully from handheld calculators to notebook PCs, but this switch was fraught with finanacial problems. In 1988 Inventec invested in research, production, and logistical support for notebooks (as well as in software for its own Chinese electronic dictionary). Three years later it started manufacturing clones for Apple. When these were prohibited by law, Inventec got a contract to produce notebooks for Zenith, one of the top ranking computer producers in Taiwan at the time. Zenith, however, experienced financial troubles and was bought out by another company. Inventec then began working with Dell, but at the time, Dell too was in bad financial straits. Finally, Inventec landed a large, and what proved to be a long-lasting, contract with Compaq. Compaq became Inventec’s sole client for notebooks, prompting a massive build-up of capacity, as discussed above.

Acer Peripherals (API) was responsible for diversification into cell phones for the Acer group, the second premier “second mover” after Tatung to emerge in Taiwan after making a “three-pronged” investment that included marketing and not just manufacturing and management. API took six years to develop telecommunications know-how to comply with the GSM standard. There were no experienced human resources available in Taiwan, so API had to start from scratch. It was a “huge” project for a Taiwan firm and highly risky.

Thus all the fast tracks of growth at the national, and even industry levels, hid ups-and-downs, fluctuations, and bankruptcies at the level of the firm, even among the agents that pioneered new industries and ramped up the fastest, the second movers.

Rewards of Ramp-Up: Economies of Scale

The larger scale created by ramping up enabled the exploitation of two types of economies of scale. One related to *recursive information*, specifically the positive sign or information that a subcontractor's large scale gave to a prospective foreign client. Scale reduced the transactions costs of subcontracting and made a subcontractor eligible to join the queue for the most profitable contracts—those that were large enough in terms of volume to overcome the small profit margins that assembling mature products entailed.

The magnitude at which subcontractors had to operate is indicated by the following example. Supposing Hewlett-Packard's global demand for keyboards was as many as 500,000 per month. HP wants to reduce the number of suppliers to streamline operations but also to diversify its risks. Thus HP's operating rule might be that no single supplier, such as BTC, would be relied upon for more than 30 percent of HPs total global demand, and that the amount supplied by any single supplier should not exceed 30 percent of BTC's own total production. In order to be able to supply HP with a maximum of 150,000 keyboards per month, BTC's monthly capacity had to be at least 500,000 per month.

In general, the process of winning a foreign contract was extremely tough: "It usually took between 6 to 9 months, starting with price quotations, the assessment of mass production capacity, on-spot exams and checks of more than 100 items, the creation of a short-list, the ultimate decision, the order, and follow-up business and re-checks" (*Wealth Magazine* 2001).

Large scale provided positive information to foreign vendors as well as foreign contractors. An assembler had to be large enough to be in the queue for the latest samples of a vendor, most of which were imported rather than made inside Taiwan. According to BTC, a supplier of keyboards as well as parts such as CD-ROMs, it was a "must" to maintain good relations with key vendors. If there was a change in technology, a vendor's samples provided BTC with a roadmap. First-tier vendors taught BTC where the market was going, by informing it about how dominant firms were allocating their R&D. Additionally "if you're not a key player, you don't get samples on time."

The notebook industry's assemblers and component manufacturers, including BTC, all mentioned a minimum *15 percent global market share* for their own product in order to be visible to cutting-edge foreign vendors. Most of the industry's cutting-edge vendors, moreover, were extremely large. In the case of Quanta, for example, it sourced its hard disk drive from IBM/Toshiba/Hitachi. It got its batteries from Sanyo/Sony, its CPU from IBM/Intel, and its

CD-ROM from Panasonic/Toshiba/Teac. These vendors were not only large but also highly diversified. Therefore the larger the *variety* of an order, the better became the service, and this provided yet another incentive for a subcontractor itself to diversify.

The second type of reward to scale concerned the conventional returns to a fixed factor: lower design costs per unit of production, vendors' price discounts for large orders, and learning-by-doing with cumulative output. Because integrative design involved many engineering hours, unit costs fell with longer runs.[29] As for learning-by-doing, it was cited by some PC companies as *the* most important reward of scale. Models that sold well and had long production runs allowed a company to move down its learning curve and become more efficient, thereby creating large cost savings.

Dawn of the Cell Phone Era

Midway into the boom in notebooks, leading notebook companies began to prepare to ramp up to manufacture cellular phones. Companies producing semiconductors, parts, components, and peripherals for cellular phones did likewise. The cell phone was an archetypal mass-produced item in the 1990s. It was close in physical size and unit value to the electronic calculator, and close in number of parts and complexity to the notebook. But technologically and commercially it was in a class of its own. Technologically, it fell into the category of telecommunications equipment instead of computer equipment. Telecom ICs tended to have a lot of analog chips, which were hard to design. The integration of parts in a cellular phone was difficult. Miniaturization of the capacitor and resistor was a challenge. The level of software required was high. Putting software into hardware occurred at different layers or protocols. Compared to the computer, compression or layering was at a much higher level. By 2000 the wireless phone at the world frontier was up to layer 3 or 4, whereas local knowledge in Taiwan had reached only layer 2. Commercially, environmental protocols and standards differed in the United States, Europe, and Japan, thus segementing the market for prospective suppliers and making it uncertain which protocol to learn.

In advanced economies, notebook companies and cell phone companies tended to be distinct because each rested on its own product innovations. In a latecomer such as Taiwan, by contrast, where innovation meant being the first locally to apply a known technology, notebook companies and cell phone companies tended to be the same.

The advantages of existing diversified firms over new specialized firms were threefold. First, without a novel technology to make the name of a new firm, the reputation of existing firms got them the best foreign contracts. Second, existing firms had more experience, especially if old and new products (e.g., the notebook and cell phone) shared technological and commercial affinities. With experience, established firms could produce at lower cost and higher quality. Third, existing firms had more endurance than new firms—a deeper pocket. They could sustain better the costs of diversifying their production in pursuit of global demand changes. These costs were of two types: internal investments to "make" skills and external investments to buy them, sometimes in the form of acquiring another firm.

The three early birds to produce cell phones in Taiwan were GVC, API, and DBTel. The last company was a newcomer but it only undertook OEM manufacturing; it did no design. Then by 2000 new entrants into the cell phone market included Arima, Compal, FIC, Inventec, and Quanta, all notebook manufacturers. Still later entrants included Hon-Hai, a large diversified parts manufacturer, Solomon and Austek (a manufacturer of motherboards), and Chi-Mei, an established company in the petrochemical industry that had also diversified into the manufacture of TFT-LCDs. With the advent of the cell phone industry, therefore, diversification by leading producers strengthened the trend in Taiwan toward bigness.

Industry-Level Changes from Upgrading

We have analyzed latecomer upgrading from the standpoint of history (the TV era, the calculator era, the notebook era, and the cell phone era) as well as from the perspective of the firm and the rise of the second mover. We now examine the effects of upgrading at the industry level. Four fundamental changes in the electronics industry are summarized: the transition from foreign ownership to national ownership, the globalization of national firms, the transformation from small-size firms to large-size firms, and the rise of market concentration.

From Foreign Ownership to National Ownership

The declining role of foreign direct investment after the television age in the development of the electronics industry is striking (we discuss FDI in services in chapter 4). In the electrical appliance industry, foreign investment was pervasive (see table 2.5). By contrast, in the computer industry, it had all but disappeared by the early 1990s (see table 2.12). With notable exceptions such as Philips, which continued to rank among the top ten foreign firms in Taiwan over two decades (see table 2.2), most foreign electronics companies behaved like their forbears in the television industry. As wages rose, their parent lacked the motivation to undertake improvements in Taiwan, and they ultimately exited. In the most fundamental sense, therefore, foreign firms operating in Taiwan were eclipsed because they failed to invest in the competitive assets necessary to compete in a latecomer environment—project execution capabilities and integrative design skills (in the case of the electronics industry).

The share of foreign firms in the paid-in capital of Hsinchu Science Park declined steadily over time, as noted earlier, from a high of 33 percent in 1986 to a low of 9 percent in 1998 (see table 2.13). The total number of approved patents was roughly equal for foreign and national firms in 1991, whereas by 1999 the ratio had become almost 2:1 in favor of the latter (see table 2.17). The share of foreign firms was consistently negligible in research and development (R&D), a rough indicator of investment in design. Even R&D *financed* by foreigners declined slightly over time as a share of the total (table 2.18).

As the relevant skills of foreign investors fell behind those of national investors, the relative performance of the former weakened. Foreign firms in 1975 accounted for over 80 percent of the electronics industry's exports. By 1998, they accounted for *less than 8 percent* (see table 2.19). In terms of number of total foreign investments, in 1978, 46 percent were 100 percent foreign owned and 22 percent were minority joint ventures (from the foreign standpoint). Twenty years later, only 32 percent were 100 percent foreign owned and 46 percent were minority joint ventures (see table 2.20). Increasingly FDI in the electronics industry took the form of joint ventures in which national firms held a majority share.

The number of foreign investments was also depleted by takeovers by national firms. The Yageo Corp., for example, acquired two of

Table 2.17
Patent applications and approvals, foreign and national, 1986–1999

	Patent applications			Patent approvals		
Year	Total	National	Foreign	Total	National	Foreign
1986	26,198	18,372	7,826	10,526	5,800	4,726
1991	36,127	22.940	13,187	27,281	13,555	13,726
1992	38,554	26,118	12,436	21,264	12,298	8,966
1993	42,145	29,308	12,837	20.232	13,992	6,240
1994	42,393	29,307	13,086	19,011	12,563	6,448
1995	43,461	28,900	14,561	29,707	20,717	8,900
1996	47,055	31,185	15,870	29,469	19,410	10,059
1997	53,164	33,657	19,507	29,356	19,551	9,805
1998	54,003	34,243	19,760	25,051	16,417	8,634
1999	51,921	32,643	19,278	29,144	18,052	11,092

Source: Adapted from Taiwan, National Science Council (various years).
Note: Patents refer to applications filed to the Intellectual Property Office, Ministry of Economic Affairs (Taiwan).

Table 2.18
R&D: Share in GDP and source of funds

		Source of funds, %		
Year	R&D/GDP	Total	Government	Foreign
1986	1.01	100	42.1	0.5
1987	1.14	100	36.0	0.6
1988	1.24	100	44.5	0.3
1989	1.39	100	35.8	0.5
1990	1.66	100	36.4	0.2
1991	1.70	100	43.0	1.5
1992	1.78	100	45.4	0.5
1993	1.75	100	43.2	0.1
1994	1.77	100	42.2	0.1
1995	1.78	100	38.9	0.1
1996	1.80	100	36.5	0.2
1997	1.88	100	34.3	0.1
1998	1.97	100	32.6	0.1
1999	2.05	100	32.2	0.1

Source: Adapted from Taiwan, National Science Council (various years).

Table 2.19
Share of foreign-owned firms in exports, by industry, 1975–1998 (%)

	1975	1985	1991	1995	1998
Food	1.5	2.6	9.3	2.4	7.1
Textiles	25.9	7.3	3.0	6.9	3.7
Minerals	13.3	3.7	8.9	26.3	9.0
Metals	10.7	5.1	5.6	4.6	1.5
Machinery	22.7	13.6	7.8	12.1	10.0
Electronics	**81.9**	**35.7**	**18.4**	**8.1**	**7.9**
Other	9.1	3.5	5.4	10.0	5.1
Total industry	19.7	10.4	8.5	7.8	7.7

Source: Adapted from Taiwan, Ministry of Economic Affairs (various years [f]).
Note: The export values of foreign firms are weighted by the percentage of their ownership shares.

Table 2.20
Types of foreign ownership in the electronics industry

Year	Number of DFIs	Distribution of DFIs by ownership, %		
		100%	>50%	<50%
1974	147	40.8	38.1	21.1
1984	216	47.7	25.9	26.4
1994	241	38.2	24.1	37.8
1998	243	32.1	21.8	46.1

Source: Adapted from Taiwan, Ministry of Economic Affairs (various years [f]).
Note: Majority/minority ownership is from the foreign firm's perspective.

Phillips plants that made passive components, as noted above. The President group took over Wang Computers (unsuccessfully). Inventec bought the Taiwan subsidiary of DEC when Compaq, Inventec's major prime contractor, acquired US-based DEC. Acer acquired Hitachi's TV plant and Siemens-Nixdorf's PC unit. ASE, a Taiwan semiconductor manufacturer, bought Motorola's manufacturing, testing and assembly plants and WUS, a printed circuit board manufacturer, bought its PCB factory. TSMC acquired ASMI, an American semiconductor manufacturer.

The mode of foreign operations in Taiwan thus shifted, from FDI to subcontracting. Presumably the opportunity costs for foreign enterprises of investing directly in Taiwan became too high as the skills of national firms rose.

Globalization

The disinvestment of foreign firms from Taiwan's electronics sector, and the globalization of national electronics firms abroad are indicated by Taiwan's ratio of inward to outward foreign direct investment (see table 1.2). This ratio fell dramatically in the 1990s.

The shift at home from foreign ownership to national ownership was a precondition for globalization in the form of *outward* FDI. Without national enterprise, Taiwan would not have become a base for outward FDI.[30] Moreover, without an understanding of the history of inward FDI in Taiwan's electronics industry, the pattern of outward FDI *from* Taiwan's electronics industry would be less comprehensible. In both instances (televisions in the case of inward FDI, IT in the case of outward FDI), *the initial foreign activity took the form of an equity investment, not subcontracting*. With respect to the American TV industry's operations in Taiwan, and the Taiwan IT industry's operations in China, both appeared to involve mostly 100 percent equity ownership. As assemblers ventured overseas, in a minority of cases their most important local parts suppliers immediately followed (see the discussion in chapter 3). These suppliers also initially formed 100 percent wholly owned subsidiaries. Despite the disincentive to FDI in China from insecure property rights, Taiwan companies preferred equity ownership over subcontracting. Taiwan firms had proprietary assets (skills in production engineering and project execution) that favored direct ownership and complete control (Hymer 1976).

Electronics was the largest industry in Taiwan's manufacturing sector (see table 3.3) and the largest outward foreign investor. Including China, it accounted for 21 percent of all outward FDI in the period 1952 to 2000, exceeded only by the banking and insurance industries (see table 2.21). Almost all IT products exhibited a rising trend over time in overseas production, especially in China (see table 2.22). China accounted for only 14 percent of Taiwan's IT industry's output in 1995. By 1999 it accounted for 33.2 percent.

A survey in 2000 indicated that the percentage of a firm's total outward investments in China was, on average, higher the smaller the firm (79 percent, 73 percent, and 65 percent for small, mediium, and large firms respectively). The reverse was true for outward investments in the United States (8.9 percent, 19 percent, and 33.5 percent respectively). The electronics industry showed the highest

Table 2.21
Outward foreign direct investment, by industry, 1952–2000 (%)

	Without China		With China	
Industry	1952–1983	1952–2000	1952–1983	1952–2000
Manufacturing				
Food	6	2	6	4
Textiles	8	3	8	4
Apparel	1	1	1	1
Chemicals	29	5	29	6
Nonmetals	9	2	9	3
Metals	5	3	5	5
Electronics	12	16	12	21
Other	10	6	10	15
Total manufacturing	90	38	90	59
Services				
Wholesale and retail	—	4	—	3
Trade	9	6	9	4
Transport	—	4	—	3
Banking and insurance	1	41	1	25
Other	1	7	1	5
Total services	10	62	10	41
Grand total	100	100	100	100

Source: Adapted from Taiwan, Ministry of Economic Affairs (various years [e]).

ratio of investing in the United States—30 percent of its total compared with only 12 percent and 14 percent for the machinery and chemical industries respectively (Taiwan Ministry of Economic Affairs 2000).[31] As Taiwan's technologies crept closer to the world frontier, its markets became higher income. Taiwan investors widened their focus from low-cost venues such as China to high-cost venues such as the United States.

The IT industry feasted on China not only for its cheap labor but also for its large domestic market. Taiwan firms saw their common language and culture conferring an advantage to them over other foreign investors. At last they could exploit scale economies of product design and develop their own brand names. Politically the IT industry and diversified groups became an important lobby to end government restrictions on mainland investments. Thus upgrading had the effect of pushing foreign-owned firms out of Taiwan and pushing Taiwan firms into the rest of the world, especially

Table 2.22
Percentage of total IT output produced overseas, 1993–1999

Product	1993	1994	1995	1996	1997	1998	1999
Notebook	0	0	0	0	0	0	3
Monitor	20	34	42	43	65	71	73
Desktop			9	14	—	12	14
Motherboard	26	34	44	40	40	38	40
SPS	46	—	77	83	89	91	94
CD-ROM	—	—	25	32	48	60	80
Scanner	0	—	0	0	11	38	58
Graphic card	29	32	47	29	32	65	63
Keyboard	68	69	85	93	90	91	92
Mouse	11	32	34	68	79	89	95
Sound card	—	—	15	28	64	65	88
Video card	—	—	0	32	15	18	35
Total	15	21	28	32	37	43	47
% in China	—	—	14	16.8	22.8	29	33.2

Source: Adapted from Taiwan, Market Intelligence Center (various years).

China, where the pot of gold comprised lower wages and bigger scale economies.

From Small-Size Firms to Large-Size Firms

Whereas the importance of foreign-owned electronics firms clearly fell over time, the fall in the importance of small-scale electronics firms (with 100 or fewer workers) is less clear. This firm size may *never* have been a dominant force in the electronics industry, conventional wisdom aside. This cannot be verified statistically due to data incomparabilities before and after 1986, although early accounts of the electronics industry argue that nationally owned entities were typically small, badly managed, and inefficient (Arthur D. Little 1974). The situation is further complicated by differences in the behavior of employment and value added. Small-size firms *increased* their share of employment in both total manufacturing and in the electronics sector (see tables 2.23 and 2.24). In manufacturing at large, employment in small firms rose from 48 percent of the total in 1986 to 58 percent of the total in 1996. It also rose in electronics, from 27 percent to 37 percent.

Table 2.23
Distribution of value added and efficiency by firm size, *manufacturing sector*, 1986, 1991, and 1996 (%)

	Small <100			Medium 100–499			Large >500		
	1986	1991	1996	1986	1991	1996	1986	1991	1996
Employment (1)	48	56	58	28	21	19	24	22	23
Value added (2)	31	36	36	25	20	18	44	44	45
Efficiency (2/1)	65	63	63	89	94	96	183	200	198

Source: Calculated from census data provided by the Directorate General of Budget, Accounting, and Statistics.
Note: Firms are classified as small, medium or large according to the number of their workers. Efficiency is measured in terms of an index. The index is pegged to the average efficiency of all firms (= 100) in a given time period. Thus, if efficiency is below 100, it is below the average.

Table 2.24
Distribution of value added and efficiency by firm size, *electronics industry*, 1986, 1991, and 1996 (%)

	Small <100			Medium 100–499			Large >500		
	1986	1991	1996	1986	1991	1996	1986	1991	1996
Employment (1)	27	38	37	27	24	22	46	38	42
Value added (2)	21	27	22	25	23	19	54	50	60
Efficiency (2/1)	76	71	59	94	95	87	118	133	143

Source: Calculated from census data provided by the Directorate General of Budget, Accounting, and Statistics.
Note: Firms are classified as small, medium or large according to the number of their workers. Efficiency is measured in terms of an index. The index is pegged to the average efficiency of all firms (= 100) in a given time period. Thus, if efficiency is below 100, it is below the average.

In terms of value added, by contrast, the share of small firms in the computer industry—Taiwan's leading exporter in the 1990s—*never exceeded 15 percent*. Large firms dominated the industry, with almost 70 percent of value added and even around 60 percent of employment. The dominance of large firms in the parts and components subsector of the electronics industry is striking as well. In electronics parts and components, firms with 500 or more workers accounted for 66 percent of value added in 1996, almost the same as for computers—69 percent (see table 2.25).

Given disparate behavior between employment and value added, *the relative efficiency of small firms in the electronics industry declined*

Table 2.25
Distribution of value added and efficiency by firm size, *subsectors of electronics industry*, 1986, 1991, and 1996 (%)

	Small <100			Medium 100–499			Large >500		
	1986	1991	1996	1986	1991	1996	1986	1991	1996
Computers									
Employment (1)	17	20	21	37	20	20	47	60	58
Value added (2)	13	15	13	36	21	17	51	65	69
Efficiency (2/1)	78	71	62	97	105	86	110	108	119
Electronic parts and components									
Employment (1)	21	35	30	23	26	22	56	38	47
Value added (2)	16	25	16	20	24	18	64	51	66
Efficiency (2/1)	74	72	53	88	90	81	115	133	139
Communications equipment									
Employment (1)	15	32	36	28	32	27	56	36	37
Value added (2)	13	20	23	33	24	27	54	56	51
Efficiency (2/1)	85	62	63	116	75	97	96	157	138

Source: Calculated from census data provided by the Directorate General of Budget, Accounting, and Statistics.
Note: Firms are classified as small, medium or large according to the number of their workers. Efficiency is measured in terms of an index. The index is pegged to the average efficiency of all firms (= 100) in a given time period. Thus, if efficiency is below 100, it is below the average.

over time, where efficiency is defined as value added per worker. This decline partly reflected a deficit in skills. It also reflected a failure on the part of small firms to invest in capital equipment and thereby realize economies of scale. The discrepancy in behavior between small and large firms (with over 500 workers) in wages and fixed assets is shown in figures 2.1 and 2.2. The divergence by firm size, as noted earlier, was far greater for fixed assets than for wages. Starting in the early 1990s, the capital assets of large firms expanded at a much faster rate than that of small firms.

We measure efficiency as *value added per worker* because value added comprises wages plus profits (it is the difference between the value of output and inputs). It may thus be regarded as a return to *two* production factors, *labor and capital*. Given that the electronics industry was changing its product composition, producing new automation equipment and re-conditioning its old production facilities, its capital stock cannot be measured accurately either by imports of capital goods (which is the way it is usually measured for latecomer countries) or by any other obvious method. Instead, we use value added per worker as a proxy for total factor productivity.

To show how efficiency changes over time for firms of different size, we take the average measure of efficiency for firms of all size in a given year, set that to 100, and then index the actual efficiency of firms of different size to that average. According to the index of efficiency in the electronics industry (table 2.24), the efficiency of small firms in 1986, 1991, and 1996 was 76, 71, and 59—well below the average and declining relative to other firm sizes (especially the largest) over time. This is in keeping with what we argued earlier about large firms, how their skills and efficiency increased in tandem with their ramping up.

As for research and developoment (R&D), there is a big difference between small firms (with fewer than 100 workers) and other firms (where R&D is measured as expenditures as a percentage of sales). This fraction for small firms rose over time but barely exceeded one percent (see table 2.26). It was highest for the largest-size firms, with 1,000 or more workers.[32] By 1997 firms with 1,000 or more workers were spending on average as much as 3.1 percent of their sales on R&D. The R&D activity of medium-size firms, with 100 to 499

Table 2.26
R&D by firm size, electronics industry, 1988, 1992, and 1997

A. Percentage of sales

Employees	1988	1992	1997
Under 100	0.7	1.3	1.4
100–499	1.1	2.0	2.3
500–999	2.0	2.2	2.0
1,000 and over	2.4	2.2	3.1
Total	1.7	1.8	2.3

B. Percentage distribution of expenditures, 1997

Employees	Personnel	Capital	Other[a]
0–99	47	20	33
100–299	45	14	41
300+	38	11	51

Source: Taiwan, Ministry of Economic Affairs (various years [c]).
Note: R&D as a percentage of sales.
a. Other refers to the current costs incurred in doing R&D, such as intellectual property sharing costs, materials, and operations.

workers, was also rising and by 1997 had reached an impressive level. This suggests that the smallest-size firms were falling behind, the largest-size firms were increasing their lead, and medium- and large-size firms were pouring more money into new technology and especially product design.

The nature of R&D also differed by firm size, as indicated by the distribution of expenditures on labor, capital, and “other” items (see table 2.26, panel B). Proportionally, small firms spent a lot on people and capital. Large firms spent a lot on current costs, such as buying technology, materials, and operations. This suggests that much of the R&D of small electronics firms was accounted for by software. Software was also important in the case of large firms (data are available for firms with over 300 workers), but large firms worked more with materials (as in the semiconductor industry) and operations related to product design and the integration of parts and components (as in the computer industry).

Assuming that new entrants into the electronics industry start small, then additional data suggest the declining importance of new start-ups. This may be inferred from entry and exit rates. *Gross entry rates for the period 1991 to 1996 were much lower than for 1986 to 1991*, 39.6 compared with 76.1 (see table 2.27 for data and definitions of gross entry and exit). All major segments of the electronics industry experienced a decline in gross entry: appliances (from 98.4 to 37.2), computers (from 214.5 to 57.0), telecommunications (from 80.7 to 54.0), and electronic parts and components (from 87.5 to 52.8). This decline may reverse itself if the telecommunications segment of Taiwan’s electronics industry, or some “new” mature product other than cell phones, gets hot. But early entries into telecommunications have tended to involve existing firms rather than start-ups, as noted earlier.

All in all, as the electronics industry upgraded, the share of value added of the small-scale firm (with fewer than 100 workers) remained low while its efficiency (value added per worker) declined. The gain in both efficiency and market share was greatest among the largest firms (with 500 or more workers).

The Rise of Market Concentration

After an initial phase of intense competition in sequentially hot, mature industries (radios, televisions, calculators, VCRs, desktop PCs,

Table 2.27
Entry and exit rates in the electronics industry, 1986–1991 and 1991–1996 (number of enterprises)

	Total	Appliances	Computers	Telecom equipment	Parts and components
1986–1991					
Entries	5,757	1,073	499	196	1,729
Exits	1,579	−6.3	−116	35	522
Entry rate, %	76.1	98.4	214.2	80.1	87.5
Exit rate, %	0.9	−5.8	−49.8	14.4	26.4
1991–1996					
Entries	4,647	828	483	218	1,680
Exits	2,306	318	71	95	564
Entry rate, %	39.6	37.2	57.0	53.0	52.8
Exit rate, %	19.6	14.3	8.4	23.5	17.7

Source: Data from Directorate General of Budget, Accounting, and Statistics.
Note: For 1986–1991: Number of entries between 1986 and 1991 as a percentage of the total number of firms in 1986. Number of exits between 1986 and 1991 as a percentage of the total number of firms in 1986. The unit for the absolute number of entries and exits is number of enterprises.

notebooks, etc.), concentration in each market in Taiwan increased. Given what we have said thus far about investments by national firms in skills and optimum-size plants, we associate rising concentration with rising efficiency rather than ill-gotten gains.

Market concentration tended to rise despite an export orientation on the part of second movers. This suggests the presence of second-mover advantage and crowding out given economies of scale and a constraint on firm-level expansion: finite global demand or scarce resources in Taiwan (e.g., experienced researchers and managerial know-how) limit the number of top competitors. The first firms in Taiwan to make the requisite investments in large-scale plants and the technological and managerial capabilities necessary to operate them efficiently gain an edge over later entrants.

The tendency toward high concentration was first evident in the television industry, which exhibited the expected S-curve. Before the commencement of mass production of televisions in Taiwan, market concentration was very high (see table 2.28); four firms accounted for over three-fourths of output. With new entry and investments in volume production, concentration fell sharply to a low of 9.5 in 1972.

Table 2.28
Market concentration in Taiwan's color TV industry, 1970–1983

Year	Four-firm concentration ratio	Herfindahl index	Equal size firm equivalent
1970	76.1	16.4	6.1
1971	36.2	3.6	27.8
1972	9.5	0.3	333.0
1973	41.6	5.6	16.9
1974	54.9	9.4	10.6
1975	59.8	12.3	8.2
1976	62.3	13.4	7.5
1977	65.4	15.2	6.6
1978	60.8	14.1	7.1
1979	65.5	12.2	8.2
1980	64.9	12.9	7.4
1981	65.2	13.1	7.6
1982	63.1	12.8	7.8
1983	62.9	12.3	8.1

Source: Adapted from Lin (1986).

Then it rose again after a shakeout, to between 60 and 65 percent, where it seems to have stabilized.[33]

There are no comparable data that show change over time for the information technology industry; the earliest four-firm concentration ratio (or some equivalent) is available for the 1990s, for two points in time.[34] Still, the duration of time between the onset of production (1988) and these two points (1998 and 1999) is about the same length as the duration of time shown in table 2.28 for color TVs, whose production started around 1970; it is roughly a decade in both cases.

Table 2.7 presents IT concentration data. Because market concentration for IT segments is not measured exclusively by a four-firm ratio, it is hard to make strict comparisons between it and market concentration in TV production. Nevertheless, in some IT products with concentration ratios (1998) at four or below (video card, sound card, desktop PC, keyboard and mouse), market concentration is either the same or higher than for color TVs in the period 1976 to 1983. Whatever these differences, a common thread is clear: after a decade or so of competition, market concentration in both industries appears to have become fairly high. The four-firm (plus or minus) concentration ratio is 60 or above, although the ratio for certain IT products, especially desktop PCs, does not yet appear to have stabilized. Measured concentration would be even higher if the various ownership linkages between leading producers were taken into account. Among the top five producers of notebook PCs in 1999 (Quanta, Acer, Inventec, Compal, and Arima), with a CR-5 ratio estimated at 78.6 percent, Inventec owned 25 percent of Quanta's equity, as noted earlier, and both companies were closely associated with Compal, one of whose original founders was also a founder of Quanta.

Concentration data for other segments of Taiwan's electronics industry are unavailable, but high concentration is reported by industry leaders. As noted earlier, five firms came to dominate the production of electronic calculators. One firm, Yageo, was reputed to hold a 70 percent market share of resistors. In the case of fabless, IC design houses, the top seven companies are estimated to have accounted for 60 to 70 percent of total revenue, and each company also tended to occupy a different market segment.[35] Producers of cell phones were still at the top of their learning curve in 2000, but a shakeout in the industry was expected soon, as it was for TFT-LCDs. Moreover, in the case of cell phones (and TFT-LCDs), not only was concentration in this market expected to rise, but aggregate concentration at the economywide level was also expected to rise insofar as major producers of cell phones tended to be major producers of notebooks or other electronic products, leading to a rise in their overall share of GNP (as discussed in chapter 4).[36]

High market concentration for IT production inside Taiwan and outward globalization of IT production from Taiwan appear to be associated—over time, both tended to increase (see tables 2.7 and 2.22). Both involved cost-cutting measures: rising concentration was a reflection of investments to achieve economies of scale, and rising globalization was a reflection of investments to tap lower-cost labor supplies.

High domestic concentration for IT production also went hand in hand with high *global* market shares for Taiwan producers as a whole. As indicated in table 2.7, Taiwan manufacturers accounted for as much as 85 percent of all scanners produced worldwide. Their share of power supplies, keyboards, mouses and monitors averaged around 60 to 65 percent of total world output. Even for notebooks, their global market share was almost 40 percent. Thus Taiwan's leading firms may have been small in size by comparison with *Fortune 500* international companies, but they were large by domestic standards and even by the global standards of the market segments in which they competed.

Concentration is likely to increase in the electronics industry as a result of mergers and acquisitions (M&As), both local and cross-border. Data on M&As are still incomplete and unreliable. To our knowledge, the most comprehensive source (Thomson Financial Security Data) does not include many mergers among small firms. M&As that never materialized may still be counted in the total. What is beyond dispute, however, is the focus of M&As on the electronics sector, whether from the viewpoint of the "target" or the "acquiror" (see table 2.29).

Table 2.29
Mergers and acquisitions in Taiwan, 1986–2000

	Number
Acquiring industry	
Electronic and electrical equipment	62
Computer and office equipment	47
Investment and commodity firms, dealers	35
Business services	19
Telecommunications	18
Wholesale trade	11
Machinery	2
Other	45
Unknown	4
Total	243
Target industry	
Electronic and electrical equipment	79
Computer and office equipment	31
Business services	30
Telecommunications	28
Wholesale trade	19
Pre-packaged software	10
Machinery	1
Other	45
Total	243

Source: Adapted from Thomson Financial Securities Data, March 28, 2001.

Thus rising market concentration, or the share of output accounted for by the largest firms, appears to be an integral part of upgrading in a mature, high-tech industry such as electronics.

Conclusion

Second movers emerged in Taiwan out of a highly competitive process that involved improving product designs and lowering production costs in global industries that were still high-tech but fast becoming mature. Given the prospect of paper-thin margins, second movers strove to be the first to squeeze the remaining surplus out of mature products. They exploited economies of scale at home and cheaper labor abroad to gain the volume necessary to reduce costs and sustain profitability. Given their pursuit of scale, automation, and mass production, they conformed with the old Fordist model. Given their rapid ramp-up and selective vertical integration, they conformed with the more modern management mode that stressed core competency. In the case of electronics second movers, their core competency lay in production engineering, project execution, and integrative design.

The second movers that were the first to invest in optimum size plants, and managerial hierarchies were rewarded with high levels of domestic market power and large market shares globally. In this respect they were part of a subset of latecomer countries (Taiwan, China, India, and Korea), all of whose major manufacturing industries were dominated by national firms rather than multinational enterprises (as in Argentina, Brazil, and Mexico). What differed among them in the electronics industry was their area of specialization. Circa the year 2000, China excelled in telecommunications equipment. India was best in software. Korea was tops in memory semiconductors. Taiwan was premier in information technology.

It is to an explanation of Taiwan's area of expertise that attention is now turned.

3 Government-Led Networking

Taiwan's *domestic* electronics network was a geographical agglomeration consisting of firms that supplied peripherals and "passive" parts and components to buyers at arms length. It involved no intralocal subcontracting, as that term is typically used. The benefits of its density to local assemblers were twofold: low transactions costs (in terms of search and transportation) and high global visibility for new orders (owing to the large share that Taiwan as a whole was able to capture in world IT markets).[1] Nevertheless, domestic networks were devoid of the "trust-based," subcontractual relationships that supposedly characterized IT production within industrially advanced economies. Both domestic networks in latecomers, and international subcontracting between them and high-wage countries, lacked autonomous, endogenous mechanisms to diffuse or generate the advanced technologies that latecomers needed to expand into new market segments. Into this vacuum stepped the "neo-developmental" state with its import substitution policies tailored to high-tech industry. The latecomer state was the midwife of new industrial growth poles around which small firms could cluster. It developed the parts and components that were formerly imported and that network members became capable of producing locally, thereby adding to the density of network transactions. The policy tools the government used for high-tech import substitution differed from those it had used to promote mid-tech industry, but the intent was similar: to expand employment and keep industry going in Taiwan. Hence, networking in the latecomer case, and the creation of high-end jobs and high-tech industries, may be said to have been "state led."

Ironically one of the government's policy "mistakes" in the 1950s and 1960s (of overinvesting in high-level human resources) turned out to be beneficial on the long run. At first there was brain-drain. Then, as brain-drain began to reverse in response to rising domestic demand, there arrived a large supply of experienced scientists and engineers. However, reverse brain-drain and the close ties between Taiwanese engineers in Hsinchu Science Park and technology centers like Silicon Valley (which was one of many US locales where Chinese-Americans worked in large numbers), were only a part of Taiwan's economic success story. (For an account of the Hsinchu–Silicon Valley tie, see Saxenian and Hsu 2001.) Nationals rather than Chinese-Americans largely built Taiwan's electronics industry, as noted in chapter 2. The government was responsible for the creation of new market segments, the incubation of start-ups (using spin-offs from government labs and science parks as media), investments in publicly funded research institutes, and promotion of private R&D, as analyzed below.

A host of conditions weakened local (intra-latecomer) networking. Historically *international* subcontracting in the electronics industry was premised on a large wage differential between early and late industrializers. The absence of a comparable differential *within* latecomers—between, for instance, firms of different size, specialization or unionization—weakened the incentive for local subcontracting (see figure 2.1 for the relatively small wage gap between firms of different size in Taiwan's electronics industry). The co-generation of technology, involving the sharing among firms of cost and risk, also supposedly supported networks among firms in advanced economies, notably Italy (e.g., see Beccatini 1990; Piore and Sabel 1984). But the absence of cutting-edge knowledge in latecomers, a prerequisite for new technology co-generation, further weakened domestic subcontracting. Instead of making high-tech peripherals, parts, and components, latecomers were heavily dependent on importing them. Importation reduced transactions among domestic firms, creating yet another condition adverse to networking. Finally, Taiwan's electronics sector was (selectively) export oriented (IT products had high export ratios whereas electrical appliances, passive components and parts, and semiconductors had relatively low export ratios, at least directly). To the extent that local producers oriented their products to foreign markets, their incentive to collaborate with local buyers was weakened still further.

We have differentiated a network from a market in terms of *personal* versus *anonymous* transactions (see chapter 1). Four types of personal transactions may occur, with varying degrees of neutrality: subcontracting, customizing specialized inputs, processing the semifinished product of another firm ("in-processing"), and procuring parts, components, or peripherals from a buyer on a personal basis. Procurement may involve the personal to the extent that buyer and seller know each other, but transactions may approximate neutrality insofar as they are based on immediate concerns of price, quality and possibly technology transfer. Of all types of transactions within Taiwan's electronics network, procurement of standard inputs was predominant.

In general, the lower the latecomer's local self-sufficiency of parts and components, the weaker will be all types of network transactions and, hypothetically, the stronger will be government-led import substitution. The higher the export propensity of the parts manufacturers, the weaker still will be the incentive for local cooperation.

Taiwan initially specialized in those information technology products that required large numbers of parts and components by virtue of the existence of a dense *non*electrical machinery industry that predated the IT industry's rise.[2] As global demand for electronics products soared, machinery makers of all types shifted to manufacturing parts and components for electronics assemblers. They supplied them with a large *number* (although a low *value*) of their total requirements (in the case of notebooks, very roughly 97 percent in terms of number but only 30 or 40 percent in terms of value, depending on the time period). Thus we first examine the *non*electrical machinery industry to establish something of a benchmark in a latecomer of "old-economy" networking. Then we analyze networks at the heart of the new economy, the electronics sector broadly defined.

The Nonelectrical Machinery Industry

Taiwan's nonelectrical machinery industry (or just machinery industry) was characterized by relatively small-scale firms because few mature products were subject to mass production. Major *exports*, such as sewing machines (Schive 1990), machine tools of various sorts (Amsden 1977), and bicycles, which are not strictly "machinery"[3] (Chu 1997), were exceptional insofar as their leading firm size was large (500 or more workers). Early sewing machine production was dominated by Singer, a multinational, and Lihtzer, a nationally owned firm. Giant, Taiwan's number one national bicycle manufacturer with international brand-name recognition, was reputed to hold a 20 to 25 percent domestic output share in the 1990s. The ten firm concentration ratio for bicycle exports was around 60 percent (Taiwan Industrial Technology Research Institute 2000). Even machine toolmakers, whose premier performers tend to be relatively small in size worldwide, had employees numbering in the hundreds, as in Leadwell, Yang Iron, Victor Taichung, and Tatung's machine tool subsidiary. Still, with the exception of bicycles, the output (measured in units) of sewing machines, machine tools, and motorcycles failed to reach a level comparable to that of later mass-produced electronics exports, such as calculators and notebooks (compare tables 2.5 and 3.1). Output in the machinery industry was

Table 3.1
Start (****) and peak output, early principal nonelectric machinery and transportation products

Year	Sewing machines	Machine tools	Bicycles	Motorcycles
1952	25,050****		****	
1961		****		
1962				****
1968				
1986				
1987				
1988				
1989				
1990				
1991				
1992				
1993				
1994	3,767,577			
1995		1,762,079		1,695,064
1996				
1997				
1998			11,926,199	
1999				
2000				

Sources: Data for bicycles refer to exports and are adapted from Taiwan, Ministry of Finance (various years). Data for machine tools from Taiwan, Mechanical Industry Research Laboratories (1999). Other products adapted from Taiwan, Ministry of Economic Affairs (various years [b]).

also more stable than in the electronics industry. It did not exhibit the seesaw demand or the rapid ramp-up that required a small firm to grow large in an extremely short amount of time. Given the absence of mass production and demand surges (except for bicycles), small-scale firms could more easily survive.

Small firms (with 100 or fewer workers) accounted for over 75 percent of employment and over 65 percent of value added in the machinery industry for the period 1986 through 1996 (see table 3.2). These shares were much higher—by a factor of over two—than those in the electronics industry (22 percent), or even those in the manufacturing sector at large (36 percent) (see tables 2.23 and 2.24). The myth of the small firm in Taiwan's economy conforms with reality mainly in the nonelectrical machinery sector. It should be noted that this sector stagnated as a share of GNP (see table 3.3). In 1981 its share was 3.7 percent compared with 9.9 percent for the electronics industry. By 1996 their shares were 4.8 percent and 24.3 percent respectively.

Early Networks: Sewing Machines and Bicycles

Networks involving sewing machines and bicycles were of longstanding. They did not materialize overnight, and they preceded exporting, foreign participation, and international subcontracting (in the form of nationally owned firms manufacturing sewing machines and bicycles for foreign buyers). The source of the entrepreneurial experience behind these networks is unclear. Presumably it derived from both pre-war manufacturing under Japanese rule and the know-how embodied in émigrés from China following the 1948

Table 3.2
Distribution of value added and efficiency by firm size, nonelectrical machinery and equipment industry, 1986, 1991, and 1996 (%)

	Small <100		
	1986	1991	1996
Employment (1)	76.8	77.9	78.7
Value added (2)	68.1	68.4	69.4
Efficiency (2/1)	88.6	87.8	88.2

Source: Calculated from data provided by the Directorate General of Budget, Accounting, and Statistics.

Table 3.3
Distribution of manufacturing value added, 1981–1996 (%)

Industry	1981	1986	1991	1996	Δ1981–1996
Food	7.1	7.1	6.4	6.0	−1.1
Textiles	12.8	10.6	8.6	6.7	−6.1
Apparel	3.5	4.5	2.0	1.0	−2.5
Chemicals	8.0	6.9	7.3	9.8	1.8
Chemical products	1.9	2.1	2.5	2.9	1
Petroleum	7.0	4.6	4.5	5.8	−1.2
Plastics	8.1	8.7	7.4	5.4	−2.7
Mineral products	4.0	3.6	3.8	3.5	−0.5
Basic metals	6.4	6.7	7.7	8.7	2.3
Metal products	5.1	5.1	5.7	5.2	0.1
Machinery	3.7	3.9	4.9	4.8	1.1
Electronics	9.9	14.1	17.8	24.3	14.4
Transport equipment	5.9	6.0	7.4	6.6	0.7
Precision instruments	1.1	1.1	1.3	0.9	−0.2
Miscellaneous	4.0	3.8	3.3	1.9	−2.1
Other[a]	11.6	12.2	9.5	6.5	−5.1

Source: Ministry of Economic Affairs (various years [b]).
a. Includes tobacco, leather and fur, wood and bamboo, furniture and fixtures, pulp and paper, printing, and rubber.

Communist Revolution.[4] As in the case of the exports of the electronics industry, foreign involvement in the 1960s in the first major machinery export—sewing machines—took the form of direct foreign investment and joint ventures (with Japanese firms) rather than international subcontracting (Singer Sewing Machine closed its manufacturing plant in Taiwan and began to rely on local OEM producers for sourcing only as late as 1999). By the time bicycles began to be exported in large numbers in the early 1970s, enough local experience had been accumulated to enable foreign involvement to take the form of international subcontracting rather than direct investment. The Taiwan government provided both industries with tariff protection for import substitution and assistance to upgrade technological skills (see table 3.4).

When Singer began operations in Taiwan in 1963, 250 assemblers and parts suppliers already existed. As early as 1952 their annual production equaled over 25,000 sets (see table 3.1).[5] The assembly of bicycles began right after World War II.[6] Annual output averaged around 30,000 to 40,000 units. Employment in 1954 and 1961 reached

Table 3.4
Tariff schedules, selected products 1973–1998

Tariff schedule	Tariff rate				
		1985		1998	
	1973	Column I[a]	Column II[b]	Column I[a]	Column II[b]
Sewing machines					
Household type	32%	30%	20%	5%	3.75%
For industrial use	20%	30%	20%	5%	3.75%
Bicycle	46%	45%	35%	15%	10%
Bicycle parts	39%	30–40%	15–30%	15%	10%
Electronic computers (1973 classification)					
Floor-mounted type	13%	—	—	—	—
Other	39%	—	—	—	—
Data processing machines		10%	5%	10%	Free
Peripheral devices					
Terminal		20%	20%	7.5%	Free
Printers		10%	10%	7.5%	Free
Other		10%	7.5%	7.5–10%	Free–2.5%
Parts		10%	7.5%	10%	Free
Telephonic and telegraphic apparatus	20–26%	20–25%	10–25%	10%	Free–2.5%
Electronics					
Electronic tubes for industrial use	7%	5%	5%	1%	1%
Picture tubes	20%	20%	20%	1%	1%
Integrated circuits	—	20%	7.5%	Free–2.5%	Free
Transistors, diodes, LED, etc.	—	20%	7.5%	Free–2.5%	Free
Passive components	—	20–30%	19–25%		
Fixed capacitor				15%	Free
Other capacitor				3–5%	Free
Resistor				5%	Free
Parts				2.5%	Free
Printed circuit boards		30%	20%	10%	Free

Source: Taiwan, Ministry of Economic Affairs (various years [a]).
a. Countries with most favored status.
b. Other countries.

about 7,400 and 10,700 persons respectively. "The amount of human resources engaged in bicycle-producing and related activities was already significant in that early period, and could be utilized when export-led assembly operations arrived later. American buyers succeeded in helping local producers to set up assembly operations.... However, to set up a bicycle assembler is one thing, to establish a whole network of local parts suppliers is another. The latter requires the pre-existence of accumulated learning" (p. 61). Between 1966 and 1970 the parts self-sufficiency rate averaged as much as 86.3 percent, an impressive figure given that a bicycle requires over 100 parts.

In the sewing machine industry's early development, Singer played a major role in upgrading skills. It conducted training classes and organized seminars for parts suppliers. Training included the study of heat treatment, the inspection of finished products, and the introduction of new concepts and techniques of factory management. Singer also provided standardized blueprints and the necessary measuring gauges to parts producers. Additionally it provided individual firms with various services, including opening its tool room to them in order to help them make tools and fixtures; solving their technical problems in casing; improving their plating facilities and work methods; controlling the dimensions of their arm shafts; providing them with foundry patterns made by Singer's tool room; redesigning punch presses and dies used in their production of bobbins; and setting up heat treatment equipment to help them make needles. A few critical parts that constitute the heart of the sewing machine (shuttle bodies and bobbin cases) had to be imported, but eventually Singer began to manufacture these locally as well.

However impressive Singer's initiative, arguably it was not acting voluntarily but rather in response to conditionalities imposed on it by the Taiwan government. Singer had a local distributor in Taiwan before its investment in production, but "a tariff and import controls on certain models provided another incentive to invest" (p. 57). As indicated in table 3.4, in 1973 (and earlier) the tariff protecting the household-type sewing machine was as high as 32 percent. In addition *the government stipulated stringent performance standards on Singer before it would grant it an operating license*:

1. By the end of the year of its establishment, Singer had to procure 83 percent of its required parts from local suppliers; provide them with standardized blueprints; and assign experienced engineers to

help them establish work methods, prepare materials specifications, and inspect final products. (Singer had a total of 140 parts suppliers, which represented about 60 percent of the total number of local parts producers, and all 140 had received technical assistance in one form or another from Singer.)

2. Singer was obliged to supply national assemblers with Singer's own locally made parts at prices no more than 15 percent above the price of parts imported from Singer's other plants.

3. Singer had to export to the maximum degree possible. In fact Snger's export volume increased at a stable annual rate of 12 percent during the period 1964 to 1976.

Most of the leading Japanese producers of sewing machines, such as Brother, moved their mid-level production to Taiwan in the 1970s. The premier Janome Company came in 1969. Soon Taiwan became the top ranking exporter in global markets of sewing machines, parts, and components, mainly of the household type. Of the three million household sewing machines exported by Taiwan in 1984, 60 percent came from Japanese subsidiaries. The rest came from Singer and smaller nationally owned companies that initially specialized in low-end models.[7]

Local production of industrial sewing machines developed later than that of household sewing machines and was dominated by nationally owned firms (despite lower tariffs, as indicated in table 3.4). Exports to advanced economies, with higher quality and technological specifications, began to be undertaken by nationally owned assemblers (throughout its lifetime in Taiwan, Singer exported mainly to developing countries).[8] Domestic competition among these assemblers was fierce. Therefore, the government encouraged the formation of an export cartel (as it later did in certain segments of the electronics industry). To ease competitive pressures, local exporters reached a "gentlemen's agreement" in 1976 to set an export floor-price per sewing machine unit.

The leading firm, Kaulin Company (brand name Siruba), became the third-ranking producer of industrial sewing machines worldwide after an intensive buildup of technological skills. Kaulin successfully developed a computer-aided industrial sewing machine with help from the government's Industrial Development Bureau (IDB).[9] In the late 1990s it invested in production facilities in China and, with its new capacity, planned to produce more sets than either of the then two market leaders, Juki and Pegasus of Japan.

A modern sewing machine comprises over 700 parts. Given the household-type sewing machine's maturity, and an experienced local machinery industry, self-sufficiency reached over 90 percent (Taiwan Industrial Development Bureau 1999). Three "factory systems," or core-satellite relationships, emerged around major sewing machine assemblers (strengthened by government subsidies, as discussed later)—Kaulin, Zenghsing, and Singer's OEM subcontractor.

The tariffs the government provided to the bicycle industry were even higher than those it provided to sewing machines, and longer lasting (see table 3.4) They were as high as 46 percent in 1973 and 35 percent in 1985 for "most favored nations." Even after liberalization a 10 percent tariff on bicycles remained.

The government also intervened in the bicycle industry to maintain export standards and "took responsibility of inspecting exports to prevent substandard bicycles from being sent overseas." As a result of government surveillance, most "underground" bicycle factories disappeared from the scene in the 1970s (Chu 1997, p. 57).

In terms of upgrading, the government's technical assistance to the bicycle industry intensified after 1986, when Taiwan's currency appreciated, domestic wages rose, and unit prices of Taiwan's bicycle exports began to decline. The bicycle industry benefited from the science and technology R&D projects undertaken by government-owned ITRI, which supported industrial upscaling and the import substitution of key components. Then the government formed a Taiwan Bicycle Industry R&D Center. It got grants from the IDB of the Ministry of Economic Affairs to undertake various R&D projects and provide consulting services to the industry (Taiwan Industrial Technology Research Institute 2000c). In 1987, the Materials Research Laboratory of ITRI helped Giant develop a carbon fiber bicycle frame. In 2000, the IDB included the electric bicycle and high-end derailleur on its list of new and important strategic projects that qualified for tax grants and other subsidies.

By the 1990s, the government-owned Materials Research Laboratory had secured 17 patents pertaining to the bicycle derailleur. For the most part the government was the major source of patents in Taiwan. As indicated in table 3.5, ITRI alone accounted for 45 percent (602 patents) of the total number of patents issued to Taiwan's top ten patentees. The National Science Council placed third and

Table 3.5
Top 10 recipients of US patents for Taiwan and Korea, 1980–1996

	Patent owner	Number of patents
Taiwan		
Industrial Technology Research Institute (ITRI)	G	602
United Microelectronics Corp. (UMC)	G	317
National Science Council	G	132
Taiwan Semiconductor Mfg. Co. Ltd. (TSMC)	G	89
Acer, Inc.		59
Winbond Electronics Corp.		25
IBM	F	23
Honeywell Inc.	F	21
Giftec Ltd.		21
Greenmaster, Industrial Corp.		20
Korea		
Samsung group		2,316
LG group		1,009
Hyundai group		348
Daewoo group		166
Korea Institute of Science and Technology (KIST)	G	135
Electronics and Telecommunications Research Institute (ETRI)	G	124
Korea Research Institute of Chemical Technology	G	49
Sunkyong group		37
Korea Advanced Institute of Science and Technology (KAIST)	G	35
Ricoh Co.	F	17

Source: CHI research database, as cited in Mahmood (1999).
Note: G = government-owned; F = foreign-owned.

two government-owned semiconductor foundries, UMC and TSMC, placed second and fourth respectively. In Korea the government was likewise a major patentee but as a runner-up to the private sector. In Taiwan the government led patent activity.[10]

The self-sufficiency ratio of bicycle inputs (or alternatively, the input import ratio) was typically high (low) but fluctuating, in response to changes at the world frontier in the technology of the bicycle frame, parts and energy source.[11] The relatively low level of import dependence in 1996 in the bicycle industry and the *non*-electrical machinery industry, in general, is indicated in table 3.6. By

Table 3.6
Import ratio of intermediate inputs, machinery and bicycle industries, 1996

	Machinery				
	General	Industrial	Other	Parts	Bicycle
All Intermediate inputs					
Coefficient of intermediate inputs (1)	0.68	0.71	0.73	0.65	0.77
Coefficient of imported inputs (2)	0.16	0.16	0.21	0.13	0.15
Import ratio (2/1), %	24	22	28	20	19

Source: Taiwan, Directorate General of Budget, Accounting, and Statistics (1996), *http://www.dgbas.gov.tw/dgbas03/6main.htm*.
Note: Coefficient of intermediate inputs and primary inputs adds up to one, that is, one dollar value of an industry's product. Coefficient of intermediate inputs equals the sum of the coefficient of imported intermediate inputs and locally made inputs.

comparison with the electronics industry, shown later, these input import ratios were extremely low, only 19 percent for bicycles and 24 percent for general machinery. Large fluctuations in import dependence in the case of bicycle parts, however, are suggested by changes in the parts self-sufficiency ratio. As was noted earlier, between 1966 and 1970 the parts self-sufficiency rate averaged as much as 86.3 percent. The rate fell to 67 percent between 1972 and 1974, as Taiwan's bicycle makers had to improve the quality of their parts in order to enter the US market. After import substitution, the parts self-sufficiency ratio regained ground, averaging 79 percent from 1975 to 1985. Then it fell to 53 percent in 1990, as further upgrading required the import of high-end parts from Japan, such as derailleurs, chain wheels, brakes, and hubs, and especially bundled modules from Shimano, the leading Japanese supplier, as dictated by some foreign buyers. By 1996 the parts self-sufficiency ratio had recovered to 70 percent (Chu 1997, as updated from Taiwan Ministry of Finance, various years).

A falling input import ratio may be expected to indicate strengthened local networking—domestic production grows and creates the basis for supplier-buyer interactions. But technological change and a fluctuating import ratio may instead act to destabilize local networking: "the by-product [of such fluctuation] is a partial disintegration of the earlier strong ties between the bicycle and parts sectors domestically" (Chu 1997, p. 65). In the case of the suppliers of Giant

Table 3.7
Giant Bicycle Company, percentage of total demand from a given supplier

Part	Supplier	On CS list, 1988	On CS list, 1999	1986	1987	1988
Brake	1	*		12.4	10.2	14.6
	2		*	4.2	4.8	5.3
	3			2.8	3.1	3.2
	4					12.4
Derailleur	1			5.7	5.1	6.5
	2				15.1	19.5
Hub	1		*	30.3	29.8	32.3
	2	*	*	38.3	31.2	35.2
Chain wheel	1	*		24.5	21.3	22.7
	2			15.4	16.8	15.5
	3			9.0	9.7	9.2
Handle steer	1	*	*	41.1	40.8	38.0
	2	*	*	34.9	32.3	35.8

Source: Taiwan, Institute for Economic Research (1989); Taiwan, Corporate Synergy Development Center (2001).
Note: Asterisk indicates companies that were registered with the Corporate Synergy Development Center as satellite companies supplying to Giant in 1988 and 1999 respectively.

registered with a government-run Corporate Synergy Development Center, five out of its 19 major suppliers in 1988 disappeared from the list in 1999. Six out of its 20 major suppliers in 1999 were not on the list in 1988. Since parts suppliers and assemblers started small in the early 1970s, both grew by exporting, and relied on exports to attain economies of scale. Given the uncertainties of export demand from OEM buyers, both parts manufacturers and assemblers tried to diversify their customer base. Therefore, no exclusive relationships arose between buyers and suppliers, which discouraged synergistic interactions and collusive technology. On average, each bicycle parts producer supplied 20 assemblers, and each assembler purchased parts from 60 suppliers (Chu and Tung 1990). Their interactions more closely resembled those of an open market than of a closed network, although buyers and sellers no doubt got to know one another personally.

Table 3.7 shows the many sources that Giant used for key parts. In 1988, four suppliers accounted for only 35.5 percent of its total procurement of brakes. Three major suppliers fulfilled only 47.4 percent of its total requirements for chain wheels. On the supply side, parts

Table 3.8
In-processing for others, by industry, 1996 (% of unit's total output)

Industry	Total output, NT$1,000 (A)	Processing for others, NT$1,000 (B)	(B/A), %
Food and beverages	511,175,448	110,264,617	21.57
Textiles	915,469,007	487,928,433	53.30
Wearing apparel, accessories, and other	159,316,300	44,568,353	27.97
Leather, fur, and products	70,716,458	11,184,935	15.82
Wood and bamboo products	59,787,908	12,884,527	21.55
Furniture and fixtures	84,338,243	7,870,740	9.33
Pulp, paper, and paper products	166,558,069	9,532,016	5.72
Printing	123,958,570	66,959,224	54.02
Industrial chemicals	491,919,347	11,843,096	2.41
Other chemicals	161,885,868	6,494,850	4.01
Petroleum and coal products	302,088,576	1,441,400	0.48
Rubber products	76,899,025	10,917,595	14.20
Plastics products	424,401,695	52,708,635	12.42
Nonmetallic mineral products	245,963,977	10,324,093	4.20
Glass and glass products	39,830,851	3,138,120	7.88
Basic metal industries	621,091,731	52,551,670	8.46
Fabricated metal products	467,545,116	100,875,769	21.58
Machinery and equipment	410,256,195	59,509,987	14.51
Metal working machinery	97,537,877	17,598,320	18.04
Special production machinery	157,982,454	17,774,193	11.25
Textile and garment	42,661,324	7,226,268	16.94
Electrical and electronic machinery	1,852,151,140	188,206,171	10.16
Electrical appliances and housewares	98,798,942	1,844,101	1.87
Data storage media and processing	607,163,297	13,947,866	2.30
Computer components[a]	117,532,745	3,089,312	2.60
Commucation equipment and apparatus	74,562,588	784,333	1.05
Electronic parts and components	729,432,399	157,579,192	21.60
Tubes[b]	76,973,709	643,941	0.80
Semiconductors[c]	323,343,198	78,345,226	24.1
Photonics[d]	37,018,214	156,595	0.40
Passive parts and components[e]	83,066,622	1,711,888	2.10
Other EP and C[f]	209,030,656	76,721,542	36.4
Transport equipment	502,118,095	40,641,609	8.09
Motor cycles and parts	73,206,412	3,606,783	4.93
Bicycles and parts	81,475,979	21,286,642	26.13
Bicycles	28,169,301	357,476	1.20
Parts	53,306,678	20,929,166	39.3

Table 3.8
(continued)

Industry	Total output, NT$1,000 (A)	Processing for others, NT$1,000 (B)	(B/A), %
Precision instruments	58,665,743	8,406,334	14.33
Miscellaneous	165,225,029	42,303,024	25.60
Grand total	7,944,835,047	1,337,417,078	16.83

Source: Adapted from Taiwan, Directorate General of Budget, Accounting, and Statistics (1998a), table 16.

a. Mother boards, interface cards, sound cards, graphic cards, fax-modem cards, network cards, etc. (SIC 3145).

b. All types of tubes: picture, vacuum, transistor, etc. (SIC 3171).

c. All types of integrated circuits, diodes, etc. (SIC 3172).

d. Optoelectronics: LCDs, LEDs (light-emitting diodes), optoelectronic components, solar cells, etc. (SIC 3173).

e. All types of passive components: electronic condensers, transformers, resistors, capacitors, etc. (SIC 3174).

f. Printed circuit boards, quartz oscillators, microwave satellite components, power supplies, etc. (SIC 3175).

manufacturers were more dependent on foreign buyers than on domestic buyers. Bicycle parts manufacturers were exporting on average almost 60 percent of their output in 1990 and 56 percent in 1999 (Chu 1997, 2001).[12]

Networking in Taiwan's bicycle industry was strongest *among* parts suppliers, rather than between parts suppliers and assemblers, as is typical in international subcontracting. Moreover the form of networking among parts manufacturers was related to *in-processing* rather than contractual procurement of a piece of hardware. In terms of total output of bicycle parts, as much as 39.3 percent represented processing for others (see table 3.8). Among bicycle assemblers this rate was only 1.2 percent. Networking, as it related to in-processing, appears to have been more of a phenomenon among small firms than between large and small firms. In-processing was driven by specialization in manufacturing techniques rather than by novel product procurement or development.

Globalization by the Taiwan bicycle industry began in the early 1990s and took the form of outward direct foreign investment rather than subcontracting. In the case of Giant, globalization meant establishing production facilities mainly in China and marketing facilities mainly in advanced countries (Giant, as noted earlier, was one of

Taiwan's few companies with global brand-name recognition). Giant formed a joint venture (1993) with the Chinese state-owned Shanghai Phoenix Bicycle company, but its main factory in Kun-shan (Shanghai, established in 1992) was wholly owned. By 2000 this factory sold about half its output domestically, with an annual capacity of over 2 million units (to be expanded to 5 million in the next few years) (Chen 2001). "Its production base in China has given Giant enough volume to become one of the world's top producers" (*Commonwealth Magazine* 2001; Yang 2000). Nonetheless, difficulties beset Giant's globalization in the form of selling its own brand-name bicycles in advanced country markets, especially the United States. Giant's US sales operations began in 1987 but broke even only in 1999. Giant fared better in Europe, and chose Holland, with a large population of bicyclists, to locate a factory.

When Giant invested in Kun-shan, it did not invite its suppliers to join it. It informed them about its plans and then left it up to them to decide if they wanted to follow. Some did, but some did not, at least at the start. Eventually most did, and now Giant's Chinese operations obtain most of their parts locally. About three hundred Taiwanese parts suppliers operate in Kun-shan, although in 1997, when Giant could not secure key inputs locally, as in the case of high-end aluminum alloy, it set up its own subsidiary, Chuansin Metal Products, to supply materials for its bicycle frames.[13]

Thus, even in the paradigmatic "old-economy" case of bicycles, latecomer networking differed from international subcontracting (or subcontracting within advanced economies). Relations between suppliers and assemblers were relatively distant. Technology generation mainly involved some organ of the government, whether in relation to an assembler (e.g., Giant) or a parts supplier. Alternatively, a foreign firm (e.g., Singer) or a foreign vendor (e.g., Shimano) played a major role. The greatest local networking took the form of small parts manufacturers processing each other's semifinished products.

We turn now to networking in the electronics industry, where the tendencies observed in the "old economy" were even stronger.

Networks in the Electronics Industry

A key difference underlying networks in the nonelectrical machinery industry and the electrical machinery industry was the *import dependence on parts* (measured in terms of value rather than number of parts). In the nonelectrical machinery industry, the input import ratio (or input self-sufficiency ratio) typically started high (as indicated by sewing machines and bicycles) and then fluctuated as a function of technological change at the world frontier and domestic import substitution. Ultimately import dependence assumed a low level, as seen in table 3.6.

In the case of electronics, by contrast, the self-sufficiency ratio started low. It had a built-in tendency to stay low insofar as users typically received a joint product when they "sourced" (bought) from a foreign rather than a domestic vendor—they got the part in question as well as state-of-the-art technical assistance. There were, however, countervailing incentives for both the government and the private firm to import substitute imported inputs (as seen below in the case of advanced liquid crystal displays).

Table 3.9 shows the import ratio of inputs for IT products in 1996.[14] In the case of computers (computer products, e.g., notebooks) intermediate inputs accounted for 82 percent of the value of a computer. Of these intermediate inputs 45 percent had to be imported. The import ratio of inputs for computers therefore equaled 55 percent. For "key" intermediate inputs, as much as 69 percent had to be imported. The import ratio of IT products was generally much higher than that of bicycles and nonelectrical machinery, whether the ratio for the latter is estimated for the early 1970s (as discussed above) or 1996 (see table 3.6). Despite ten or so years of experience, most IT products still had an import ratio above 50 percent. In the case of key components, import dependence averaged around 70 percent.

Networking may be expected to have been highest in those segments of IT that had the lowest import dependence, such as "other" electronic parts and components (holding constant additional characteristics that might impact on networking, e.g., firm size).[15] Using *in-processing* as one measure of networking, the expected relationship appears to hold, although the number of observations is small (see table 3.8). Parts and components had the lowest import dependence and the highest in-processing rate among electronics products.[16] For other than parts and components, the in-processing ratio was very low, less than 3 percent.

Whereas data exist on in-processing, none are available to examine subcontracting. There is, however, little theoretical reason to expect subcontracting in a latecomer's IT sector, and nothing on the

Table 3.9
Import ratio of intermediate inputs, electronics industry, 1996

	Computers				Electronics[a]					
	Product	Peripheral	Storage	Compo-nent	Elect. tube	Semicond.	Photonics	EP&C[b]	Comm. equipment	Total[c]
All intermed. inputs										
Coefficient of intermed. inputs (1)	0.82	0.82	0.82	0.78	0.73	0.63	0.77	0.71	0.76	0.53
Coefficient of imported inputs (2)	0.45	0.50	0.21	0.41	0.32	0.40	0.37	0.25	0.39	0.14
Import ratio of inputs (2/1)	55%	61%	26%	52%	44%	64%	48%	35%	51%	27%
Key components										
Coefficient of key component (1)	0.61	0.60	0.10	0.55	0.25	0.34	0.37	0.24	0.39	0.04
Coefficient of imported key component (2)	0.42	0.47	0.04	0.38	0.20	0.29	0.23	0.13	0.33	0.03
Import ratio of key component (2/1)	69%	78%	46%	69%	80%	85%	62%	57%	85%	67%

Source: Taiwan, Directorate General of Budget, Accounting, and Statistics (1996), *http://www.dgbas.gov.tw/dgbas03/6main.htm*.
Note: Coefficient of intermediate inputs and primary inputs adds up to one, that is, one dollar value of an industry's product. Coefficient of intermediate inputs equals the sum of the coefficient of imported intermediate inputs and locally made inputs. Key components are defined as inputs from all the high-tech sectors listed in this table.
a. As defined in table 3.8.
b. Electronics parts and components, including passive and "other."
c. All sectors, including primary, manufacturing, and services.

demand or supply sides to suggest empirically that it exists. In terms of demand the parts, components, and peripherals that Taiwan IT assemblers buy locally have tended to be standard in design; there has been no need for assemblers to enter into formal relationships to procure such products. Moreover, while market concentration ratios have tended to be high in Taiwan's IT sector (see table 2.7), and some subsectors have formed export cartels, domestic competition thus far has been intense. Therefore, assemblers (e.g., notebook manufacturers) have been able to buy 97 percent of their *number* of inputs locally at competitive prices.

The benefits of subcontracting thus were weak, while the costs of subcontracting, as suggested from interviews with assemblers, are perceived to be high. The costs include inspection, monitoring, and lock-in (which is a high risk under conditions of rapidly changing product demand). An Inventec executive was quoted as saying (see chapter 2): "Subcontracting is a step that is to be avoided, if possible."

On the supply side, Taiwan's manufacturers of parts and components have had little incentive to tie themselves to a local buyer. If foreign buyers supply them with larger orders, more stable demand, more valuable technical assistance, the incentive for a local tie-in is small. Overall, Taiwan's electronics industry has been highly export oriented: exports exceeded domestic sales in 1996 by a factor of 1.26. In the IT industry (data storage media), the factor was 2.84. For electronics parts and components (excluding tubes, semiconductors, and photonics), it was lower, 0.80 and 0.62 (see table 3.10). But while the export factor of IT parts and components was low compared with the electronics industry in general, and certainly the whole IT industry, it was relatively high in comparison with the export factor of bicycle parts and nonelectrical machinery and equipment industries. Thus the incentive for domestic subcontracting of electronics inputs on the supply side was no stronger than on the demand side. Exporters are more likely to establish formal relations of one sort or another with their (major) foreign buyers than with their (minor) local buyers.

There is no consistent evidence that when assemblers from Taiwan invest in lower-wage countries to reduce their labor costs and exploit economies of scale, they bring their Taiwan suppliers with them overseas. "Except for some large enterprises, Taiwan firms were not able to require their suppliers to go abroad with them and to make

Table 3.10
Annual value of domestic sales and direct exports, electronics and bicycle industries, 1996

	Domestic sales, NT$mil (1)	Exports, NT$mil (2)	Ratio (2/1)
Total	854,285.8	1,077,697.4	1.26
Electric machinery, appliances	134,303.7	35,722.8	0.27
Electric machinery, housewares	115,102.4	30,386.2	0.26
Lighting equipment	21,385.2	7,466.3	0.35
Data storage media	175,168.3	496,976.2	2.84
Computer components[a]	44,072.9	82,706.7	1.88
Video, TV, and radio products	37,566.7	43,376.8	1.15
Communications equipment	33,222.8	48,111.2	1.45
Electronic parts and components[b]	286,821.3	390,118.1	1.36
Electronic tube	19,249.1	58,963.0	3.06
Semiconductors[c]	97,171.8	189,551.5	1.95
Photonics and components[d]	13,341.3	33,859.0	2.54
Passive parts and components[e]	51,925.0	41,784.9	0.80
Other electronic parts and components[f]	105,024.2	65,959.7	0.62
Bicycles	3,190.7	25,365.2	7.95
Bicycle parts and component	22,491.2	11,359.6	0.50

Source: Taiwan, Directorate General of Budget, Accounting, and Statistics (1998a), table 16.

a. Mother boards, interface cards, sound cards, graphic cards, fax-modem cards, network cards, etc. (SIC 3145).

b. All types of tubes: picture, vacuum, transistor, etc. (SIC 3171).

c. All types of integrated circuits, diodes, etc. (SIC 3172).

d. Optoelectronics: LCDs, LEDs (light-emitting diodes), optoelectronic components, solar cells, etc. (SIC 3173).

e. All types of passive components: electronic condensers, transformers, resistors, capacitors, etc. (SIC 3174).

f. Printed circuit boards, quartz oscillators, microwave satellite components, power supplies, etc. (SIC 3175).

joint foreign direct investments. Thus, at the beginning stage of FDI, firms would source mainly from their suppliers at home, under arrangements made by their parent (their parent would be responsible for providing them with imported inputs). Only as the size of an assembler's overseas operations grew did parts suppliers find the operating scale large enough to warrant their making an overseas commitment" (Ku et al. 2000, p. 81).[17] Still, as late as 1999, the value of parts supplied to a foreign subsidiary by locals was relatively small—in 1999 the estimates were 39 percent for subsidiaries operating in Southeast Asia and 19.4 percent for subsidiaries operating in China (Taiwan Ministry of Economic Affairs 2000).

Thus networking within the IT industry of a latecomer such as Taiwan has largely been arm's-length in nature. Neutral transactions predominated over subcontracting, in-processing or procurement based on "trust" (however measured).[18] Neutrality also appears to have spilled over into the way Taiwan companies globalized in lower-wage, neighboring Asian countries. Many parts manufacturers ultimately invested overseas, but they preferred to wait until scale warranted such an investment.

Geographical Clustering

Despite weak networking, Taiwan's IT assemblers benefited from a dense, local (and regional) geographical agglomeration of parts, components, and peripheral suppliers. Density may be measured by the weight of machinery industries (electrical and nonelectrical) in total manufacturing activity, and by the share of manufacturing output in GDP (see table 3.11). In terms of the importance of the machinery industry in total manufacturing output, Taiwan's share was not all that different from that of Brazil, India, and Malaysia (the latter's share was relatively high due to the presence of foreign electronics assemblers). It was below that of Japan and even Korea. In 1990, including major European countries, Italy had the highest share as well as some of the most dynamic "industrial districts" (geographical agglomerations of networked firms) (Beccatini 1990; Piore and Sabel 1984). Taiwan, however, excelled among latecomers in terms of the heavy weight of its total manufacturing sector in GDP. In 1990 its share was highest among latecomers (36 percent), although below that of Italy in the early 1950s (48 percent).

Table 3.11
Density of manufacturing sector and machinery industry, international comparisons, 1953, 1975, and 1990 (%)

	1953	1975	1990
Taiwan			
Machinery/manufacturing	na	18	23
Manufacturing/GDP	14	29	36
Korea			
Machinery/manufacturing	na	14	32
Manufacturing/GDP	9	27	31
Malaysia			
Machinery/manufacturing	7	17	28
Manufacturing/GDP	9	18	24
India			
Machinery/manufacturing	na	23	27
Manufacturing/GDP	12	16	19
Argentina			
Machinery/manufacturing	na	19	13
Manufacturing/GDP	31	32	22
Brazil			
Machinery/manufacturing	na	23	25
Manufacturing/GDP	24	29	26
Mexico			
Machinery/manufacturing	na	14	17
Manufacturing/GDP	24	23	23
Japan			
Machinery/manufacturing	na	33	41
Manufacturing/GDP	na	na	28
Italy			
Machinery/manufacturing	na	31	36
Manufacturing/GDP	48	na	23

Source: Adapted from United Nations Industrial Development Organization (various years).
Note: Machinery/manufacturing = the share of electrical machinery and nonelectrical machinery in total manufacturing output. Manufacturing/GDP = the share of the manufacturing sector in GDP.

Table 3.12
Nonreturn rates among foreign male students studying in the United States, 1964–1969

Country	1964 Students (A)	1969 Percentage of nonreturn rate (B)	1969 Potential nonreturn pool, (A × B)
Argentina	521	21.6	112
Brazil	528	8.2	43
Chile	387	13.3	51
China	1,716	38.3	657
India	6,136	7.2	442
Indonesia	635	2.8	18
Korea	2,067	11.0	227
Mexico	1,145	18.8	215
Taiwan	3,426	11.7	401
Thailand	1,168	3.6	42

Source: Adapted from Myers (1972).
Note: Absolute number of students in 1964. Nonreturn rates apply to five years after graduation.

Density is evidenced by Taiwan's high *global* market share in diverse product segments. As shown in table 2.7, the products of Taiwan's IT industry typically enjoyed global market shares ranging from a high of 85 percent for scanners to a low of nearly 40 percent for notebooks (which, however, attained the highest output value of IT products). High global market shares created visibility for Taiwan producers; when a buyer wanted an IT product, a sensible place to shop first was Taiwan, which favored further rises in market share and still greater density.

The high quality of Taiwan's machinery agglomeration was buttressed by the high rate of Taiwan's "reverse brain drain" and investments in engineers, as noted in chapter 2.[19] Given the number of students from Taiwan studying abroad in the 1960s, and given their high *non*return rate at the time, Taiwan had one of the largest pools among late industrializers of potential returnees, many of whom did return starting in the 1980s with the emergence of profitable business opportunities (see table 3.12). The potential returnee pool was almost as large from Taiwan as from India, a much more populous country, and much larger than the pool from Latin America's most

Table 3.13
Engineers: Share in total tertiary student enrollment, 1960–1990

	Share in 1960, %	Share in 1990, %
Decreasing share		
Mexico	20.0	16.9
Brazil	12.0	9.6
India	7.0	5.0
Argentina	13.0	12.0
Increasing share		
Malaysia	8.0	10.2
Korea	19.0	21.7
Turkey	12.0	14.8
Thailand	4.0	9.2
Indonesia	4.0	10.4
Taiwan	19.8	30.2
Chile	20.0	25.0
China	40.9	53.9
Regions		
Developing	12.1	12.3
North Atlantic	13.7	10.0
USSR, Eastern Europe, Cuba	40.6	29.7
Japan	14.0	16.9
Total	21.1	15.6

Source: UNESCO (United Nations Economic and Social Council, various years).

industrialized countries. Taiwan also excelled in terms of investments in engineers. Tertiary schooling received substantial funding by latecomer standards, and among tertiary students, a relatively high proportion studied engineering (see table 3.13). In 1990 over 30 percent of tertiary students in Taiwan were enrolled in engineering courses. Thus Taiwan's electronics industry benefited from high density in manufacturing activity, machinery production within manufacturing, and an abundant supply of locally trained and foreign-trained engineers.

The density of machine building in Taiwan was part of a region-wide agglomeration. By the 1990s parts, components, and peripherals in the IT industry tended to be sourced in Asia (for the computer industry, see, e.g., Dedrick and Kraemer 1998). As noted earlier, not just Taiwan but also Korea, Malaysia, and Japan had high shares of machinery building in manufacturing output (see table

3.11). Not just Taiwan but also China and Korea had relatively large potential pools of returnees in the 1960s (see table 3.12). Not just Taiwan but also Korea, China, and Japan had high shares of engineers in tertiary enrollments (see table 3.13). Over time Taiwan's direct exports were increasingly destined to Asia, especially China (Hong Kong and the Mainland) and the ASEAN[20] countries, although the share of the latter fell with the Asian financial crisis of 1997 (Taiwan Ministry of Finance, various years). While Japan was at the core of Asia's electronics sector in terms of market size and technological capabilities, flows of manufactured exports, foreign investment, and even technology were not unidirectional from and to Japan, as such flows tended to be in the case of North and South America. As Taiwan and Korea began to get closer to the world technological frontier, still less developed Asian countries such as China and Vietnam traded directly with them, received foreign investment from them, and even bought technical assistance from them. The Asian electronics agglomeration was multidirectional, just as manufactured trade before World War II among Asian countries had tended to be multidirectional, in contrast with the colonial pattern of trade that characterized North and South America (or Europe and South America) (Amsden 2001).

Government Leadership in High-Tech

The Taiwan government's role in high-tech was major insofar as it was meant to create the new market segments in which national companies could then compete. Its strategy featured import substitution and the germination of parts suppliers *around a lead firm, or second mover*. Whereas the government had spawned new industries in the old economy using state-owned enterprises (SOEs) and import-substituting policy tools such as tariff protection, local content regulations and development banking, it did so in the new economy using spin-offs from state-owned research institutes and science parks, and import-substituting policy tools such as subsidies to public and private R&D, tax breaks, and financially favorable conditions for residents of science parks.

By 2000 there were more than 15,000 professionals who had worked at one time or another for ITRI (the government's premier research center devoted to high-tech industry).[21] Of these 15,000 professionals, more than 12,000 had in fact gone to work in one or another high-tech sector. Of these 12,000, 5,000 had been employed in Hsinchu Science Park.[22] ITRI had also been responsible for spinning off the two pillars of Taiwan's semiconductor industry, UMC and TSMC.

The government aimed to break technological bottlenecks to enable nationally owned second movers to compete globally in "new" high-tech subindustries and then to pass their know-how on to local parts suppliers. By the 1970s the fast growth of labor-intensive exports had depleted Taiwan's "unlimited" labor reserves. Major projects in heavy industry were already in place. Therefore, it was keenly felt that the next set of growth opportunities had to be created in high-tech industry and that the government had to play a major role in cultivating them. "To many policy makers in Taiwan, the classical price mechanism type of resource allocation was simply too slow a process to promote industrial development. They advocated that more direct industrial policy measures be considered to speed up development of high-tech industry" (San 1995, p. 35).

The government promoted high-tech industry along several fronts: by means of fiscal policy, the creation of science parks, and the proactive investments of public R&D institutes, some of which assumed multiple roles. ITRI, for example, undertook key technology projects to give pivotal industries, such as semiconductors and PCs, a head start. Thus its spin-offs became Taiwan's leading IC firms. ITRI also actively initiated projects to explore major areas in which it believed the private sector might profitably invest next. After an industry got started, ITRI would undertake smaller-scale projects to import substitute key components. The government's objective was always to create local growth opportunities and local value added, besides upgrading the level of local technology. All forms of promotion converged in industries judged to be "strategic," in terms of their technology intensity, value-added, market potential, industrial linkages, energy consumption and pollution content.

The government passed the Development of Critical Components and Products Act in 1992 to select 66 inputs for import substitution in order to reduce a persistent trade deficit with Japan.[23] Despite a bias on the part of domestic users of high-tech components in favor of imports, scarcities of such components promised high prices and high profits for firms that could make them instead of import them. Users of such inputs had an added incentive to make them in-house in order to stabilize their supply. For its part, the government became committed to import substituting high-tech components to prevent "hollowing out"—the movement of manufacturing jobs overseas. This threat was politically explosive in the case of China, all the more so as wages in Taiwan continued to rise.

Government leadership in strengthening science and technology (S&T) is illustrated below using the examples of CD-ROMs, LCDs, and IC design (compact disk read-only memory devices, liquid crystal displays, and integrated circuits respectively). Then key government programs are briefly reviewed.

Import Substitution-cum-High-Tech Promotion

1. CD-ROMs[24]

The CD-ROM, an optical storage device, was chosen as a targeted industry in 1992 by means of extended discussion among government officials, academics, and leading business people. Several related key technologies, such as the optical pickup head, were also identified for promotion. The MOEA's Department of Industrial Technology (DO-IT) handled the so-called supply side—it invited research institutes, mainly ITRI, to submit R&D proposals to develop the selected items. Resources came from the Science and Technology R&D fund in four consecutive years, 1993 to 1996. By the end of 1996 the total budget was roughly US$10 million.

The Industrial Development Board (IDB) of the MOEA handled the so-called demand side; it invited private companies (based on specified criteria) to participate in the development process. The programs involved were the Regulations Governing the Development of New Industrial Products by Private Enterprises and the Regulations Governing Assistance in the Development of Leading Products. These two programs provided R&D grants to private enterprises to engage in new product development. Grants had to be repaid if and when sales actually materialized.

The CD-ROM project involved 25 firms in joint development and technology transfer.[25] The number of patents derived was four for CD-ROMs and 24 for CD-ROM pickup heads. Ramp-up was astonishingly fast (see the general discussion of ramp-up in chapter 2). As indicated in table 3.14, Taiwan's share of CD-ROMs in world output rose from 1 percent in 1994 (218,000 sets) to 50 percent only five years later (48,690,000 sets).

While the firms that acquired CD-ROM technology from ITRI were able to begin assembly operations at once, and while the CD-ROM at the time was already a mature product, technological change

Table 3.14
CD-ROM industry, 1991–1999

Year	Output, thousand units sets		Percentage (B/A)	ITRI cooperation (number of firms)
	World (A)	Taiwan (B)		
1991	936			1
1992	1,050			7
1993	6,740			25
1994	17,966	218	1	25
1995	38,572	3,600	9	25
1996	51,000	9,170	18	25
1997	61,000	16,000	26	
1998	89,300	30,780	35	
1999	96,860	48,690	50	

Sources: Adapted from Taiwan, Industrial Technology Research Institute (1997) and Taiwan, Market Intelligence Center (various years, 1997).
Note: CD ROM = compact disk read-only memory.

continued to be rapid. As indicated in table 3.15, manufacturers had to upgrade their know-how repeatedly in order to produce CD-ROMs of higher speed. Moreover they had to import key components from Japan. Gradually local production of disks and spindles took place. But the two most critical inputs, the optical pickup head and ASIC set, were still being imported after 1996, although they were in the process of being developed by ITRI.

Taiwanese firms had taken the lead from Japan as the major producers of CD-ROMs, but Japanese companies were shifting to other new and improved standards, such as the DVD-ROM and the CD-RW. Most Taiwanese firms were reluctant to enter into DVD-ROM production because they considered the royalty fees demanded by Japanese companies prohibitive. Then ITRI transferred the technology of the DVD-ROM to 13 firms in 1997. Around 2000 the price of the DVD-ROM was twice that of the CD-ROM, but replacement was expected to be prolonged.

2. TFT-LCDs[26]

Liquid crystal displays were pioneered in the late 1970s and 1980s by Japanese firms, first in their simpler form (TN, or twisted nematic, and STN, supertwisted nematic) and then in their more complex form (TFT, or thin film transistor).[27] TFT-LCDs represented a great

Table 3.15
Technological upgrading in CD-ROM industry, 1994–1999 (% of total output)

	Speed													
Year	2	4	6	8	10–12	16	20	24	32	36	40	44–48	>50	Total
1994	100													100
1995	40	47	13											100
1996			13	67	20									100
1997H2						23	22	55						100
1998Q4								2	11	27	60			100
1999Q4										6	31	47	16	100

Source: Adapted from Taiwan, Market Intelligence Center (2000).
Note: CD ROM = compact disk read-only memory. H2 = second half; Q4 = fourth quarter.

challenge to a manufacturer owing to their extremely high financial as well as processing requirements. Profitability depended on low defect rates and high yields.

By the mid-1990s Korean *chaebol* (Samsung, Hyundai, and LG), in collaboration with their ministries charged with promoting technological innovation, had succeeded in entering the TFT-LCD industry and providing a modest challenge to Japanese hegemony. Some Taiwanese firms were competitively producing TN/STN LCDs by the early 1990s, but they hesitated to enter the more capital-intensive TFT-LCD market.

Two events probably propelled them into action. Prior to the 1997 Asian financial crisis, Samsung, Hyundai, and LG had planned large expansions to catch up with Japanese manufacturers. But the crisis led them to mothball their plans. For their part, Japanese business groups that were suffering from prolonged recession and overcapacity became unable or unwilling to continue making the huge investments in TFT-LCDs necessary to keep up with the competition. A few, therefore, decided to cooperate with Taiwanese firms by granting them technology licenses and giving them OEM orders.[28] Suddenly leading Taiwanese firms announced plans to obtain technology from Japanese partners and make big investments to produce TFT-LCDs. As indicated in table 3.16, Unipac, an affiliate of UMC, and Chung Hua, an affiliate of Tatung, joined forces with Matsushita. Acer joined with IBM, and Hannstar, a manufacturer of

Table 3.16
TFT-LCD industry in Taiwan, 2001

Firm	Parent	Parent's focus	Initial production	Year founded	Technology source
Acer Display Technology	Acer	Computers	1999	1996	IBM
CMO (Chi Mei Opto.)	Chi-Mei	Petrochemicals	1999	1998	Own
Chung Hua	Tatung	Electronics	1999	1970	Mitsubishi
HannStar Display	Walsin-Lihwa	Electric wire	2000	1998	Toshiba
Quanta Display	Quanta	Computers	2001	1999	Sharp
Unipac Opto.	UMC	Semiconductors	1999	1990	Matsushita
Prime View International	Yuen Foong Yu	Pulp and paper	2001	1992	Own

Sources: Company data and Taiwan, Industrial Technology Research Institute (2000b).
Note: Thin film transistor liquid crystal display.

electrical wire, hooked up with Toshiba, all in 1998. Prime View International and CMO invested using their own technology (Prime View started research early and CMO worked at acquiring the necessary technology over a long time period).

The entry of Taiwanese firms changed the global distribution of large TFT-LCD capacity. Taiwan's share of global capacity increased from 0 percent in 1998, to 2 percent in 1999, to 15 percent in 2000, and to 26 percent in the first quarter of 2001. With huge increases in capacity, the international price of TFT-LCDs fell sharply. The price of a 14.1-inch TFT notebook panel dropped from US$1,100 in the third-quarter of 1997 to a little over $600 in the fourth-quarter of 2000. With large investments and falling prices, mergers and acquisitions (M&As) came on the agenda. Acer and Unipac announced a merger plan in March 2001. Chi-Mei Optoelectronics announced its intention to establish TFT-LCD plants in Japan jointly with IBM-Japan.

ITRI had initiated an R&D project on TFT-LCDs in 1988. Acer and Chung Hua Picture Tubes had collaborated in this effort. However, neither of these companies, nor any other Taiwan firm, relied on ITRI's technology when the time came to invest in TFT-LCD capacity. In this regard ITRI's efforts were a failure. Nevertheless, the competitiveness of the high-tech groups in Taiwan that entered into TFT-LCD production depended on further technological development, and it was expected that ITRI would play a leading role at this higher stage. It had established Taiwan's first LTPS TFT-LCD laboratory in 2000, and had developed some key components for more advanced types of panel display.

3. Integrated Circuit (IC) Design

The basis of a networked semiconductor industry stemmed from the Taiwan government's creation of two world-class semiconductor manufacturers, United Microelectronics Corporation (UMC) in 1980 and the larger Taiwan Semiconductor Manufacturing Company (TSMC) in 1987. Both were spin-offs from government-owned ERSO's experimental IC factories, although they emerged at different stages and from different projects.[29] TSMC was also a "foundry" that specialized only in wafer production. It eschewed investment in auxiliary operations, unlike the vertically integrated device manufacturers (IDMs) that dominated the semiconductor industry worldwide (the stages involved in the production of an integrated circuit are designing, manufacturing, masking [sealing], packaging, and testing). The strategy to specialize was the outcome of a deliberate government decision influenced by a prominent state official, K. T. Li, and by Morris Chang, who came to Taiwan at the government's invitation in 1985 to head ITRI and later TSMC.[30] Chang had been a senior vice president in Texas Instruments and the highest ranking Chinese-American in US high-tech industry.

In 1985 three IC design companies in Taiwan (Quasel, Mosel, and Vitelic) that had been established with government support by "returnees" from the United States were in financial trouble and again requested government help.[31] They wanted a local specialized foundry that could provide them with much faster and better service than foreign large-scale IDMs, which regarded their orders as peripheral to their main business. The intellectual property of a design was also better protected by a foundry than an IDM.

Taiwan's IC design industry leaped from eight houses in 1985 to 50 houses in 1988. Sales grew at 175 percent in 1988 and 143 percent in 1989 (see table 3.17). This was "partly due to the growth of the domestic market and partly due to the establishment of TSMC" (Taiwan Market Intelligence Center 1989, p. 390; see also Lin 1987)

Table 3.17
Taiwan's integrated circuit design industry, 1986–1999

Year	Firms, number	Sales, US$bil	Growth rate of sales, %	Export ratio, %
1982	4	—	—	—
1986	18	0.02	—	—
1988	50	0.08	175	74
1990	55	0.22	11	36
1991	55	0.27	18	51
1992	59	0.34	30	50
1993	64	0.44	36	54
1994	65	0.47	6	35
1995	66	0.71	56	39
1996	72	0.79	13	36
1997	81	1.11	67	48
1998	115	1.46	29	43
1999	127	2.36	58	38

Sources: Adapted from Taiwan, Market Intelligence Center (various years) and Taiwan, Industrial Technology Research Institute (various years).

and (Chiang and Tsai 2000). In 1999, 91 percent of the fabrication work demanded by Taiwan's IC design houses was done locally. The top seven IC design houses are estimated to have accounted for 60 to 70 percent of total IC design revenue, as noted in chapter 2. In the same year, 62 percent of semiconductor output was sold locally.[32]

Taiwan's IC design companies benefited from local supporting industries other than foundries. The IC mask industry, like the foundry industry, was set up by the government. ERSO transferred mask technology from two American companies in 1977 and 1980, IMR and Electromask respectively, and began providing commercial masking services to local IC producers. The responsible division was then spun off as the Taiwan Mask Corporation in 1989 (Taiwan Electronics Research and Service Organization 1994). Having a domestic masking service is estimated to have saved local firms up to 20 days or more in the complete IC production cycle (Lin 1987).

Some American electronics firms had moved into southern Taiwan's export processing zone in the 1960s to do packaging, testing and assembly (e.g., General Instrument, Motorola, Microchip, and Texas Instruments). Gradually, these industries were localized—both Motorola and Microchip, for example, sold their packaging capacity to nationally owned firms in 1999. In that year Taiwan's packaging capacity ranked first in the world—99 percent of domestic packaging demand was supplied locally, and local packagers got half their business from domestic firms (Taiwan Industrial Technology Research Institute 2000).

The human resources involved in the IC design industry, like the IC industry as a whole, came largely from ERSO and other government institutions or programs, and of lesser importance, from abroad. Most of the early IC design houses, such as Syntek (1982), Holtek (1983), and PTD (1986), were either Erso spin-offs or were set up by former Erso staff. In turn these firms had (unintended) spin-offs of their own, such as Chip Design Technology (1985), and Tontek (1986) from Syntek. When foreign design firms, such as Motorola and Philips, set up IC design facilities in Taiwan in the late 1980s, they either recruited from Erso or asked ERSO to conduct their training courses (Lin 1987). Returnees became important only in the 1990s. Out of the top ten IC design houses in Taiwan, it is estimated that two were run by returnees in 1989, but by 1995 that number had increased to five (Hsu 1997).

Start-Ups: Firm-Level Targeting

Venture capitalism flourished in Taiwan, one of the first latecomer countries in which it did so, and played a major role in supporting Taiwan's high-tech industry.[33] The government was the catalyst. It began promoting venture capital funds to finance start-ups in 1983, at the instigation of K. T. Li, the statesman mentioned earlier who was behind the rise of Taiwan's high-tech industries in general (Li 1988).[34]

Nevertheless, venture capitalism cannot be credited with Taiwan's large (although steeply declining) number of start-ups (see table 2.27 on entry and exit rates for firms in the electronics industry). According to venture capital data for 1995 to 2000, start-ups received only a minor share of funds (see table 3.18). Of the five stages of a firm's life cycle (seeding, start-up, ramp-up, maturity, and restructuring), start-up received only 13.3 percent of total VC funding in 1995.[35] If the available data are accurate, the lion's share of funding went to ramp-up and maturity (the former included the transformation of privately held companies into publicly held companies through initial public offerings—IPOs).[36] By 2000 the share of total venture

Table 3.18
Venture capital, investment in stage of clients' life cycle, 1995–2000 (%)

Stage	1995	1996	1997	1998	1999	2000
Seeding	8.0	10.1	4.2	9.3	6.3	7.8
Start-up	13.3	17.8	24.1	25.7	25.1	32.8
Ramp-up	49.2	55.2	49.3	46.1	44.0	42.1
Maturity	24.2	16.2	21.2	18.9	23.9	16.4
Restructuring	5.2	0.7	1.3	0.8	0.7	0.9
Total	100.00	100.00	100.00	100.00	100.00	100.00

Source: Adapted from Taiwan Venture Capital Association (various years).

capital allocated to start-ups had risen to 32.8 percent, but this was still below the share allotted to expansion and maturity.

In cases where an outside agent developed a start-up, typically that agent was the government rather than a venture capitalist (in fact the government started one of Taiwan's earliest venture capital firms). Sometimes the government did this directly, as in its founding of Taiwan's two world-class, state-owned semiconductor foundries, UMC and TSMC. Usually the government supported indirectly, by providing start-ups with the finance, facilities, and access to de-bugged technologies that were necessary for them to grow.

A major form of government support in Taiwan was the science park, the first located south of Taipei in Hsinchu, the second in southern Taiwan in Tainan. Start-ups were cherry-picked by the government for residence in these parks. Park residents received a set of comprehensive and generous subsidies that included tax and import duty exemptions, grants and subsidized credit, the provision of below-market rents in high-quality factory buildings or sites, living amenities for high-caliber researchers (including bi-lingual language instruction for expatriates' children), and access to government and university research facilities. "The engine of economic growth in the 1980s in Taiwan [was] the information industry, while the Science-based Industrial Park [was] the driver of the engine" (Liu et al. 1989, p. 35).[37] Out of Taiwan's total R&D spending, Hsinchu Science Park accounted for a large and increasing share—for as much as 18 percent in 1998—although it accounted for less than 1 percent of total output (sales as a share of GNP) (see table 3.19). Even as Taiwan produced an ever larger number of Ph.D.s (roughly 16,000 in 1998 compared with 6,000 in 1990), the share employed by

Table 3.19
Share of Hsinchu Science Park in Taiwan's total R&D, GNP, and number of PhDs, 1989–1998 (%)

Year	Hsinchu sales/GNP	Hsinchu PhD.s/ total PhD.s	Hsinchu R&D/ total R&D
1989	0.01	2.0	4.6
1990	0.02	2.8	4.8
1991	0.02	2.7	5.1
1992	0.02	2.5	4.7
1993	0.02	2.8	6.1
1994	0.03	3.5	7.1
1995	0.04	4.7	10.0
1996	0.04	5.6	12.9
1997	0.05	5.9	15.0
1998	0.05	6.2	18.0

Source: Adapted from Taiwan, National Science Council (various years).

firms in Hsinchu Science Park rose, from 2 percent to over 6 percent in the same period.

Many of the second movers examined in chapter 2 were affiliated in one way or another with Hsinchu Science Park: Acer and some of its subsidiaries such as Acer Sertek; Accton, Lite-On Technology, Lite-On Communications, Z-Com, Delta Green Energy Company, Tecom, Realtek, and Microelectronics Technology. D-Link situated its first fully automated plant there.

Technology Diffusion from Government

In the old economy, favored firms had been promoted by the Taiwan government by means of tariff protection, export incentives and subsidized credit. By the 1990s export incentives had become prohibited under new international law (as specified by the World Trade Organization, WTO), and tariff protection had become increasingly unwieldy—imports of high-tech components had to be accessible to export-oriented IT assemblers at world prices. The use of protection was thus circumscribed. Taiwan's tariffs in the mid-1980s, *were not insignificant* even for many computer-related products, whether for all countries or for "most favored nations" (see table 3.4). But they were low compared with those for sewing machines and bicycles, prototypical old economy industries. By the

1990s protective tariffs for IT products had become negligible, partly as a result of Taiwan's efforts to join the WTO (which had been contingent on China's prior entry). Instead of protection for imports or promotion for exports, the Taiwan government encouraged nationally owned firms in the new economy by extensively, deeply, and systematically subsidizing their "R&D," broadly construed to include all types of science and technology.

Government promoted high-tech in three ways (examples of which were given earlier): (1) it undertook research and development in its own laboratories, which then diffused know-how to the private sector or spun-off a private sector firm; (2) it initiated joint research projects with the private sector; and (3) it subsidized private R&D. Throughout the 1980s, government-sponsored R&D typically accounted for as much as half of all R&D related to industrial technology. Such sponsorship declined sharewise only slightly in the 1990s.[38] The government's share in the financing of total R&D stayed at around 32 percent (see table 2.18).

The government's promotional efforts in the field of computers and IT are less well-known than its efforts in semiconductors, but they were critical nonetheless. The Industrial Development Bureau of the Ministry of Economic Affairs began to promote the information technology sector very early, and arguably had a big positive impact on its growth (Taiwan Electronics Research and Service Organization 1994).[39] Only two years after the birth of the American microcomputer industry (as dated in chapter 2), Erso signed the first of several four-year contracts with the IDB to develop computer technology. Beginning in July 1979, Erso sent teams of engineers to the Wang Computer Company (US) for a ten-month training course. Trainees received instruction in both computer hardware and software design. Instruction was renewed every four years until 1991, and helped diffuse computer know-how broadly. In 1984, ERSO was also instrumental in helping Acer develop what became Taiwan's first 16-bit IBM-compatible personal computer. ERSO helped Acer by developing a legally acceptable basic input-output system (BIOS) for use in PCs exported to the United States. National firms could thus participate in the early phase of the global PC boom. Partly due to its second-mover advantage, Taiwan's IT industry was able to sustain its lead over other Asian rivals. Further Erso set up a laboratory with expensive and specialized equipment to enable private firms to test their products before exporting them (in 1983 this laboratory was spun-off as an independent entity, the Electronic Testing Center). Other computer technology developed by ERSO and transferred through training courses to private computer firms included the ethernet and the Token Ring network, the work station, the terminal and monitor, and file management software.

Center-Satellite Systems

One of the most direct ways in which the government contributed to networking was to establish a Corporate Synergy Development Center (originally called the Core-Satellite Development Center).[40] The idea, promoted by the Industrial Development Bureau of the Ministry of Economic Affairs, was to germinate a *center-satellite factory system* in appropriate Taiwan industries. The system was designed to strengthen small firms by incorporating them into the orbit of a large enterprise. It was hoped that the small firm would thereby face more stable demand so that it could concentrate on upgrading its operations. Better cooperation between the center and the satellite was also expected to raise the level of productivity and efficiency economywide.

Both center and satellite received financial inducements from the government to cooperate. Satellites obtained technical assistance from the center related to just-in-time inventory management, cost rationalization, quality assurance, and other upgrading programs. Centers enjoyed opportunities to invest in promising start-ups, better performance on the part of their suppliers, and subsidized management-consulting fees to install management systems in their suppliers that were in their own interests to install in any case.

At first, the CSD focused on promoting center-satellite systems that were vertical. Vertical systems were of two types. In one, the center bought parts from the periphery. In the other, the periphery further processed inputs from the center (in-processing). Then in 1995 the IDB required the CSD to offer additional services to facilitate *horizontal* cooperation among different types of firms within an industry, such as sharing marketing channels or at least sharing global market intelligence (as in the case of the IT industry's Marketing Intelligence Center). Thus a third type of system emerged, the horizontal system.

The CSD helped to build, maintain and monitor a common C-S framework for each industry. It also helped to coordinate and upgrade technological capabilities, managerial expertise, and e-commerce for registered firms. Those firms participating in the program found assistance related to total quality management, total cost rationalization, and satellite quality assurance most helpful. By 2000 the CSD had registered 192 C-S systems that involved 3,115 firms.

In reality the relationship between center and satellite in the electronics industry remained mostly arm's-length, particularly in IT. The C-S system, in its two vertical variants, appears to have caught on most in the automobile industry, whose satellites, many in the nonelectrical machinery industry, were relatively small (see table 3.2 for the firm-size distribution of nonelectrical machinery). In the electronics industry, by contrast, where small firms were responsible for only 20 percent of total value added, government-subsidized C-S systems appear to have fewer adherents. As indicated in table 3.20, the largest number of affiliates (370) was in electrical machinery (e.g., turbines, motors, and generators). Of all the 2,680 passive parts suppliers to the IT industry in 1996, only 221 were registered with the CSD three years later. The 50 center electronics firms that were registered with it accounted for less than one-third of the 160 large electronics firms that, together, were responsible for around 60 percent of total electronics value added (see table 2.22).[41] On the other hand, the transportation and nonelectrical machinery sectors represented 11.4 percent of total manufacturing output but as much as 38.3 percent of total CSD-registered firms.

Performance Standards

As we have just seen, despite the government's lip service to liberalization, and despite its actual opening of markets to greater foreign competition, industrial policy continued in practice to play an important role in Taiwan's high-tech industries. The general success of industrial policy (as measured by global market share in IT) relates to the maturity of the technology Taiwan was acquiring and to performance standards.

Taiwan targeted "high-tech" products for import substitution that were already mature by world standards, as shown in chapter 2. Thus the government's targeting was not a shot in the dark: national enterprises had to face economic uncertainty but not the technological unknown. Still, the potential margin of error on the government's part was large because technological uncertainty was not necessarily trivial. For example, the government made the right choice, among

Table 3.20
Center-satellite system, by industry, 2001

Industry	Center firms number	Total firms number	Percentage of firm share[a]	Percentage of industry share[b]
Transport and nonelectric machinery	79	1,080	38.3	11.4
Automobiles	22	448	(15.9)	
Motorcycles	21	257	(9.1)	
Bicycles	5	43	(1.5)	
Aerospace	5	46	(1.6)	
Machinery	26	286	(10.2)	
Electronics	50	712	25.3	24.3
Machinery	17	370	(13.2)	
Appliances	10	121	(4.3)	
Information Technology	23	221	(7.8)	
Other	49	1,025	36.4	64.3
Food	5	42	(1.5)	
Consumer goods	10	76	(2.7)	
Steel products	12	208	(7.4)	
Chemicals	7	91	(3.2)	
Textiles	11	55	(2.0)	
Miscellaneous	4	553	(19.6)	
Total		2,817	100	100
Horizontal cooperation	9	267	8.6	—
Incubation	5	31	1.0	—
Grand total	192	3,115	—	—

Source: Corporate Synergy Development Center, Web site: *http://www.csd.org.tw*.
a. 100% = 2,817.
b. Share of industry in total manufacturing output, 1996 (see table 3.3).

several possibilities, in the case of IT. Its "decision to bet on CMOS proved critical for Taiwan's ability to synchronize the development of semiconductor technology and its PC-based information technology so as to achieve a high synergy effect" (Chang and Tsai 2000, p. 187).[42] Besides careful and concerted studies of technological developments and trends by committees of government, business, and university experts, the allocation of subsidies generally succeeded because, as in the past, the government tied them to concrete, measurable, and monitorable performance standards.[43] What was different in the high-tech stage of upgrading was that these standards tended to emphasize investment in assets that were knowledge-based.

Performance standards functioned in Taiwan's high-tech industries in two ways: as criteria that firms had to meet to be eligible to qualify to receive government subsidies and as requirements they had to fulfill as a condition to *continue* to receive incentives. Selectivity on the government's part was necessary, given that the demand for subsidies by firms and research institutes exceeded their supply. Conditionality itself worked because Taiwan's manufacturing sector—as evidenced by the firm managers we interviewed—had accumulated enough experience and skills potentially to produce high-tech products profitably. As projects became profitable, they generated the revenue for beneficiaries to repay their loans and to meet government R&D requirements—its cardinal conditionality. Successful projects, in turn, reinforced the government's commitment to promotion.

The conditions for admission into Hsinchu Science Park (circa 1980) were as follows:

1. A firm had to have the ability to design products for manufacturing according to a business plan.
2. It had to have produced products that had undergone initial R&D that was still in process.
3. It had to have manufactured products with a potential for development and innovation.
4. It had to have engaged in high-level innovation and R&D in a research department that conformed with a minimum specified size.
5. It had to have adopted production processes that required the introduction of training in advanced technology, or the spending of fairly large sums on R&D.
6. It was required to employ a staff within three years after marketing a product or service comprising no less than 50 percent of local technical personnel.
7. Its operations had to contribute significantly to Taiwan's economic reconstruction and national defense (Liu et al. 1989).

Winners were selected by a tripartite committee of experts drawn from private industry, government, and academe, as they were in other government programs.

To qualify for government funds for strategic products/industries (such as CD-ROMs or TFT-LCDs), the following standards had to be met:

1. Firms had to demonstrate their financial soundness and economic capabilities.
2. They had to prove that they operated a research department.
3. They had to demonstrate substantial past R&D achievements.

Once a product receiving government promotion was successfully developed, intellectual property rights were handled as follows:

1. Ownership was shared equally, as jointly owned property, between the MOEA and the firm that had developed the product, since the government had actually invested 50 percent of total development costs.
2. If the MOEA wished to sell part of its intellectual property rights, the firm that shared these rights with the government had the right of first refusal.
3. In the event that the firm failed to engage in production or start the sale of the targeted leading product within three years after the completion of the development plan—for reasons such as bankruptcy, poor marketing strategy, or operational difficulty—the firm not only lost its intellectual property rights entirely but also had to repay, in installments, the money the government had invested.

To receive subsidies for R&D, firms in strategic industries had to commit to spending a certain fraction of their own revenues on additional R&D. The fraction partially depended on their size. The larger the firm, the greater was the fraction. If the amount they spent was below the prescribed ratio, then they had to contribute the balance to a research and development fund designated by the government.

All told, the government pro-actively promoted the accumulation of knowledge-based assets in strategic industries to maintain Taiwan's standing as a production base. The performance standards it exacted for its subsidies further promoted high-tech industry.

Conclusion

The second movers that were responsible for graduating to higher value-added products in Taiwan's electronics industry were aided by a dense agglomeration of small- and medium-size suppliers of parts and components. It would be incorrect, however, to assume that this geographical cluster behaved like the textbook "network" typically illustrated by examples from Reggio nell 'Emilia in Italy or Silicon Valley in California. Local suppliers to domestic assemblers engaged in almost no subcontracting, as that term is ordinarily used. They engaged in little "in-processing," or the manufacture for another firm of a specialized stage within a production process. Their value lay in selling competitively priced and punctually delivered passive components at arm's-length. Thus the institution of the manufacturing network appears to behave differently in latecomers compared with more advanced industrialized economies, even in the same industry, just as the institution of the first and second mover behaves differently.

Given the electronics industry's technological immaturity by frontier standards, and given its high dependence on imports for active parts and components, local networks were not in the vanguard of technological upgrading. Instead, that role fell to foreign vendors and to the government. Government agencies became responsible for incubating high-tech start-ups and strengthening Taiwan's science and technology. Despite market liberalization, the government was instrumental in promoting the import substitution of key parts and components. It created the new market segments in which Taiwan's private sector ultimately excelled. It did so, however, by employing new policy tools by comparison with those it had deployed in the old economy.

When the electronics industry in Taiwan first took shape, most of the firms started out small; only a few started with group backing (e.g., Mitac and First International Computer, members of the Lien Hwa and Formosa Plastics groups respectively). By the second- or third-product-cycle generation, leading firms had accumulated considerable skills and wealth. Large, existing firms therefore, rather than small firms, tended to become the "second movers" in "new" market segments. Although to this day there is evidence in the electronics sector of many new start-ups and fresh entrants (census data, however, show that both entry and exit have tended to decline sharply over time), often these newcomers are aided by the venture capital affiliates of large-scale, old-timer firms. We lack systematic data by way of proof, but it appears from the assessments of venture capitalists that in recent years the most promising start-ups tend to be tied in one way or another to an existing large-scale firm.

4 Modern Services: Comeback by Big Business Groups

Rising domestic incomes and market liberalization began to transform Taiwan's service sector. Starting in earnest in 1986, liberalization loosened the government's regulatory grip and subjected new and old players to greater competition. The major beneficiary among nationally owned firms was the diversified business group. Its previous project execution experience and accumulated capital from the old economy enabled it to expand rapidly into services. Given temporary government restrictions on foreign ownership, national groups became the second movers in the "newest" high-tech market segments. Overall, they significantly increased their share of GNP.

Big Business Groups

As in other latecomer countries the old economy in Taiwan was dominated by diversified business groups. These groups became the agent of diversification into services because of the types of skills they had acquired in the old economy. This form of business pervaded in latecomers because without world-class capabilities in a single, specialized technology family, enterprises tended to grow by diversifying into the most profitable new business opportunities, sometimes technologically unrelated to their original specialization. As groups diversified, they became good at diversification, a critical skill in itself. A group affiliate in one industry could then cross-subsidize an affiliate in another industry, overcoming the imperfections and rigidities of long-term capital markets (Amsden 2001). As a group expanded, it was often the case that it was able to attract the best talent and assign professional managers to manufacturing operations. This increased its technological capabilities in production engineering. With each sequential diversification, it could become good at entering new business fields at low cost and at high speed, thereby increasing its project execution skills (Amsden and Hikino 1994).

Groups themselves could be interconnected to each other through various formal or informal ties.[1] Those in Taiwan were allegedly connected at the top in "banana-bunched" formations (Numazaki 1993).[2] For example, the chairman of the President group, which specialized in processed foods, and the chairman of the Tainan Spinning group, which specialized in textiles, were one and the same. If these connections are taken into consideration, the concentration of output in the biggest groups was probably greater in Taiwan than what is suggested by their reported share in GNP.

As indicated in table 4.1, until the mid-1980s Taiwan's top 100 business groups—in terms of sales—accounted for only around 30 percent of GNP. This share was relatively modest by comparison with that of South Korea, whose economy was concentrated in the hands of four large *chaebol*. But it was large by comparison with that of other latecomer countries, including Argentina, Brazil, Mexico, and India, although a group's reported market share depended on how it consolidated its subsidiaries' holdings, and financial accounting practices tended to vary across countries and even across groups in the same country. Of the top fifty groups from latecomer countries in the early 1990s, Korea was estimated to have ranked first with twenty-one. Taiwan ranked second with ten. Mexico (with more than quadruple Taiwan's population) ranked third with seven, but not all groups in Mexico were as focused on manufacturing as they were in Korea and Taiwan (Amsden 2001).

The core business of Taiwan's top 100 groups was initially squarely in manufacturing. As indicated in table 4.2, manufacturing generally accounted for 85 percent or more of the roughly 100 top groups' core businesses in the 1970s and early 1980s. As the electronics industry expanded and as groups based in this industry began to rank among the top 100 (e.g., Acer and Lite-On), the central importance of manufacturing as the core activity of groups was reinforced. Nevertheless, over time an increasing number of groups (old-timers or newcomers to the top 100) had their core activity in services—as many as 23 groups out of 104 in 1996. If construction services are included in this total, the number of groups with a core in services rises to 31.

Table 4.1
Top 100 business groups' sales and employment as a percentage of GNP, 1973–1998

	1973	1975	1977	1979	1981	1983	1986	1988	1990	1992	1994	1996	1998
Top 100 sales (A)	3.5	4.3	6.2	10.6	13.4	15.8	23.7	43.4	62.3	73.4	101.5	121.3	150.6
Growth rate, %	—	–4	14	19	1	9	9	21	15	2	18	9	20
GNP (B)	11	15	22	33	47	52	83	128	163	215	250	297	328
Percentage (A/B)	32.3	28.0	28.7	31.9	28.8	30.1	28.7	33.8	38.3	34.2	40.6	42.9	54.0
Top 100 employment (C)	277	283	300	313	308	330	335	375	397	436	489	577	770
growth rate, %	—	1	3	2	–1	4	1	6	3	5	6	9	17
Total employment (D)	5,125	5,521	5,980	6,426	6,672	7,070	7,733	8,108	8,283	8,632	8,939	9,068	9,289
Percentage (C/D)	5.4	5.1	5.0	4.9	4.6	4.7	4.3	4.6	4.8	5.0	5.4	6.3	8.3
Group number	100	100	100	100	100	96	97	100	100	100	100	100	100
Collected CCIS	111	106	100	100	100	96	97	100	101	101	115	113	179

Source: Adapted from China Credit Information Service (various years).
Note: Sales and GNP, US$bil. Employment = thousand persons. Average annual growth rates: Sales are in 1996 constant NT dollars. The average growth rate in sales for 1973 to 1998 is 11 percent. The average growth rate in employment for 1973 to 1998 is 5 percent.

The conversion rate for NT$ into US$ was 37.9 (1973), 37.95 (1975 and 1977), 35.98 (1979), 37.79 (1981), 40.22 (1983), 35.45 (1986), 28.12 (1988), 20.11 (1990), 25.40 (1992), 26.24 (1994), 27.49 (1996), and 32.22 (1998). The definition of a group by the CCIS must meet the following criteria:

1. Group must contain three or more subsidiaries.
2. Core company must be located inside Taiwan.
3. National ownership of the core company must be greater than 50 percent.
4. Core company must own more than 50 percent of the shares of its subsidiaries, or must be the largest shareholder.
5. Core company must own more than 33 percent of a subsidiary's shares or must be the largest shareholder if there is cross-holding.
6. Group must have a minimum value of assets and sales (whose absolute level has varied over time).

In defining a group, CCIS also took a subjective factor into account: how companies themselves identify their subsidiaries. It is unclear, however, how CCIS actually used this subjective factor. The number of groups for which information is collected by the CCIS usually exceeds 100, except for 1983 and 1986. For these two years, group data are for less than 100.

Table 4.2
Core business of Taiwan's top 100 groups, 1973–1998

	1973	1975	1977	1979	1981	1983	1986	1988	1990	1992	1994	1996	1998
Food	16	19	15	12	14	12	15	17	15	13	15	15	18
Textiles, shoes	34	32	26	22	20	17	19	14	13	12	19	17	23
Plastics, chemicals	11	10	14	17	20	17	14	13	13	12	14	14	18
Paper, pulp, plywood	9	6	5	3	3	2	3	3	3	3	3	2	3
Cement	2	3	4	5	4	6	5	4	4	4	4	2	4
Metal products	7	8	8	12	10	7	7	9	7	4	8	8	9
Machinery	2	2	1	2	0	0	1	3	2	3	2	2	6
Electronics	7	7	8	7	10	8	12	13	14	18	18	19	39
Transport equipment	6	7	5	6	4	7	5	3	5	7	3	5	6
Manufacturing total	94	94	86	86	85	76	81	79	76	76	85	84	126
Trading, commerce	2	1	2	3	6	6	5	6	7	7	7	6	5
Finance	1	1	1	3	5	7	3	4	4	5	8	8	15
Airline, marine	2	1	0	1	1	1	1	1	3	2	2	4	10
Auto sales	—	—	—	—	—	—	3	2	2	2	3	1	6
Computer service	—	—	—	—	—	—	—	—	—	—	1	0	2
Engineer, consulting	—	—	—	—	—	—	—	—	—	—	1	1	1
Miscellaneous	9	8	8	5	3	4	5	8	8	5	4	5	1
Services total	14	11	11	12	15	18	17	21	24	21	26	25	40
Agriculture, fisheries	2	0	1	1	1	1	1	1	1	1	0	0	1
Construction	—	—	—	—	—	—	2	2	2	7	9	9	16
Miscellaneous	1	1	2	1	2	1	0	0	0	0	0	0	3
Other total	3	1	3	2	3	2	3	3	3	8	9	9	30
Grand total	111	106	100	100	103	96	101	103	103	105	121	118	186

Source: Adapted from China Credit Information Service (1999).

Note: The CCIS defines a core business as the industry in which a parent company operates. The main line of business of the parent company is defined as the core business of the group. The parent, or core company, is the one from which the group's CEO makes decisions affecting other subsidiaries in the group.

Because the core company of some groups operates in more than one line of business, and is counted more than one time, the total number of listed core companies may exceed that of the total number of groups (enumerated in table 4.1).

Finance includes leasing and installment, banking, finance and insurance, investment and holding and securities investment. Textiles includes leather working and shoes.

The increasing importance of services in a group's business is evident from examining the industry affiliation of the top business groups' subsidiaries. Their affiliations, within manufacturing and between manufacturing and services, provide an historical road map of Taiwan's industrial transformation (see table 4.3). Initially subsidiaries of the top groups were primarily in industry. In 1974 and 1976 only 17 percent of such subsidiaries were in services. The most important manufacturing industries in which groups located their subsidiaries at the time were textiles (including shoes), plastics and chemicals, and food processing. Over time the importance of the first two industries declined while food processing maintained its standing and even gained in 1997 and 1998 in overall number of subsidiaries. The machinery industry was consistently relatively unimportant for group investments; as noted in chapter 3, it was mainly dominated by small-scale firms. Transportation equipment was also generally overlooked, although it acquired some importance over time (and had greater foreign participation than machinery). The industry within manufacturing that gained the most affiliates was electronics (including electrical appliances). Beginning in the late 1980s, a growing number of groups became directly involved in production in this sector. As noted in chapter 2, while groups in the electronics industry tended to specialize in electronics, they tended to be more diversified *in* their electronics products than leading electronics companies in Europe or the United States (electronics companies in Taiwan, Japan, and Korea were similar in this regard). Of general interest, the number of affiliates in most industries fluctuated from year to year, suggesting a dynamic pattern of entry and exit among subsidiaries within groups, either those already in the top 100 or those entering it.

Services began to account for half of all group subsidiaries in 1995. The most important services became trading and commerce, and finance (broadly defined to include banking, insurance, leasing, securities and real estate). Construction also rose (cyclically) in importance as large groups created internal construction arms to ramp up capacity rapidly (as discussed in chapter 2 and below).

As leading groups established themselves in electronics and began to diversify into services, their overall size rose relative to gross national product. In 1986, sales of the top 100 groups still accounted for less than 30 percent of GNP. By the early 1990s, that share had risen to over 40 percent. By 1998, it had risen to over 50 percent.[3] Both high-tech industry and the modernization of services can thus be said to have revived Taiwan's group structure (see table 4.1).

The Service Sector

The share of Taiwan's service sector in GNP rose steeply in the decade between 1988 and 1998, from 50 to 63 percent (see table 4.4). Despite this increase, and despite a rise in the number of service subsidiaries accounted for by the top 100 groups, there was relative stability in the service sector's internal composition. Its distribution of gross value added among different types of services, its distribution of and firm size barely altered. There were changes in composition and scale within some subindustries, but in the years after liberalization the structure of the service sector did not exhibit any dramatic shifts, partly because telecommunication services expanded after the 1996 census benchmark. All the same there were already harbingers of changes to come. The absolute number of large enterprises operating in services increased. Foreign firms expanded their activity, although national firms usually retained industry control. The more high-tech types of services also witnessed an increase in collaborations and alliances among business groups, as competition intensified and capital and technological requirements for entry rose in absolute terms. The likelihood increased of consolidations among new entrants and rising market concentration.

Table 4.5 shows the relative stability in the share of gross value added accounted for by major subdivisions within services—commerce and trade, transportation and communication, finance, business, and social and personal. There is an expected rise (although slight) in the share of financial services, especially real estate. There is a relative decline in the importance of transportation (possibly as a result of liberalization of air travel, competition, and declining prices), and a much smaller decline in the share of communication services, which includes telecommunications. Overall, however, the shares of the large subdivisions, and most of the specialized services within them, form a similar pattern at the beginning and end of a decade that was defined by market opening. Given these structural similarities before and after market opening, resource allocation under repressed markets was not highly distortionary.

Table 4.3
Group subsidiaries by industry, 1973–1998

	1973	1975	1977	1979	1981	1983	1986	1988	1990	1992	1994	1996	1998
Manufactures													
Food	69	56	56	60	48	43	50	76	74	56	65	93	81
Textiles	191	162	138	115	108	100	104	112	68	72	80	82	123
Plastics, chemicals	107	76	79	95	104	83	71	88	73	67	77	91	128
Electric machinery	39	44	43	47	51	62	81	98	138	118	113	152	269
Steel	38	36	27	42	51	48	43	62	44	44	43	55	65
Machinery	13	14	13	16	14	12	7	33	12	14	21	20	35
Transport equipment	17	19	20	15	19	20	20	17	31	30	30	37	58
Cement	8	8	11	8	13	16	16	15	17	20	26	28	32
Wood products	25	19	18	14	12	4	5	5	4	5	1	0	3
Leather	—	—	—	—	—	—	6	5	2	2	3	4	—
Shoes	—	—	—	—	—	12	6	10	12	7	11	8	1
Other manufactures	—	—	—	—	—	—	—	—	—	—	42	54	32
Other													
Agriculture, fisheries	37	19	16	18	19	21	14	21	16	13	11	0	9
Construction	19	16	22	29	42	35	48	30	34	84	90	98	48
Miscellaneous	86	94	91	59	46	45	49	52	84	85	—	—	—
Services													
Air and sea transport	22	10	3	9	10	5	3	4	8	8	13	26	22
Retail trade	—	—	4	4	7	8	14	13	15	55	83	59	97
Auto sales	—	—	—	—	—	12	8	10	16	19	22	18	25
Transport and storage	12	5	20	23	21	20	17	17	22	22	25	30	32

Computer service	—	—	—	—	—	14	15	45	23	23	18	32	59
Trading	83	87	75	73	99	101	89	113	96	107	123	121	168
Rental and leasing	—	—	—	—	—	13	24	24	39	25	26	28	33
Finance and insurance	7	4	5	6	36	20	9	10	11	19	22	29	35
Engineering consulting	—	—	—	—	—	6	5	5	5	17	31	37	33
Advertising	—	—	—	—	—	7	5	5	3	8	5	—	4
Investment	—	—	—	—	—	21	34	52	85	54	47	67	244
Securities	—	—	—	—	—	—	—	10	4	14	22	53	197
Restaurants and hotels	6	4	4	5	7	10	10	20	14	15	22	19	35
Social service	5	5	6	7	6	4	8	11	14	14	15	—	—
Utilities	—	—	—	—	—	—	—	—	—	—	—	1	7
Broadcasting	—	—	—	—	—	—	—	—	—	—	—	—	12
Telecommunication	—	—	—	—	—	—	—	—	—	—	—	—	13
Other services	—	—	—	—	—	—	—	—	—	—	138	181	175
Total[a]	784	678	651	645	713	742	761	963	964	1017	1225	1423	2075
Total number of subsidiaries[a]	784	678	651	645	713	745	738	832	816	918	1091	1215	1944
Subsidiaries in services, %	17%	17%	18%	20%	26%	32%	32%	35%	37%	39%	50%	49%	57%

Source: Adapted from China Credit Information Service (various years), as modified and consolidated by Chu and Hong (2002).
Note: Textiles and shoes includes leather working. Agriculture and fisheries includes livestock. Finance includes leasing and installment, banking, finance and insurance, investment and holding, and securities investment. Until 1993, the "other" category includes both miscellaneous manufactures and services. After that, other manufactures and other services are listed separately.
a. These two totals differ because some subsidiaries operate in more than one industry.

Table 4.4
Distribution of national product among agriculture, industry, and services, 1958–1998

Year	Agriculture	Industry (manufacturing)	Service
1958	26.8	24.8 (16.8)	48.4
1968	19.0	34.4 (26.5)	46.5
1978	9.4	45.2 (35.6)	45.4
1988	5.0	44.8 (37.2)	50.1
1998	2.5	34.6 (27.4)	63.0

Source: Adapted from Taiwan, Council for Economic Planning and Development (various years).

In terms of the share of services accounted for by enterprises with 500 or more workers (which may or may not be a member of a business group), their average share even declined, although only slightly, from 38 percent in 1986 to 34 percent in 1996 (see table 4.6). Communications and financial services remained dominated by large-scale firms. But there was a fall in the share of such firms in services that ranged from transportation, to insurance, to publishing.

Nevertheless, the absolute number of active enterprises with 500 or more workers in services doubled between 1986 and 1996, from 174 to 361 (see table 4.6). The fixed assets per large-scale enterprise also almost doubled. Not unexpectedly, the subservices with high values of assets per worker also tended to be the subservices with either many large firms (e.g., transportation and finance) or high shares of value added accounted for by large firms (e.g., communication and broadcasting).

To get a rough idea of the degree to which large-scale enterprises converged in services with business-group subsidiaries (they were one and the same entity), we examine the top ten companies in wholesale, retail and department store trade from 1975 to 1999, the largest subsector in services (see table 4.7). Far Eastern Department Store, which consistently ranked among the top five in subservice from 1975 through 1999, was part of a group that ranked ninth among Taiwan's top 30 groups in 1999 (see table 4.8). Far East also controlled Far Eastern Enterprise, the tenth ranking retailer in 1999. The President Chain Store, which ranked first in wholesale, retail, and department store sales in 1990, 1995, and 1999, was a joint venture between the convenience-store multinational, Seven-Eleven, and the President group, whose flagship industry was processed foods.

Table 4.5
Percentage distribution of gross value added among service subindustries, 1986–1996 (%)

Service	1986	1991	1996
Commerce and trade	36.4	38.0	38.9
Wholesale trade	6.1	7.9	9.1
Retail trade	17.0	15.7	16.5
Foreign trade	10.7	11.2	10.5
Eating and drinking	2.6	3.2	2.7
Transportation and communication	23.8	18.7	15.3
Transportation	15.9	12.8	9.6
Wharehousing and storage	0.3	0.5	0.3
Communication	7.6	5.4	5.3
Financial services	22.8	25.6	26.4
Finance	17.2	17.2	16.0
Securities	0.6	2.4	1.9
Insurance	3.6	3.2	4.6
Real estate	1.5	2.8	3.9
Business services	4.2	4.9	6.0
Legal and accounting	0.5	0.5	0.7
Architecture and engineering	—	0.3	1.0
Merchandise brokerage	0.4	0.3	0.3
Consultancy	0.7	1.1	0.8
Data processing and information	0.4	0.7	0.7
Advertising	0.4	0.8	0.9
Commercial design	0.5	0.2	0.4
Rental and leasing	0.8	0.5	0.6
Other business services	0.5	0.6	0.8
Social and personal	12.9	12.9	13.5
Sanitary and pollution control	0.2	0.5	0.6
Medical and health	5.1	5.0	5.8
Publishing	0.8	1.1	0.9
Motion pictures and allied	0.4	0.2	0.2
Radio and TV broadcasting	0.8	0.6	0.7
Arts	0.0	0.0	0.0
Entertainment	0.5	0.9	1.1
Hotels and other lodging	1.8	1.3	1.1
Personal services	3.4	3.3	3.0
Total Services	100.0	100.0	100.0

Source: Adapted from census data provided by the Directorate General of Budget, Accounting, and Statistics, Executive Yuan.

Table 4.6
Value-added share in services, absolute number and fixed assets per employee, large enterprises (≥500 employees), 1986–1996

	Value added, % share			Number (absolute)			Assets per worker, NT$1,000		
Service	1986	1991	1996	1986	1991	1996	1986	1991	1996
Wholesale trade	4.0	6.4	6.3	6	13	17	601	687	1,845
Retail trade	6.2	11.0	14.3	10	39	58	438	1,077	1,305
Foreign trade	3.5	5.1	2.1	8	11	9	415	671	1,606
Eating and drinking	5.5	10.5	9.5	5	12	11	429	1,142	579
Transportation	51.8	48.0	41.9	42	44	46	3,242	5,149	8,207
Warehousing and storage	12.7	17.3	10.8	2	1	1	147	1,695	2,325
Communication	100.0	100.0	99.8	2	2	2	3,236	4,761	7,090
Finance	76.2	73.3	79.0	24	31	54	861	1,768	3,453
Securities	—	3.4	46.8	—	2	14	—	2,218	1,866
Insurance	84.9	89.3	73.1	14	27	32	652	578	392
Real estate	—	5.2	1.7	—	7	2	—	168	386
Legal and accounting	—	9.9	13.9	—	2	4	—	49	66
Architecture, engineering	—	—	17.3	—	—	3	—	—	380
Merchandise brokerage	—	—	—	—	—	—	—	—	—
Consultancy	29.2	29.0	16.8	3	5	3	262	279	—
Data processing	20.5	17.2	8.8	1	3	2	371	425	474
Advertising	—	3.1	—	—	1	—	—	61	—
Commercial design	14.1	—	—	1	—	—	139	—	—
Rental and leasing	20.5	—	—	1	—	—	669	—	—
Other business services	14.5	22.8	26.3	2	4	10	248	569	—

Sanitary and pollution	34.7	43.2	5.9	1	4	2	20	36	384
Medical and health	46.8	49.1	48.1	27	37	54	1,076	1,061	1,592
Publishing	56.6	57.4	40.5	10	12	12	663	1,034	1,347
Motion pictures	17.8	17.3	8.2	2	1	1	416	352	705
Radio and TV broadcasting	57.0	62.5	33.9	4	4	5	1,170	2,058	5,126
Arts	—	—	—	—	—	—	—	—	—
Entertainment	—	—	4.1	—	—	2	—	—	2,768
Hotels and other lodging	38.0	30.1	37.4	9	10	15	1,216	2,462	2,821
Personal services	—	2.4	4.0	—	1	2	—	1,638	4,265
Total services (average)	38%	35%	35%	174	273	361	1,678	2,050	2,921

Source: Adapted from census data provided by the Directorate General of Budget, Accounting, and Statistics, Executive Yuan.

Table 4.7
Top 10 companies in wholesale, retail, and department stores, 1975–1999

Company	Owner	1975	1980	1985	1990	1995	1999
Far Eastern Department Store		1	1	1	2	3	5
National Electric		2					
Today's Department Store		3	2	2			
Shin Shin		4	6	7			
First Department Store		5	8				
Jen-Jen		6					
Jiang Jiun Electric		7					
Shin Kong Mitsukoshi	J	8	4	5		4	3
Lai Lai Shopping Mall			3				
Chun Hsin			5				
Evergreen Department Store			7	6			
Ya Tung Department Store			9				
Asiaworld Department Store				3			
Sunrise Department Store				4	8	9	
President Chain Store	J				1	1	1
Pacific Sogo Department Store	J				3	5	4
Evergreen Tokyu	J				4		
Fen Chun Lai Lia					5	10	
Homey Department Store					6		
Hua-Tsu Cosmetics					7		
Hyper Mart					9		
China Rebar					10		
Presicarre	J					2	2
Retail Support International	J					6	
Chung Yo Department Store						7	
Far Eastern Enterprise						8	10
ACER Sertek							6
Makro Taiwan	F						7
Taiwan Familymart	J						8
JT Tobacco International	F						9

Source: Adapted from China Credit Information Service (1990, 2000).
Note: J = joint venture, where the foreign partner holds less than 50 percent equity. F = company with more than 50 percent foreign ownership. Sometimes number of rankings is less than ten.

The President group (eleventh ranking among the top 30 groups in 1999) was also the joint venture partner of Carrefour (France) in Presicarre, a superstore that ranked second in retail sales in 1995 and 1999, and the owner of Retail Support International, which ranked seventh in retailing in 1995. (President also ranked among the top ten food service companies in Taiwan given its joint venture with Starbucks, the multinational coffee-house chain.) Among the remaining top ten wholesalers and retailers in 1999, only two (Taiwan Family Mart and JT Tobacco) were *not* related to one of the big groups.

Thus, taking wholesale, retail, and department store trade as representative of services in general, there were some large independent providers. At the same time the groups played a conspicuously important and key role. Their success suggests the presence of scale and scope economies. Compared with a single-product service provider, the group enjoyed economies in the form of reputation (a large customer base and the best joint venture partners), and multiple-product marketing (lower unit distribution costs).

Diversification

The motive for diversification by a latecomer firm was always the same: reducing reliance on a mature product with a declining profit rate in the absence of sufficient technological capabilities to innovate a new product with a higher margin. Due to rapid technological change at the world frontier in the electronics industry, there were enough new products being diffused to latecomers to enable those specialized in electronics to diversify *within* that industry from older to newer product lines. The first to do so enjoyed the benefits of second-mover advantage (see chapter 2). But in groups with core businesses subject to slow global technological change (e.g., textiles, shoes, steel, foodstuffs, and petrochemicals), diversification was not necessarily confined to new product lines within the same industry (although in some cases—e.g., China Steel—it primarily was).

Thus the nature of diversification for purposes of upgrading was varied, and followed many different paths toward services. Sometimes services were related to a company's original core industry, and sometimes they were not. Sometimes they were related in terms of business skills rather than technological affinities. Sometimes services represented a major investment and sometimes just a

Table 4.8
Top 30 groups' involvement in selected services, 1999

Rank	Business group	Bank	Bills finance	Cable TV	Private power plant	Mobile phone service	High-speed rail bid	Fixed-line phone network bid
1	Lin Yuan					KG Telecom. Co., Ltd	The Chinese High-Speed Rail	
2	Formosa Plastics	Ta Chong Bank	Polyvest		Mai-Liao Cogeneration	Transasia Telecom. Inc.		
3	Shin Kong	Taishin International Bank	Tai Shin					Taiwan Fixed Network Eastern Broadband
4	Acer Incorporated					Taiwan Cellular Corporation		Taiwan Fixed Network
5	Yulon							
6	Ho Hsin		China Trust	Ho Hsin	Her-Ping	KG Telecom. Co., Ltd		New Century Infocom.
7	Evergreen	Fubon Commercial Bank				Taiwan Cellular Corporation	Taiwan High-Speed Rail	Taiwan Fixed Network
8	Lien Hwa, Mitac							
9	Far Eastern	Far Eastern International Bank	Dah Chung		Jia-Hui	Far Eastone Telecom.		New Century Infocom.

10	Philips Taiwan							
11	President		Grand		President			New Century Infocom.
12	China Steel						The Chinese High-Speed Rail	
13	Hotali-Wei Chuan							
14	Tatung							
15	Hua Lon							
16	Ching Fong							
17	Reuntex	Bank Sinopac						
18	China Rebar	The Chinese Bank	Great Chinese	Rebar				Eastern Broadband
19	Yieh Long				Miao-Li			
20	Fubon	Fubon Commercial Bank	Fubon			Taiwan Cellular Corporation	Taiwan High-Speed Rail	Taiwan Fixed Network
21	Yen Foong Yu	Dah An Commercial Bank	Dah Chung					
		Bank Sinopac						
22	Tuntex						The Chinese High-Speed Rail	

Table 4.8
(continued)

Rank	Business group	Bank	Bills finance	Cable TV	Private power plant	Mobil Phone	High-speed rail bid	Fixed-line phone network bid
23	Lite-On							Savecom
24	Pacific Wire & Cable					Taiwan Cellular Corporation	Taiwan High Speed Rail	Taiwan Fixed Network
25	Taiwan Semiconductor Manufacturing							
26	Teco					Mobitai Communication Corp.	Taiwan High Speed Rail	Eastern Broadband Savecom
27	Pou Chen							
28	China Airlines							
29	Kinpo-Compal							Savecom
30	Pacific Construction							

Source: Chu and Hong (2002).

"re-investment"—the purchase of noncontrolling equity in a firm by another firm, just as any individual would purchase such equity. Sometimes diversification and globalization went hand-in-hand, and sometimes globalization was minimal (investment in production or distribution overseas).

While heterogeneous, what characterized most major diversifications into services was exploitation by a big business group of its scale, scope, and skills. The most important skills were related to project execution (Chu and Hong 2002). In the cell phone service example, all groups built up their operating systems within a year's time, and then entered into a period of fierce price competition with each other for second-mover advantage only three months after beginning operations. Both ramp-ups and start-ups were extremely fast by world standards. Such skills and retained earnings and experience that groups had accumulated from long involvement in traditional industries gave them an advantage over new or single-product firms. When the investment scale to enter a high-tech service exceeded that of any individual group, alliances were formed among groups to pool resources, as in banking and telecommunications.

The rising incidence of diversification is suggested by the rising number of subsidiaries per business group (see table 4.9). The average number of employees per *subsidiary* stayed roughly the same in 30 years spanning 1971 through 1998, and the average number of employees per *group* rose. These two behavioral characteristics were due to the rise in *the average number of subsidiaries per group*, an indicator of diversification.

By way of illustrating the importance of old-economy assets in entering services, we now examine the diversification pattern of five of the top 30 groups that we interviewed (see table 4.8): Evergreen (seventh ranking), Far Eastern (ninth ranking), President (eleventh ranking), China Steel (twelfth ranking), and Ruentex (seventeenth ranking).

Traditional Industry's Legacy

The Ruentex group had its core capability in textiles—the owner began his career in textiles in Shanghai, and started the Ruen Hua Dyeing and Weaving Company in Taiwan in 1953 with American foreign aid. He also invested in land development.

Table 4.9
Number of employees and subsidiaries per group, 1971–1996

Year	Number of groups	Number of subsidiaries in all groups	Average number of subsidiaries per group	Employees in all groups (1,000)	Average number of employees per group	Average number of employees per subsidiary
1971	100	625	6.3	277	2770	443
1973	111	784	7.1	283	2550	325
1975	106	678	6.4	300	2830	417
1977	100	651	6.5	313	3130	481
1979	100	645	6.5	308	3080	478
1981	100	713	7.1	330	3300	463
1983	96	745	7.8	335	3490	468
1986	97	738	7.6	375	3866	524
1988	100	832	8.3	397	3970	477
1990	101	816	8.1	436	4317	529
1992	101	918	9.1	489	4842	527
1994	115	1091	9.5	577	5017	460
1996	113	1215	10.8	688	6088	556

Sources: Adapted from China Credit Information Service (various years) and Chu and Hong (2002).

Land development provided a bridge to the formation of Ruentex's first diversification, the Ruentex Construction and Development Corporation in 1977, which completed its first skyscraper with an elevator in 1983. A year later Ruentex Construction and Engineering Company was founded. In 1988, both companies developed Taipei New World, a shopping-hotel complex that generated $286 million in revenues in 1988. In 1990, Ruentex Construction and Engineering Company entered into a technical agreement with Takenaka Taiwan Company to improve its quality and lower its costs, and a year later Ruentex Construction and Development Corporation was given a 5A rating by China Credit Information Service Ltd. At about the same time Ruentex Architects and Associates was established along with RIDI Interior Design, to provide quality interior design planning and construction services. Fuh Hua Real-Estate Management started public issuance of its shares in the same year, 1991. In 1992, Ruentex Construction and Engineering Company won a national award for the best construction site management, and Ruentex Building Maintenance Company was established. In 1994, Ruentex Construction and Development Corporation completed an issue of overseas convertible bonds, laying the foundation for global expansion. In 1995, Ruentex Construction and Engineering Company signed another consultancy agreement, this one with Schal Bovis to upgrade knowledge on construction management such as design review, value engineering, project management, and procurement strategies. Runhong Engineering Company was established, and a technical cooperation agreement was signed with Partek Corporation of Finland to develop precast concrete technology in design and construction.

As Ruentex was upgrading its construction capabilities, it was also modernizing its textile operations. It expanded its new Yangmei plant and introduced new types of weaving and related equipment in 1994, as well as upgrading production efficiency and product quality through computer automated production processes. Ruentex's textile affiliate began to try its hand in retailing when in 1993 it obtained Taiwan's exclusive rights to sell Nautica products.

Finally, in 1996, Ruentex founded RT-Mart International to engage in distribution, wholesaling and retailing in Taiwan and China. The model was the American retailer Costco, a type of mass wholesale warehouser. After Ruentex opened its first RT-Mart, and bought out two other stores, it quickly ramped up to a total of 16 outlets in Taiwan. In the category of superstores, it soon ranked second to Presicarre (it does not appear in table 4.7 because of its accounting procedures). In 1998, it opened its first RT-Mart in Shanghai, China. By 2001, eleven outlets were operating in China.

Entry into retailing involved a large investment, since a minimum number of stores was necessary to acquire brand-name recognition and good vendor services. Speed was essential to get stores operational as soon as possible. Toward both ends—finance and time to market—the textile business and construction and engineering arm of Ruentex played a key role:

> The rapid growth of RT-Mart International should be attributed to the full support from Ruentex Construction and Engineering Co., and Runhong Engineering Company, during the construction of the store, as well as the financial support from Ruentex Industries Ltd. and Ruentex Construction and Development, the two listed companies of the group, the support from all affiliated businesses and the know-how and experience of the professionals from the group . . . RT-Mart International is a 100% "local" business, with the correct operation philosophy and efficient management model; the room for further development is limitless (Ruentex, *Annual Report*, 1998, p. 41).

By the year 2000, out of Ruentex's total sales of around $5 billion, roughly 10 percent came from textiles, 8 percent from construction, and nearly 25 percent from retailing.

The tight connection between the old economy and retailing in the evolution of Ruentex was not unidirectional; soon retailing began to bail out construction. Ruentex agreed to sell the French company, Auchan, a 67 percent share of RT-Mart Taiwan (not China) over a four-year period allegedly to give Ruentex enough cash to help its troubled construction arm (*United Daily News*, December 23, 2000).

In any event, a whole other diversification path, in addition to the one that led to retailing, was being pursued by Ruentex simultaneously, in which the old economy played only a small part. It was centered on finance. With the proceeds from textiles and construction Ruentex founded the Kwang Hua Securities Investment and Trust Co in 1985. A year later Kwang Hua launched the Formosa Fund in London, which became the first mutual fund for foreigners to invest in Taiwan companies. With this connection Ruentex became the minority joint venture partner in 1987 of Aetna, the second foreign life insurance company allowed to operate in Taiwan. In 1992, Ruentex became an owner of Bank Sinopac and invested in the China Development Corporation.

By 2000 insurance accounted for 30 percent of Ruentex's revenues and commercial banking accounted for another 15 percent. Besides being the most profitable part of Ruentex's portfolio, *investments in finance enabled Ruentex to understand the financial side of many different businesses*, which helped diversification through re-investments. Soon Ruentex's re-investments numbered as many as 32 (see table 4.10).

Historically the Ruentex group was well connected with Taiwan's long-ruling political party, the Kuomintang (KMT). Aetna, Ruentex's joint venture partner, was reputed to own a small share in the KMT's investment fund. The KMT was a main shareholder in Bank Sinopac and the China Development Corporation, in which Ruentex held stakes. Nevertheless, the success of Ruentex was not merely political. Some considered it the most professionally managed of all Taiwan's groups. Even in the 1980s it claimed to have the highest number of managers with MBA degrees. Its owner, Yin Yen-Liang, said in repeated interviews that he attributed his company's success to his top professional managers, in whose decision making he did not interfere (Tsai 2000).

Like Ruentex, the Far Eastern Group got its start with American foreign aid in textiles. But from textiles Far Eastern initially diversified into apparel and synthetic fibers (and later into retailing). At the time a new process to manufacture synthetic fibers had just come on stream, and the owner of Far Eastern made the correct bet that the new technology would become dominant. The scale of Far Eastern's chemical plant was large by Taiwan standards but tiny by world standards, and Far Eastern only succeeded because it became very good at producing different chemicals in small lots. From chemicals, Far Eastern diversified into cement and then into construction. Finally, like Ruentex, Far Eastern used its capabilities in construction to diversify into services. According to the chairman and CEO of the Far Eastern group, Douglas Tong Hsu, he spent three years of his life overseeing the construction of an elegant, high-rise building that included a department store and hotel, and expanded his group's ventures in real estate.

The President group as well had a construction arm (Tone San Construction) that aided it in establishing its various retailing outlets (joint ventures with Seven-Eleven, Carrefour, Starbucks, its own cosmetics chain, its acquisition of 21 Century Best Foods, modeled on Kentucky Fried Chicken, and its own furniture store chain). But additionally President's diversification into services was highly synergistic with its core competence. The food chain extended from plantations, to food processing, to distribution (wholesale and retail). Since processing is typically done near the consumer, President had begun to establish distribution networks early in its history as an adjunct to its main food-processing business. Its entry into retailing of its own processed foods—from milk to meat, instant noodles to instant coffee, beverages to frozen foods—was a natural extension of this activity. But retailing, both in Taiwan and in China, became an increasingly central aspect of President's business, as President anticipated that Taiwan's entry into the WTO would render food processing in Taiwan uncompetitive (President estimated that the manufacture of instant noodles, for example, cost about 80 percent in China what it cost in Taiwan). By 2000, food processing represented only 40 percent of President's assets.

President made very large investments in both food processing and distribution in China—diversification and globalization were intimately bound. In the case of its First Food Division (mostly packaged foods, including noodles and breakfast cereals), by the late

1990s President had invested in processing facilities in Beijing, Tianjin, Wuhan, Kunshan, Chengdu, Guangzhou, Shenyang, and other cities in mainland China, as well as in Indonesia. Retailing outlets had already been established in China's largest cities, and were in the process of being established in its second-tier cities. Marketing channels were considered key to competitiveness in food processing. The more products, and the higher the quality of distribution networks in terms of location and service, the better the returns from marketing.

By 1998 President's total investment in China was around $US1.1 billion, estimated to be the largest of any single Taiwan company. Around 40 percent of President's revenues came from China. Its business strategy had become to develop a core competence in food chain logistical management—financing in one country, acquiring raw materials from plantations in another country, processing in still another country, and distributing (wholesale and retail) worldwide.

The diversification of the Evergreen group was also highly synergistic. In 1968 Evergreen's founder bought used cargo vessels with a loan from the Japanese trading company, Marubeni. Evergreen's breakthrough was leveraging its investments in emerging-economy markets. It was the first to offer long-term shipping service from Asia to the Middle East at a time when trade with the Middle East began to boom. It learned its business in these "soft" markets and then went global.

Evergreen became highly diversified in relationship to maritime shipping. It began to build its own containers, first in Taiwan, then in Malaysia and China. It acquired a Japanese shipyard and began to build some of its own vessels. It entered into ship repair and even invested in a hotel chain in East Asia.

Its big departure from maritime trade came in 1988 when Taiwan's Ministry of Transportation announced an "open skyways" policy. Evergreen founded EVA Airlines, to serve the Taiwan internal market and then to serve various routes from Taiwan to the rest of the world. Evergreen exploited its old-economy capabilities in maritime cargo transport to manage EVA. Roughly 45 percent of EVA's business was air cargo transport, which by world airline standards is a very high share compared with passenger service.

China Steel entered services largely through re-investments, using the capital it had acquired in its traditional sector, steel, in which it had accumulated experience to produce steel efficiently by world standards over the course of 25 years. Diversification took the form of creating “more orderly” steel markets through takeovers of other steel companies engaged in severe price competition. At a board meeting in 2000, approval had been granted for China Steel to acquire a 25 percent stake (to be raised to 30 percent) in Taiwan’s second largest steel mill, Yieh Loong Enterprise, which suffered from insufficient integration and hence input supply problems. The takeover (China Steel controlled two out of three seats on its board of directors) promised lower capital costs and higher productivity. China Steel had also bought a carbon steel company directly from its owner, which represented a new market segment within the steel industry. Diversification increased with privatization (as a private company, China Steel no longer had to send its budget to the Congress, although the Ministry of Economic Affairs still owned 40 percent of its equity, controlled 6 out of 11 seats on its board, and had to approve all its diversifications). All together, China Steel had established or acquired 14 subsidiaries related to steel making.

Among China Steel’s noncore-related holdings were the 100 percent-owned subsidiaries Gains Investment Corporation and China Propsperity Development Corporation. The latter was designed to develop, with government involvement, a local science type park in Kaohsiung, Taiwan’s southern industrial city. In 1994 China Steel co-founded Taisil Electronic Materials Corporation with the American firm Memc. The new company produces silicon wafers. China Steel’s most recent and largest investment was taking charge of the construction of the Kaohsiung subway system, in partnership with Siemens (Germany). CSC holds a 35 percent share in the project.

China Steel’s big worry, however, became competition in its core business from the China mainland. It planned to collaborate with China’s premier steel company, Baoshen, to develop complementary production facilities in China.[4]

Thus diversification patterns of the five big groups just examined were diverse, but all capitalized on experience and competencies derived from the old economy. Big business groups in the past may have been well-connected politically, but those we examined were also well-managed. Through exploiting their core capabilities and retained earnings, they overcame declining profit margins in their traditional industries and entered services, some in a very big way.

Nonorganic Diversification

Whatever the group-specific mode of diversification, the move from the old economy into services typically involved every major group in some degree and form of *acquisition*, *re-investment* or *alliance* with another group. These methods of expansion were "nonorganic" because they did not involve a group in creating, single-handedly, a new subsidiary de novo.

Acquisitions

Taiwan's laws were generally unfavorable to mergers and acquisitions (M&As), although the interpretation of such laws by the courts varied by time period (Chang 1992). Most CEOs emphasized the difficulties of diversifying by buying other companies, especially healthy ones. Based on partial data, it seems that most major mergers and acquisitions in Taiwan for the period 1986 to 2000 occurred in electronics and computer services (see table 2.29). Nevertheless, the expansion and diversification of four of the five major business groups examined above involved an M&A of one form or another at one stage or another of their growth.

In 1976 Ruentex Industries grew out of a merger between the Hua Hsin Textile Company and the Ruentex Textile Dyeing Company. Much later, as noted above, Ruentex expanded the number of its RT-Marts by buying two existing retailing outlets. The President group got into fast foods by buying 21 Century Best Food, a competitor to Kentucky Fried Chicken. President also bought the Taiwan subsidiary of Wang Computer, which ultimately went bankrupt. In the case of Evergreen, its entry into the airline business involved buying shares in three domestic carriers, Great China Air, Taiwan Airways, and Uni Airways, which all merged under the Uni Airways banner in 1998. China Steel acquired other steel mills as well as an aluminum mill (at government prompting) through acquisition. Among the electronics companies examined in chapter 2, seven had expanded by buying *foreign-owned* subsidiaries, some operating in Taiwan (Delta, Acer, Inventec, Btc, D-Link, TSMC, and Realtek). The "de-globalization" of the electronics industry in Taiwan (reduction in the importance of local foreign firms) partly took the form of national firms acquiring foreign ones.

As exemplified by President's unprofitable acquisition of Wang, hardly all M&As in Taiwan were successful. But some clearly aided the expansion and diversification of second movers.

Re-investments

The most popular way for Taiwan companies to diversify nonorganically was through "re-investment," or buying noncontrolling shares in other companies.[5] Leading companies outside Taiwan, in OECD countries, may or may not engage in similar activity, but re-investment appears to have been more pronounced in Taiwan than elsewhere.

The mode of diversifying through re-investment gained momentum in Taiwan with the electronics boom. Many groups missed out on that boom because their timing was off or their knowledge-based assets were insufficient to enter the electronics sector through establishing a subsidiary from the ground up. Re-investment was designed to correct this by enabling a firm to share in the profits (losses) of the electronics sector without having to share in the management. The mode of diversifying through re-investment gained additional momentum as groups bought into finance companies, especially venture capital companies, which then provided them with information on other firms' profitability and thus facilitated further re-investment.

Re-investment may be analyzed in terms of information. Where a company's information is insufficient to enter a growing industry directly, it will try to capture the high returns of such an industry through re-investment. Successful re-investment itself requires information, and where such information is plentiful (through access to industry-specific or financial data), re-investment will also tend to be frequent.

Table 4.10 provides statistics on the number of re-investments of the companies we interviewed. These statistics are not necessarily generalizable to other Taiwan firms, but the high number of re-investments per company is striking, whatever the company's core industry or overall size (re-investments themselves vary in size, and clearly vary in terms of equity ownership—table 4.10 distinguishes between re-investments with/without 10 percent or more equity). High re-investment rates characterize the business groups with a specialization in electronics (Acer, Tatung, and Teco). In terms of information, all three groups had inside knowledge about the electronics industry, which facilitated their re-investing into new start-ups or companies just going public in that sector. The rate of re-investment was low for notebook manufacturers (Inventec and Quanta) and was zero in the case of Z-Com, a new company. Presumably in the period before 2000, the capital of these companies

Table 4.10
Re-investments, circa 2000

Company	Number of re-investments (A)	Number with >10% equity (B)	Percentage (B/A)
President	70	53	76
Tatung	67	42	63
Acer/API	62	46	74
Teco	52	31	60
Formosa Plastics	33	25	77
Delta	32	16	50
Ruentex	32	21	66
Accton	29	14	48
Cathay Life	27	6	22
Far East	25	17	68
China Steel	22	15	68
Lite-On	22	10	45
GVC	21	17	81
USIFE	21	14	67
D-Link	18	5	28
BTC	17	11	65
Evergreen	16	8	50
Realtek	16	7	44
Inventec	12	10	83
MTI	8	5	63
Z-Com	0	0	—
TSMC	19	16	84
Quanta	22	11	50
Average	28.2	18.1	60

Sources: Company data.

was tied up in internal expansion. There also appears to be a close relationship between the number of a company's re-investments and the number of its re-investments with equity greater than 10 percent—the simple correlation coefficient between the two was estimated to be 0.95.[6] Given Taiwan's restrictive company laws, re-investments became a popular mode of diversification.

Alliances

Like the high-tech electronics products that Taiwan's second movers were competitive in producing, the high-tech services they were competitive in providing were already mature by the time Taiwan began to liberalize them. As maturity suggests, there were no impenetrable technological barriers to entry. Moreover, just as the opening of a "new" high-tech electronics industry in Taiwan attracted many entrants, so the liberalization of services, and the relatively few formal limitations that the government stipulated for entry, attracted many early entrants. But entry into some high-tech services typically involved more capital than entry into most electronics markets (barring semiconductors, which were produced initially by state-owned firms). An estimate of the costs in 1996 of a license for a national cell phone service provider was US$218 million (Chen 1997). In 2001, four third-generation mobile phone service licenses varied in estimated value (depending on the assumptions) from US$524 million to US$2.2 billion (Nomura Securities 2001). Given these nontrivial investment thresholds and the high risk of failure due to multiple entry, new entrants into high-tech services—such as cell phone telecommunications, banking and high-speed rail—all tended to involve business consortia.

Alliance partners in cell phone telecommunications, banking, and high-speed rail are identified in tables 4.11, 4.12, and 4.13 respectively. The shareholders tend to include many of Taiwan's biggest business groups. Yuang Ding Investment, for example, the largest shareholder of Far Eastone Telecommunications, is a holding company of the Far Eastern group which, as noted above, got its start in textiles and also diversified into retailing. Most of the top 30 business groups became involved in at least one type of high-tech service (see table 4.8).

As competition grew fierce, conditions of overcapacity resulted. In turn, overcapacity created the impetus for consolidation through merger and acquisition. In the case of cell phones, whose service had been liberalized in 1996, by 2001 one major operator (Taiwan Cellular Corporation) had acquired another major operator (Trans Asia Telecommunications). Far Eastone was also expected to acquire Mobitai.[7] Thus anyone looking ten years from now at Taiwan's cell phone telecommunications market in 2001 would probably see only two or three big consortia operating, each including the largest business groups. Biggness was a determining factor in survival insofar as Trans Asia, the acquired firm, and Mobital, the firm expected to be acquired, were the smallest (measured by total assets) of the five initial competitors (see table 4.11). Nevertheless, it would be wrong to equate high concentration and biggness with inefficiency.

Table 4.11
Cellular phone service industry, major shareholders, 1997

Company/shareholders	Stock share, %
Taiwan Cellular	
Pacific Electric Wire & Cable	10.0
Dentsu Investment	17.5
Fubon Life Insurance	4.5
Fubon Insurance	0.9
Acer	10.0
Acer Peripherals	5.0
Yageo	5.0
Evergreen Heavy Industries	5.0
Continental Engineering	7.5
US GTE	12.0 (F)
Total asset index	100
Trans Asia Telecommunications[a]	
Tai Ya Investment	50.0
Speed Investment	15.0
Shiang Investment	6.0
Yang Investment	9.0
Southwestern Bell	20.0 (F)
Total asset index	29
KG Telecommunications	
Taiwan Cement	20.0
China Synthetic Rubber	10.0
China Life Insurance	5.0
China Trust Investment	5.0
TECO	8.0
MTI	5.0
Cathay Life Insurance	5.0
Bell Canada[b]	10.0 (F)
Total asset index	54
Far Eastone Telecommunications	
Yuang Ding Investment	62.4
Hwa Kai Leasing	8.0
Chiao Tung Bank	4.0
AT&T	12.0 (F)
Total asset index	144

Table 4.11
(continued)

Company/shareholders	Stock share, %
Mobiltai Communication	
TECO	38.0
China Steel	20.0
Fen Chun Lai Lai Department Store	20.0
Tecom	5.0
Cains Investment	5.0
Sumitomo	12.0 (F)
Total asset index	29

Sources: Company balance sheets and prospectus as of December 31, 1997
Note: F = foreign-owned. Total asset index: 100 is assigned to Taiwan Cellular Corporation, and the size of the total assets of the other companies are indexed accordingly.
a. Bought out by Taiwan Cellular in May 2001.
b. Withdrew in August 2000. NTT DoCoMo bought 20 percent of KG's shares in November 2000.

The early stages of the cell phone service industry in Taiwan, like the early stages of most electronics subindustries, were marked by intense competition. This competition appears to have induced "industrial upgrading and technological innovation" in tandem with consolidation and concentration (Chen 1997, p. 99).

Government-Led Networking: Services

The consortia of big business groups operating in Taiwan's high-tech service industries may be regarded as "networks" of a sort. They are not based on anonymous market forces but rather on profit-maximizing behavior-cum-personal-ties. Nevertheless, they are unlike networks in advanced countries in at least one critical respect. They are led by the government to an unusual degree, just as networks are led by the government in the electronics industry.

Whereas Taiwan's networks in the electronics industry were led by the "developmental" state (as promoter of science and technology), those in the high-end service industries were led by the "regulatory" state. Like the regulatory states in advanced economies, the Taiwan government influenced services through its rules related to licensing (entry) and pricing. But the regulatory state in Taiwan had a much bigger impact on entry than the regulatory state in most

Table 4.12
Taiwan's new 15 banks, 1992

Bank	Main group	Capital, NT$10 mil	Other groups
Dah An	Walsin Lihwa	100	Pacific, Sampo, Kolin, I-Mei. USIFE
Cosmos	Prince	120	Lucky Cement, China Man-Made Fiber, Tah Tong Textile, Shih Lin Paper, San Fu Motors
Far Eastern	Far Eastern	100	Oriental Union Chemical, Asia Cement, Lealea Net, San Fang Chemical, Taiwan Wacoal
Ta Chong	Chen's Group; Formosa Plastics	105	Kuan Ho, Formosa Chemicals, Nan Ya Plastics, Formosa Plastics
Asia Pacific		100	Taichung Business Bank, ADI
Chung Shing	Wang's Group	135	Hua Eng, Lily Textile
Grand Commercial	Tainan Group	126	Tung I Investment, Universal Cement, Tainan Spinning
E. Sun Commercial		100	Tidehold, Tung Ho Steel, Eagle Holding, Lite-On, Guo Sheng, Hsin Tung Yang
Union Bank	Union	120	AGV Products, Tian Hau Construct.
SINOPAC	KMT	100	Central Investment Holding, Chien Hua, Chii Sheng Industrial, Tuntex Intl., Ruentex, Fen Chun, Formosa Taffeta, South East Soda, Hong Kuo Invest.
Baodao Commercial	Jisun	100	Yakult, Era Audio & Visual, Kuan Yuan Paper
Fubon Commercial	Fubon, Evergreen	100	Chia Hsin Cement, China Times Publishing, Kwong Fong, Mercury & Assoc.
Chinese Bank	China Rebar	100	Chia Hsin Flour
Pan Asia	Ever Fortune	100	
Tai Shin	Shinkong	100	Weichuan Foods, We Wong, TECO, Tung Ho Steel, Cota Commercial Bank

Source: Adapted from Kao (1992) and *Wealth Magazine* (1991).

Table 4.13
Participants in Taiwan's high-speed rail project, 1999

	Taiwan high-speed rail	Chinese high-speed rail
Local main groups	Continental Engineering Corp.	China Development Industrial Bank
	Evergreen Group	RSEA Engineering Corp.
	Fubon Group	Kwang San Group
	Pacific Group	Hung Kou Group
	TECO group	Lin Yuan Group
	(Each holds 16% share)	Tuntex Group
		China Steel Corp.
		Walsin Lihwa Corp.
		(each holds 7.5%)
Foreign groups	GEC Alsthom (France)	Japan National Railway
	Siemens (Germany)	Mitsubishi Heavy Industries Mitsui
	(Switched to Japan Shinkansen System in 1999)	Kumagai Gumi
System to be adapted	Originally: ICE (Europe); Now: Shinkansen	Japan Shinkansen System

Data Sources: *United Daily*, 1997/9/1, 1997/9/25; and *High Speed Railway Newsletter*, 2000/7/28, 2000/12/3, 2001/1/30, at *http://www.hsr.gov.tw/.*
Note: Taiwan High-Speed Rail Co. won the contract in 1998. It later switched its partner and adopted the Japanese Shinkansen System at the end of 1999.

advanced economies, particularly the United States. It imposed more stringent restrictions on *foreign* entry, particularly in the early phases of a service industry's modernization. Through 2000, foreign participation in one of Taiwan's cell-phone service companies was limited to 20 percent (see table 4.11). Foreign banks could engage in some types of business but, until 1990, were not allowed to accept local deposits.[8] Foreign builders of Taiwan's high-speed rail were required by their client, the Taiwan government, to include national firms as joint venture partners or collaborators. Foreign real estate companies could not speculate in land and foreigners in general faced other restrictions on land ownership (Lee 2001).

Restrictions on foreign investment in services were later selectively lifted under pressure from the United States and from the need for Taiwan to comply with World Trade Organization law in order to become a WTO member. *But government restrictions on foreign investment in services in the early stages of market opening (at minimum, the first four or five years) allowed nationally controlled firms to capture second-mover advantage.*

Table 4.14
Foreign share in the top 500 firms in manufacturing and nonmanufacturing, 1990–1999 (%)

	Manufacturing		Nonmanufacturing	
Year	Sales	Employment	Sales	Employment
1990	17.4	17.8	6.8	12.1
1991	17.1	16.0	9.5	13.3
1992	15.5	14.4	10.2	14.9
1993	16.3	15.6	9.8	16.5
1994	15.5	15.9	9.8	14.4
1995	15.9	15.0	11.3	15.5
1996	15.0	14.4	14.3	18.9
1997	15.0	13.5	13.6	13.4
1998	15.3	12.8	15.0	13.8
1999	14.7	12.0	16.6	15.3

Source: Adapted from China Credit Information Service (2000).

Foreign Direct Investment

The decline in the importance of foreign direct investment in the electronics industry reflected a general tendency toward decline in FDI in the whole manufacturing sector. In 1990, foreign firms accounted for 17.4 percent of the sales of Taiwan's top 500 manufacturing companies. By 1999, they accounted for only 14.7 percent (see table 4.14). In contrast, their share over the same time period rose in services. It started in 1990 at a mere 6.8 percent and then climbed to 16.6 percent in 1999 (see table 4.14). The highest percentage in services, in 1999, exceeded that in manufacturing in any year after 1991.

The predilection over time of foreign firms to invest in Taiwan's service sector rather than its manufacturing sector is borne out by statistics on *approved* foreign direct investment in different industries (not all approved investments, however, actually materialize). In the period 1952 through 1979, manufacturing on average attracted three-quarters of all foreign investment. As the demand for services rose, and services began to be liberalized after 1986, the share of manufacturing fell to about two-thirds. That of services rose to one-third, from only around 17 percent in 1952-79 (see table 4.15). Presumably this shift in the focus of foreign investors reflected the opening of Taiwan's service markets, and the growing specialization in services by foreign investors worldwide.

Table 4.15
Approved inward foreign direct investments, by industry, 1952–1995 (%)

Industry	1952–1979	1980	1985	1990	1995
Manufacturing	75.5	93.3	77.0	62.8	67.5
Services	17.3	5.1	22.2	35.0	30.6
Trade	0.3	0.2	0.7	12.3	9.2
Transport	1.9	0.7	0.6	1.7	5.8
Financial	4.3	0.9	13.9	13.7	8.9
Food and other	10.7	3.3	7.0	7.3	6.7
Total	100.0	100.0	100.0	100.0	100.0

Source: Adapted from Taiwan, Ministry of Economic Affairs (various years [e]).

Table 4.16
Top 10 companies in advertising, 1999

Company	Owner	Rank
Dentsu	F	1
J. Walter Thompson	F	2
Hwa Wei & Grey	J	3
United Advertising		4
Ogilvy & Mather	F	5
Saatchi & Saatchi	F	6
H&Y Communication	F	7
McCann-Erickson	F	8
FCB Taiwan	F	9
Leo Burnett	F	10

Source: Adapted from China Credit Information Service (2000).
Note: F = company with more than 50 percent foreign ownership; J = joint venture with a foreign company, where the foreign partner holds less than 50 percent equity.

The share of sales and employment accounted for by foreign investors varied depending on the service (see table 4.5 for the relative importance of different services). In the wholesale, retail, and department store subsector, national firms or joint ventures were predominant (see table 4.7). In advertising, by contrast, foreign firms were overwhelmingly predominant among the top ten, although this service accounted for less than one percent of total value added (see table 4.16). In securities, foreign firms were almost nonexistent. In food service, the top two spots starting in 1990 were foreign fast-food chains (McDonald's and Kentucky Fried Chicken). But local firms were among the top ten runners-up (see table 4.17). There were

Table 4.17
Top 10 companies in food service, 1988–1999

Company	Owner	1988	1990	1996	1999
Quanta Foods		1			
Birdland (KFC)[a]	F	2	2	2	2
Wendy	F	3	3		
Ten Ren (Hardy's)	F	4	4		
National Office		5	5	3	10
McDonald's	F		1	1	1
China Rebar				4	
China Pacific Catering					3
Chao-Chee Foods					4
Evergreen Sky Catering					5
Home Chain Food					6
21 Century Enterprise					7
Dante Coffee					8
President Coffee[b]	J				9

Source: Adapted from China Credit Information Service (1990, 2000).
Note: F = company with more than 50 percent foreign ownership; J = joint venture with a foreign company, where the foreign partner holds less than 50 percent equity.
a. KFC = Kentucky Fried Chicken.
b. Joint venture with Starbucks Coffee.

almost no foreign companies in property and casualty insurance, but foreign firms gained ground in life insurance (see table 4.18). In computer services, foreign and national companies vied over time for top slots (see table 4.19).

Thus the importance of foreign firms in services varied by subsector. Overall, foreign firms gained ground during the 1990s in the sales of Taiwan's top 500 service providers, just as they lost ground among its top 500 manufacturers (see table 4.14). By international standards, however, what is striking about Taiwan is the relatively small share of foreign firms in every major sector, whether manufacturing or services (or agriculture, for that matter). Despite American pressure for market opening in Taiwan, despite political pressure within Taiwan for liberalization, and despite the fact that the 361 largest service providers accounted for 34 percent of total service value added in 1996, the share of foreign firms in the sales of the top 500 service companies amounted to only around 17 percent.

Table 4.18
Top 10 companies in life insurance, 1975–1999

Company	Owner	1975	1980	1985	1990	1995	1999
Cathay Life		1	1	1	1	1	1
Shin Kong Life		2	2	2	2	2	2
First Life		3	6	6			
Nan Shan Life	F	4	3	4	4	3	3
Overseas Life		5					
Kuo Hua Life		6	4	3	3	4	4
Taiwan Life			5				
China Life			7	5	5	6	6
Aetna Life of America	F				6	5	5
Prudential Life	F				7	8	9
Mercuries Life						7	8
Fubon Life						9	7
Metropolitan Insurance	F					10	
Far Glory Life							10

Source: Adapted from China Credit Information Service (1990, 2000).
Note: F = company with more than 50 percent foreign ownership.

Consolidation and Concentration

As entry into liberalized services increased and created excess capacity, the preoccupation of business groups turned from diversification to consolidation, as we saw in the case of cellular phone service. Simultaneously, certain of the more mature services began to exhibit (or continued to exhibit) high concentration (share of output accounted for by the largest firms). The tendency toward high concentration after (or during) a period of intense competition paralleled a similar tendency we observed earlier in the electronics industry (see chapter 2).

The data on concentration in Taiwan's service sector are limited to only a few markets, in a very limited number of years: convenience stores, super stores, life insurance, and securities. The norm in the late 1990s appears to have been either high or rising concentration. In convenience stores and super stores,[9] the share of the top four companies was around 75 percent (see tables 4.20 and 4.21). In two years the four-firm concentration ratio in convenience stores rose from 66 to 75 percent. These shares may alter in the future, but once a retail chain has attracted customers and has attained a large scale, it enjoys economies related to brand-name recognition, location, and

Table 4.19
Top 10 companies in computer services, 1985–1999

Company	Owner	1985	1990	1995	1999
Acer Sertek		1	2	4	
First International[a]		2			
China Computer		3			
Syscom Computer		4	8	10	
EDP Taiwan		5			
Fortune Information		6		8	
NCR Taiwan	F	7			
Systex		8	6	7	7
Aurora System		9	7		
Tatung Chinese Character		10			
IBM Taiwan	F		1	3	3
NEC Taiwan	F		3	2	4
Taiwan Fuji Xerox	F		4	6	8
Qware Systems			5		
Well-Meaning Computer			9		
Ability Enterprise			10		
Fujitsu Taiwan	F			1	5
Synnex International				5	1
China Data Processing				9	
Samsung Electronics	F				2
Onking Chain Store					6
Eastern Multimedia					9
Elitetron Electronic					10

Source: Adapted from China Credit Information Service (1990, 2000).
Note: F = company with more than 50 percent foreign ownership.

Table 4.20
Market shares (% of sales) of top four convenience stores, 1997–1999

Convenience store	1997	1998	1999
7-11[a]	36	39	42
Family Mart	12	14	14
Life	11	11	11
OK	8	4	8
Other	34	32	25
Total	100	100	100
CR (4)	66	68	75

Source: Adapted from *Wealth Magazine* (2000).
a. Owned by President group, which holds a franchise of 7-11.

Table 4.21
Market shares (% of sales) of top 4 super stores, 1998 and 1999

Super store	1998	1999
Carrefour[a]	30	31
RT Mart[b]	13	19
Makro[c]	18	14
Far Eastern[d]	19	9
Other	29	27
Total	100	100
CR (4)	71	73

Source: Adapted from *Wealth Magazine* (2000).
Note: CR (4) = share in sales of the top four companies.
a. Presicarre Stores is a joint venture between President Enterprise and French Carrefour.
b. RT Mart was owned by Ruentex and is a joint venture with the Fen Chun group.
c. Makro is a joint venture between a Dutch super store and the Fen Chun group.
d. A subsidiary of the Far Eastern group.

Table 4.22
Market shares (% of new contracts) of top 4 life insurance companies, 1997–1999

Company	1997	1998	1999
Cathay Life	29	29	23
Nan-shan	16	16	18
Shin Kong	16	14	14
Aetna	6	7	10
Other	33	34	35
Total	100	100	100
CR (4)	67	65	65

Source: Adapted from *Wealth Magazine* (2000).

procurement. In the case of life insurance, the concentration ratio between 1997 and 1999 remained at around 65 percent despite new American entrants (see table 4.22). Concentration in the late 1990s in Taiwan was lower in the securities market than in the insurance market (see table 4.23), presumably because the securities market was less sensitive to brand-name recognition, younger, and experiencing fluctuating growth. On the other hand, the securities market was more likely to experience consolidation than the life insurance business, most of whose players, national and international, were already established and large scale.

Table 4.23
Market shares (% of new contracts) of top 6 securities companies, 1997–1999

Securities company	1994	1995	1996	1997	1998	1999
Yuanta	4.0	5.2	5.5	6.3	5.9	5.6
Jih Sun	4.3	4.4	4.3	4.6	4.3	4.1
Jing-hua	1.8	1.8	2.1	2.7	3.6	3.5
Capital	2.2	2.7	3.2	3.5	3.4	3.3
MasterLink	1.5	1.6	1.9	2.5	2.9	3.2
President	3.3	3.7	3.7	3.9	3.0	3.0
Other	82.9	80.7	79.3	76.6	76.9	77.3
Total	100	100	100	100	100	100
CR (6)	17.1	19.3	20.7	23.4	23.1	22.7

Source: Adapted from *Wealth Magazine* (2000).

Conclusion

Latecomer upgrading in the service sector shared many characteristics in common with latecomer upgrading in high-tech manufacturing, although with variations around a theme.

In both cases the opening of a new market was the trigger for upgrading. The first firms to invest in large-scale facilities, modern management, technological know-how and distribution (in services only) enjoyed second-mover advantage. In both cases prior experience mattered. Major players in retailing, finance, insurance, transportation (airlines and high-speed rail), and cellular phone service emerged out of the business groups that had gotten their feet wet in the old economy. They established new service subsidiaries using their accumulated capital and project execution skills and increased their overall share in GNP. This controversial form of enterprise therefore proved itself to be viable at least in the early stages of the new service economy. In both manufacturing and services, as the number of entrants rose and demand became saturated, there began a process of consolidation and rising concentration. By 2000 this was just becoming evident in services.

Networks were also important in both cases, but the networks in electronics were focused on supplying parts and components to assemblers, whereas those in services were focused on pooling financial resources among the biggest groups. Both types of networks were state led, although the nature of state intervention differed. In electronics, the *developmental* state promoted import substitution, science, and technology. In services, the *regulatory* state limited the operations of foreign firms in the early stages of a service's liberalization.

What differed most was the pattern of foreign investment. Foreign direct investment from advanced economies in the electronics industry started with a high share of total output that declined sharply over time, whereas the reverse pattern prevailed in the service sector, partly in response to later market opening. The rising share of foreign service providers also reflected the economic power of their global brand names. To achieve equally valuable reputations, Taiwan's national service providers pinned their hopes on expanding in the giant China market.

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5 Policies for Upgrading

Our study has shown that standard theories of the firm have to be adapted to explain latecomer upgrading. Without adaptation it is difficult to grasp past government policies that promoted latecomers' high-tech industries, or future policy directions that are needed to push them further along. A class of "network" theories posits that latecomer upgrading will be led by thousands of small specialized firms that create cutting-edge skills through jointly developing new technologies and forming bonds with foreign networks, whose entrepreneurs share the same ethnicity or culture as their own. But such theories fail to capture the reality that even within latecomers' most "networked" sector, electronics, most transactions are arm's-length. "New" commercial technology is typically generated by government research centers and the lion's share of output is accounted for by large firms (with sales in the hundred-millions or billions of dollars), not small ones. To the extent that existing theory postulates that upgrading will be led by big business, exploiting the intellectual property of its corporate R&D, its global brand name, and its worldwide distribution channels, as does "first-mover" theory, then it too fails to capture reality. Most latecomers' high-tech sectors are characterized by the production of mature products and the inability to create brand-name recognition in foreign markets. In liberal mainstream theories the heroes of economic development are foreign investors and market forces. But these theories overlook the fact that in the fastest-growing latecomers, high-tech industries tend to be dominated by nationally owned firms, and governments continue vigorously to promote such firms as well as "new" high-tech market segments.

In fact the experience of Taiwan in both electronics and modern services strongly suggests that as latecomers upgrade, they begin to look increasingly like advanced economies insofar as their nationally owned business enterprises become larger in scale and more global in scope, and their markets become more concentrated. Given these similarities, "first-mover advantage" probably comes closest to the mark among other frameworks in describing the reality of catching up. Nevertheless, Taiwan also suggests that being behind the world technological frontier and producing mature, "high-tech" products with falling profit margins are the ingredients with which to theorize about upgrading. They are the starting point to comprehend why the institutions and government policies of latecomers have differed and continue to deviate from those of economies at the frontier.

By way of concluding our study, therefore, we turn to policy. We briefly review major differences between first and second movers and their respective networks. Then we summarize how policy in Taiwan has differed from advanced-country norms, and why new aberrant policies may be warranted in the future. Finally, we explore the generality of our upgrading theory for latecomers other than Taiwan.

Invalid Assumptions

Both first and second movers exploit the same generic advantage—they are first in their respective domains to invest in optimal-size plants, salaried managers and technological resources. In both cases their actions allow them to capture economies of scale. After intense competition, the exploitation of scale economies allows industry leaders to consolidate their position, precipitating a rise in industry-level concentration. But, we would argue, key differences between first and second movers remain, and justify the deviant types of high-tech policies that Taiwan has exhibited.

One, the basis of their competitiveness differs even in the same industry. The first mover earns technological rents by exploiting its unique, cutting-edge knowledge-based assets. These rents allow it to reinvest in new product development and global marketing, which sustain its first mover advantages over sequential product cycles (Chandler Jr. and Hikino 1997). The second mover, by contrast, is not at the hub of world knowledge and must contend with low margins from producing mature products even in high-tech industries. It competes on the basis of relatively low (but rising) wages for its engineers, who accumulate skills in project execution, production engineering and detailed design. These skills enable the second mover to ramp up fast in order to exploit scale economies and chase global demand for the hottest products, which are determined exogenously by first movers.

Given these differences, the policy implications that flow from theories that assume identical technology and productivity across firms in the same global industry are not necessarily valid (e.g., the Heckscher-Ohlin free-trade model). Imperfect knowledge precludes a laissez-faire, Pareto optimal solution for second movers, that may choose between either increasing their competitiveness by lowering real wages, or trying to acquire the firm-specific, proprietary knowledge of first movers. There is no one-best way.

Two, the structure of leading enterprises differs. The first mover tends to limit its diversification to markets broadly defined by its own R&D. The second mover, due to its limited product development capabilities, tends to extend its diversification to whatever industries global demand dictates. Thus, within the electronics sector, the second mover is likely to be more diversified than the first mover. Outside it, the second mover's diversification pattern is likely to be altogether technologically unrelated, as in Taiwan's traditional business groups that have become leaders in advanced services.

Given these differences, the policy implications that flow from theories that assume that specialization creates the optimal firm structure and corporate governance system are not necessarily germane for latecomers.

Three, sources of knowledge differ. The private R&D of first movers includes basic or at least applied research, whereas that of latecomers remains closely coupled with production and detailed design. This requires second movers to "source" their high-tech inputs from overseas and creates scarcities of inputs (e.g., pentium chips) when a "new" mature product is still hot. Governments everywhere promote science and technology, but in the upgrading stage of a latecomer such as Taiwan, they incubate start-ups, import substitute high-tech components and parts to break technological bottlenecks and create well-paying domestic jobs, and assume the risk for long-term R&D to commercialize up-and-coming technologies at the frontier. Government R&D in latecomers is initially closer to the applied and basic end of the research spectrum than is private R&D.

Given differences between first and second movers in private R&D and scarcities in hot inputs, theories that limit government interventions in science and technology to generic skill formation are not necessarily valid for latecomers.

Four, marketing activity is likely to differ. If a latecomer firm produces for world markets under subcontract to a foreign firm because it lacks its own proprietary product designs, then investments in its own-brand marketing are restricted to peripheral products. The "three-pronged" investment of first movers—in manufacturing, management, and marketing[1]—will become two-pronged, excluding marketing. A dependence on foreign brand names and distribution is likely in the absence of the knowledge-based assets that are necessary to create a cutting-edge product, one that commands consumer loyalty and brand-name recognition worldwide. The accumulation of knowledge-based assets, however, is "limited by the *type* of market" that the latecomer can penetrate.

Given this circularity (an absence of innovative products limits the type of a latecomer's global market, and limited global demand constrains how much a latecomer firm can spend on new product development), theories that assume homogeneous products are invalid for latecomers.

Five, globalization is likely to differ. Initially the lion's share of a latecomer's outward foreign direct investments will occur where production costs are lower (poorer countries), whereas those of an advanced economy will occur where demand for new products is greatest (richer countries). At a given movement in time, an advanced economy may access the lower wages of another country through subcontracting whereas a latecomer may access them through FDI. If the share of national ownership in total output differs in the two cases, then the ratio of inward to outward FDI, FDI_I/FDI_O, will differ as well. The greater national ownership and the lower an industry's inward to outward FDI ratio, the greater is its potential to exploit economies of scale and reduce average unit costs of production, development, and distribution.

Given the relatively large-scale economies derived from outward FDI for latecomers' nationally owned firms, and given the entrepreneurialism of these firms in exploiting mature, high-tech advantages, theories that are indifferent between foreign and national ownership are not necessarily valid for latecomers.

Neutral Networks

Like first and second movers the networks that have emerged in the engineering industries of early and late industrializers also differ in key respects. The most pronounced differences lie in the unit value of their transactions, the degree to which their transactions take the form of subcontracting and are based on "trust" (subcontracting is virtually nonexistent *within* Taiwan's electronics networks), and the degree to which "new" industries and "new" technologies evolve autonomously or are a function of systematic government intervention and planning.

Given these differences, networks in latecomers are not especially flexible or fast to adjust to new market conditions. This is despite the fact that speed is essential in the latecomer environment. The product cycle relevant to a latecomer is particularly short given the maturity of the high-tech products it produces, and it is especially urgent for a latecomer to ramp up physical capacity and move down its learning curve rapidly.

The dense networks in Taiwan's information technology (IT) sector provided assemblers with virtually all of their *passive* component requirements. This did, in fact, contribute to their flexibility and was of critical importance in lowering their search and transactions costs. But these components were typically low in unit value. Unlike the case in countries at the world technological frontier, high-tech components had to be imported. In theory, the foreign import of *active* components may contribute to greater speed. To ramp up, an assembler need not internalize their production. Instead, it can rely on imports. In practice, many of the active inputs that had to be imported for assembly of notebook PCs and cell phones, for example, were supplied from abroad, under oligopolistic market conditions. When demand was hot, such inputs could be procured only by the world's largest buyers. Or if available, such inputs were priced monopolistically. These supply conditions increased Taiwan's time-to-market or unit costs. To overcome these disadvantages, either the size of an assembler had to increase to command the attention of foreign vendors (or to win foreign manufacturing subcontracts in the first place) or scarce, active inputs had to be produced locally.

Over time both phenomena occurred in Taiwan. Assemblers and major parts manufacturers became much larger, leaving behind the stereotype of the small-scale firm except in the *non*electrical machinery sector, whose share in GNP stagnated. IT firms that had become large in scale then began to import-substitute key inputs, such as TFT-LCDs (thin film transistor liquid crystal displays).

In terms of firm size, few manufacturing enterprises from *any* late-industrializing economy have grown large enough to appear on *Fortune*'s list of the 500 top global firms. In the case of Taiwan its dominant businesses still do not compare in scale or scope with those of South Korea (size differences, however, narrow considerably when market segment is controlled for). Nevertheless, Taiwan's nationally owned industrial leaders are among the largest in the developing world (Amsden 2001). Taiwan's 100 biggest business groups, many of them based in electronics, increased their share of GNP from 29 percent in 1986, the start of accelerated market liberalization, to 56 percent in a little over a decade. Only 20 percent of output (value added) in the electronics sector is now accounted for by small firms with 100 or fewer workers. In terms of market concentration, 60 percent of the electronic industry's value added is attributable to only 160 firms in total, all with at least 500 workers (the census bureau's highest cutoff for measuring size). In individual segments of IT, the pillar of Taiwan's prosperity in the 1990s, the net entry rate of new firms has fallen and industrial concentration has become high. In 1999, for instance, the five-firm concentration ratio was 72 percent for notebook PCs and 62 percent for desktop PCs. The four-firm concentration ratio was 96 percent for video cards and 62.4 percent for mouses.

Taiwan's networks of small-scale firms did not autonomously import substitute high-tech components through the "co-generation" of technology because they were too far behind the world technological frontier to do so. That role fell either to large-scale private firms in collaboration with government research centers (as in the case of CD-ROMs) or to government R&D labs operating independently. In the case of the semiconductor industry, for example, the government spun off a chip-manufacturing foundry from one of its research institutes in response to requests by "returnees" (Chinese-Americans) who had established IC (integrated circuit) design houses in Taiwan and wanted a local, specialized foundry that could provide them with much faster and better service than foreign integrated chip manufacturers. The IC mask industry, like the foundry industry, was also set up by the government. One of its laboratories was spun off as a private firm, and local masking capacity is estimated to have saved up to 20 days or more in the complete IC production cycle. Despite the contribution of returnees to the professionalization of management in Taiwan and technology diffusion, the human resources involved in the IC design industry, as in the electronics industry as a whole, were mainly locally trained, and many came from government organizations or training programs. It is therefore fair to say that Taiwan's networks were state led.

The Neo-developmental State: High-Tech Industry

In the theory of upgrading we have tried to develop, the maturity of high-tech products and their declining profit margins drive the second mover to capture economies of scale and invest in the skills and organizational structures that are necessary to survive. The competitiveness of the second mover depends on its ability to enter new market segments quickly, to manufacture with high levels of engineering excellence, and to be first-to-market by means of the best integrative designs (in the case of IT). Given the specificity of these skills and organizational structures, and the lower opportunity costs they entail for second movers than first movers (whose efforts and organizational structure are oriented toward developing and marketing genuinely novel products), nationally owned firms in conjunction with government-owned research centers become the pioneers in follower countries of high-tech industries.

The follower status of latecomers' high-tech industries makes them vulnerable to new product development at the world technological frontier. When such development is rapid, followers' high-tech activity booms, their stocks rise in price, and their production workers and professional engineers and managers see a rise in their real earnings, including stock bonuses. When new product development at the frontier stagnates, due to global economic downswings, followers' high-tech activity is subject to conflicting forces. On the one hand, first movers may subcontract more production overseas to cut their costs. On the other hand, the total volume of their subcontracting and their creation of new hot market segments may contract. If the revenues of second movers fall, this may encourage mergers and acquisitions among them but discourage investments in more advanced R&D to generate truly new products. Unemployment overall may be expected to rise sharply, as it began to do in Taiwan in 2001. Unless long-term investments in more advanced R&D continues, however, the latecomer risks competition from still lower-wage countries when global expansion resumes.

Once national second movers complete the upgrading exercises analyzed in previous chapters, and once the business cycle in high-tech industries turns downward, new policies come on governments' agenda. By 2001, the Taiwan government found itself precisely in this position. Three sets of policies required consideration in its capacity as "neo-developmental state" for high-tech industry—one related to competition, one related to R&D, and one related to employment. Another set of policies required consideration in its capacity as "regulatory state" of newly liberalized services. We discuss the two policy sets and sectors separately.

Competition Policies

With regard to competition we would argue that the Taiwan government should do everything possible to enable and allow second movers in high-tech industries such as electronics to enhance their market power. Mergers and acquisitions and outward foreign direct investments should be legalized and facilitated with minimal concern about competition. This is because Taiwan's electronics industry already operates in a highly competitive global environment, both with respect to foreign investment and foreign trade. Gains in the form of scale economies from M&As and outward FDI are likely to be substantial, and losses in the form of lower competition and higher prices are likely to be insignificant.

The quality of competition depends not only on market structure but also on professional management. Looming on the horizon in many leading firms in most Taiwan industries (including electronics) is a "succession" problem, or the question of who will succeed as CEO once a first-generation owner–chief executive retires. In part, succession depends on ownership. Thus, the more publicly traded the equity of a company is, the more likely that its CEO will be chosen on the basis of merit rather than family ties. Therefore government policies are welcome that favor public ownership, a slow but steady diffusion of management control, and financial transparency.[2]

Research and Development Policies

With the exception of a few outstanding companies (e.g., Samsung Electronics in Korea), the second movers of latecomer countries still typically undertake only D (design and development) and not R (research).[3] As lower-wage countries seek to fill their shoes as "original equipment manufacturers" or "original design manufacturers," second movers face a greater urgency to undertake R. Thus we would argue that the Taiwan government should not only continue the R&D that it has undertaken in the past (i.e., import substitution of high-tech parts and components, access to frontier technology for commercialization by national firms, and the diffusion of know-how to the private sector). It should also step up its applied and basic R&D, and increase incentives to private firms to invest in their own applied research.

The effectiveness of incentives to applied research by the private sector depends on brand-name marketing. Without an innovation, it is difficult for a company to establish its own brand name for "mass" marketing (the mass depending on the innovation), and without mass marketing, the unit costs of applied research are prohibitive. The resolution of this dilemma for Taiwan companies lies in *developing brand-name recognition in the large China market*. The competitive advantages of Taiwan companies in China are obvious: language and cultural commonalities. The disadvantages to the government of tighter economic ties with China are presumably political. The economic returns to removing controls on Taiwan investments in China, however, are likely to be very large if Taiwan firms can use China to establish their reputations, with a view toward global brand-name marketing.

Employment Policies

In the past, a sharing in the fruits of growth was a mainstay of Taiwan's economy. Rising real wages and equal income distribution provided the basis of support for Taiwan's selective industrial policies that favored high-tech firms (Amsden 2001). These firms themselves created loyalty among their workers by offering them stock bonuses. These stocks were taxed by the government at their face value rather than at their market value, which amounted to a subsidy in the case of companies whose stock prices sharply rose.

Nevertheless, structural unemployment among middle-level workers, managers, and engineers has emerged as a looming social problem in tandem with upgrading (most low-level jobs have already been transferred abroad through outward FDI). In every single sector in Taiwan, with the exception of manufacturing, one may observe a downward trend over time in the growth rate of employment. This is true of *all major branches of services*, although circa

Table 5.1
Growth rate of employment, by sector, 1981–2000

Sector	1981–1986	1986–1990	1991–1995	1996–2000
Agriculture	0.33	−3.80	−2.12	−4.95
Industry	2.12	1.89	0.72	0.19
Manfufacturing	3.12	1.28	−1.58	1.66
Mining	−8.89	−10.48	−5.33	−5.97
Utilities	4.76	1.16	0.02	0.02
Construction	−1.11	5.47	8.35	−3.64
Services	4.13	4.74	3.64	2.62
Commerce	4.64	4.10	3.44	2.43
Telecommunications	3.01	2.77	1.25	0.52
Finance	6.83	12.86	7.21	5.82
Business services	4.32	13.15	8.78	7.05
Social services	3.81	5.10	4.18	2.64
Administration	3.22	2.33	0.63	−0.11
Total	2.56	2.21	1.78	0.97

Source: Adapted from Taiwan, Directorate General of Budget, Accounting, and Statistics (various years).

2000 the growth rate of employment in the fastest-expanding fields (finance and business) was still high (see table 5.1). The downward trend in employment growth may be attributed to the rise in the capital- and technology-intensity of new industries and modern services, as we saw earlier in the case of electronics.

Structural unemployment in the middle-level employment range may moreover be expected to worsen given the nature of upgrading. In electronics, upgrading shifted output towards larger firms. Large enterprises tend to be more capital intensive (measured by fixed assets) than small enterprises. Among the electronics firms we interviewed, output tended to grow at double digit rates, whereas employment sometimes grew at single digit rates or not at all (see tables 2.8 and 2.9). In services, firm size remained constant over time in the sense that the output share of services accounted for by firms of different size did not exhibit any structural shift. Instead, the rising share of business groups in services took the form of an increase in the *number of subsidiaries* per group operating in the service sector rather than a rise in the size of an average subsidiary. The formation of new subsidiaries, however, is likely to slow as diversification is superseded by consolidation. Between 1973 and 1998, the sales of

Taiwan's top 100 business groups grew at an average annual rate of 11 percent (in constant 1996 Taiwan dollars), whereas their employment grew at less than half that rate, at only 5 percent (see table 4.1). Even before the onset of global recession in September 2001, Taiwan's unemployment rate had risen from 3 to 5 percent within less than a year.

Sequentially "new" industries must be brought on stream to offset a downward trend in employment growth. If the past is any guide, to do so requires more R&D: as just suggested, the rise of new industries, on the one hand, and the rise in R&D (private and public), on the other hand, appear to have been closely coupled in the 1980s and 1990s. The surge in the growth rate of manufacturing employment between 1996 and 2000 may be attributed to yet another "new" product cycle in the electronics sector, one in which the output of notebooks boomed and the manufacture of cell phones got underway.

Given the crucial role of the government in the promotion of science and technology in the past, there is reason to believe that a continuation of this role will be essential in the future to bring new industries on stream and to buttress employment growth. Nevertheless, more specific employment-stabilizing policies may also be warranted, such as tax breaks for worker training. The more training workers get, the higher are employers' costs of their layoff or dismissal.

The Regulatory State

The Taiwan government's entire industrial policy apparatus was geared toward promoting nationally owned firms, private and public, in both industry and services. Competition from foreign investors was structured in such a way as to strengthen national firms through technology transfer and "spillovers." National ownership was aided by decolonization after World War II, which cleared the decks of Japanese-owned manufacturing and service companies and put the main banks in government's hands (Amsden 2001).

Allegedly the Taiwan government's bias in favor of national ownership ended with market liberalization beginning in 1986. Among other measures, liberalization included privatization and market opening to new entrants. In reality, private national owners in key services, such as banking and telecommunications, were given a head start over foreign service providers, however brief their advantage. This aided large-size business groups that were in the best position in terms of capital and project execution skills to diversify into new service segments.

We would argue based on past performance that the government's bias in favor of national ownership is warranted. The most entrepreneurial firms have been nationally owned. It is they that have taken the lead in entering new industries and in building the necessary skills to manufacture mature, high-tech products profitably. Foreign-owned firms in most segments in the electronics industry usually followed rather than led second movers. Most of the groups we interviewed with roots in traditional industries did a capable job of diversifying into modern services.

Nevertheless, government promotional policies toward services have to differ from those toward high-tech industries such as electronics. In both cases scale economies are important. But most service markets are oligopolistic by nature and less subject to foreign competition than most manufacturing markets. It is more difficult therefore to strike a balance between policies to promote competition and policies to capture scale economies. Moreover, if the trend toward globalization continues to strengthen, then more new foreign competition will appear in the service sector than in the manufacturing sector because service liberalization is more recent. Therefore the challenge to government policy is to strike a compromise between the positive contributions of multinational firms (technology transfer) and their negative effects ("crowding out" aspiring national enterprises that are entrepreneurial and beginning to invest in globalization).

Allowing limited foreign participation to help maintain market competition and to upgrade technology and management skills should be the policy objective of the government in services. Policies should also be monitored carefully and evaluated frequently to ascertain if the balance is being maintained between the objectives of competition and economies of scale.

Generalizability of the Latecomer Model

A big question that upgrading raises is: How generalizable is the model that we have developed? Generalizability is an issue with regard to latecomers other than Taiwan, high-tech industries other than electronics (we consider services in conjunction with country generalizability), and time periods other than the end of the twentieth century. All three dimensions are briefly examined below.

To Other Latecomers

The question for other latecomers is what institutions to cultivate in order to develop high-tech industry.

We began our analysis of Taiwan's high-tech sector with the proposition that when a high-tech product begins to be produced in a latecomer, it is already "mature," with profit margins that are fast becoming paper-thin. To produce such products profitably, a large-scale firm is required that is capable of achieving huge output volumes.

In theory, that firm can either be a state-owned enterprise, a private national company, or a multinational corporation. In Taiwan the government deliberately made sure that the spin-offs from its R&D labs took the form of private firms in order to ensure management flexibility, even though the government held a controlling share behind the scene. But mainly the government's job was to nurture high-tech nationally owned firms. These enterprises proved far more entrepreneurial than the foreign multinationals that had entered Taiwan's electronics sector in the early period.

Therefore, in the case of other latecomers, we would hypothesize that *high-tech industry will grow faster, the greater the nurturing role of the developmental state and the greater the role played by private, national second movers*.

The government also played a major role in the service sector, not through owning productive enterprises but through regulating markets and thereby providing support to nationally owned firms. At present, it is unclear what type of firm, national or foreign, will win the competition that is now under way in many services. But it is clear from Taiwan that the type of national firm that is proving itself capable of competing against foreign firms is the diversified business group. This form of business is the major type of national firm to succeed in services.

Therefore, in the case of other latecomers, we would hypothesize that *modern services will grow faster, the more controlled the pace of inward foreign direct investment, the greater the nurturing role toward national companies by the regulatory state, and the greater the tendency of national companies to assume the form of diversified business groups*.

To Other Time Periods

Arguably many national second movers in the "new" mature high-tech industries of the 1990s owed their existence to the decision by first movers in advanced economies to lower their manufacturing costs by means of foreign subcontracting rather than foreign direct investment. This made it easier in latecomer countries for nationally owned firms to evolve. The international subcontracting decision, however, may conceivably have been only a fashion of the times. Vertical disintegration and subcontracting arose in advanced economies when management wisdom considered them good practice. Conceivably, when a firm's center loses too much control and the pendulum swings in the other direction, good management practice may revert to centralization, including tighter financial control from the top and a preference for equity holdings overseas. Foreign direct investment may then be expected to replace subcontracting. National second movers in latecomer countries will consequently find serious competitors in their home markets in the form of foreign investors. The nature of upgrading under these conditions may differ radically from the one just described.

Nevertheless, starting in the 1980s or earlier, international subcontracting was arguably a function of developments in latecomer economies, not advanced economies. Once nationally owned firms with relatively low wages and high skills in project execution and production engineering emerged in latecomers, international subcontracting became a viable alternative for first movers to foreign direct investment. From this perspective, so long as the relatively low wages and requisite skills are out there, subcontracting may be expected to prevail over foreign direct investment as the mode of advanced country globalization in high-tech industry. Subcontracting entails heavy monitoring costs, but it obviates the need for first movers to sink capital overseas and to make large fixed investments in facilities and human resources.

To Other Industries

In the 1990s latecomer upgrading in manufacturing was rooted in a particular industry, electronics, broadly construed to include software and hardware, telecommunications as well as semiconductors, electrical appliances, and data processing equipment. Thus upgrading coincided with an electronics revolution at the world frontier.

Arguably, in the absence of an equivalent revolution, latecomer growth could be much slower due to fewer "new" mature high-tech products to penetrate. Even if a comparable industry to electronics emerges as an engine of growth, it might require a culture that a latecomer cannot easily nurture. Moreover high-tech industries tend to be vulnerable to booms and busts as demand peaks for once-hot products and the debut of newer products occurs with a lag. By 2001 Taiwan's economy was experiencing a sharp contraction owing to a downswing in global electronics demand and recession in the world's major economies.

In fact a group of industries that are ripe for latecomer upgrading and that include subsectors that are innovative—chemicals, pharmaceuticals, and bio-tech—is beginning to exhibit upgrading characteristics akin to those already observed in electronics. The major difference is the absence in such industries of "networks," or clusters of parts and components suppliers around a central growth pole. Otherwise, the similarities with electronics are striking.

In Taiwan's chemical industry, including petrochemicals, consolidation is occurring on a scale comparable to what occurred in electronics. Single product chemical firms, a function of earlier government licensing that favored market specialization among a relatively large number of small enterprises, have begun to merge with each other, leading to larger size companies and higher market concentration.[4] Firms have also begun to invest more in R&D and to globalize in order to gain scale, to expand their customer base, and to circumvent local environmental regulations.

In the pharmaceutical industry, most advanced among latecomers in India, the upgrading that is underway shares even more generic characteristics than the chemical industry with the electronics sector. The manufacture of pharmaceuticals has a culture similar to that of electrical engineering insofar as competitiveness rests on a large supply of technically skilled professionals that operate in "new" mature high-tech industries. The only difference is that researchers in these industries, as opposed to electronics, are trained in natural science and medical science as well as in (chemical) engineering. India's second movers in "pharma" tend to be nationally owned. After a period of intense competition, concentration among them has become high. The government has played a major role in promoting industrial growth, as it has tended to do in electronics. It has championed import substitution in the name of making cheap drugs available for the poor, and it has protected nationally owned firms long enough for them to have a chance to survive a global tightening of patent enforcement. The government has heavily supported private R&D and has also encouraged small start-ups (Mourshed 1999).

With respect to bio-tech, its success, whether in advanced or latecomer countries, has still to be proved. Therefore there are as yet no "new" mature products for latecomers to exploit. In Taiwan, however, one can already see an institutional framework being put into place not too different from that in electronics to promote bio-tech. Academic departments formerly oriented toward agronomy are diversifying into bio-tech. Government institutes concerned with bio-tech research (in Academia Sinica and ITRI) have gained substantial state funding.[5] The admissions policies of science parks (in Tainan especially) have begun to favor bio-tech firms. The R&D of these firms is small in absolute value relative to that of manufacturers of semiconductors or opto-electronics, for instance, but its rate of growth is higher (Taiwan, National Science Council, various years).

As for the business cycle and high-tech product cycles in major advanced economies, especially the United States, latecomers, whether they are or are not export oriented, appear to be very vulnerable to them. Latecomers that have already upgraded along the lines drawn above, however, promise to suffer least because they have accumulated the national organizational structures, skills, and policies necessary to move quickly into new industries.

Notes

Chapter 1

1. For "first-mover" advantage, see Chandler Jr. (1990) and Chandler Jr. and Hikino (1997).

2. One could distinguish among (1) the inventor (first to develop a patent or technology), (2) the product pioneer (first to develop a working model), and (3) the market pioneer (first to sell a new product). The last corresponds to the standard definition of the first mover (Golder and Tellis 1993). It also corresponds to our use of the term "second mover," or the first firm from a latecomer country to sell a new "mature" product. Both the first mover from an advanced economy and the second mover from a latecomer country succeed because they are first in their respective domains to make a three-pronged investment: in optimal size plants, in technology and professional management, and in marketing (Chandler Jr. 1990). Most second movers from latecomer countries, however, have not yet succeeded in marketing their own brand-name products, as discussed later.

3. "The 'fundamental' law of labour is the law of division. There is a further law connected with this—that of 'collective force' as expressed in the 'collective' surplus generated by association, the collective product being the result not of the addition of individual efforts, but of their multiplication when they are brought together in association" (Proudhon, as cited in Bartoli 1987, p. 1035).

4. Hamilton himself did not write directly about firm size or scale economies, but he advocated government policies for developing countries that improved the conditions for both, such as protection from foreign competition and selective subsidies (as well as easy money). See Hamilton (1913 [1791]).

5. See Chandler Jr. (1990), Chandler Jr. and Hikino (1997), Lieberman and Montgomery (1988), and Lieberman and Montgomery (1998).

6. See, among many others, Borrus (1997), Chou and Kirby (1998), Hamilton (1991), Numazaki (1997), and Saxenian and Hsu (2001). According to Christensen et al. (2001), "Taiwan's economy, in contrast (to South Korea's), exudes Schumpeterian capitalism. Few of its companies can muster an all-out attack on global industrial concerns as the Koreans have done. But thousands of new companies financed with private equity start there each year, many with strategies targeting disruptive markets. Not surprisingly, Taiwan sailed through the recent Asian economic crisis with barely a scrape" (p. 92). Unfortunately, the authors do not name a single small Taiwan company that

succeeded in introducing a "disruptive" technology. Taiwan may also have averted the 1997 Asian financial crisis because its government did not liberalize its financial markets rather than because its firms size was relatively small. Taiwan appears to be doing much worse than South Korea in the 2001 cyclical downswing.

7. OEM refers to original equipment manufacturer and ODM refers to original design manufacturer.

8. For the concept of "combinative capabilities," or sets of varied skills needed to compete, see Kogut and Zander (1992) and Mathews and Cho (1998).

9. Assume first that the scale of a latecomer's production in a given industry depends initially only on domestic production. If a foreign firm acquires some of that production capacity, then the production scale of nationally owned firms in that industry will fall, and their unit costs will rise. Then assume that the scale of production of a national firm also depends on its outward foreign direct investment. If its total capacity rises due to that outward investment, then its overall scale will increase. If its foreign capacity substitutes for its domestic capacity (as it may tend to do in the case of small firms), but unit costs are lower due to lower wages overseas, then the firm's profits will be higher. It can now invest more in capacity, thereby lowering its unit costs further, or it can lower its prices, thereby increasing potential demand and the prospects for investing overseas in additional capacity.

10. Without nationally owned and nationally controlled enterprises to shift selective operations abroad, a country itself cannot globalize. At most the foreign-owned enterprises operating in one country can globalize further, to still other countries, but the total number of countries with their own multinational enterprises will remain the same.

11. Holding ownership constant, the ratio of inward and outward FDI may also be expected to depend on a country's size. The larger the country, the more likely it will attract inward FDI and eschew outward FDI. If a large population entails "unlimited" labor supplies (Lewis 1954), there is also no need for a firm to invest abroad in search of lower wages, as in India and China.

12. The ratio may be biased if exchange rates are biased because inward FDI is usually measured in undeflated US dollars, whereas outward FDI is measured in an undeflated local currency converted into dollars.

13. For the mode of outward investment, see Hymer (1976), Vernon (1966), and Akamatsu (1961 [1938]).

14. For the literature on "spillovers," see among many others, Aitken et al. (1997), Blomstrom and Kokko (1998) and Okada (1999). For historical cases of foreign investment spurring economic development, see Calderon et al. (1995) for Mexico, Hill (1989) for Indonesia, Schive (1978) for Taiwan, and Hou (1965) for China. For critical assessments of the role of foreign investment in economic development, see Cairncross (1962) and Amsden (2001), who argue, inter alia, that foreign investment usually arrives after a growth momentum has started; it does not initiate industrial transformation although it may accelerate it.

15. Industrial Technology Research Institute. Its most publicized success was the spin-off of the Taiwan Semiconductor Manufacturing Company.

16. For Taiwan's economic development, see, among others, Ahn (1998), Amsden (1985), Chow (2002), Chu (1994), Fields (1995), Galenson (1979), Gold (1988), Lee (1971), Ranis (1992), Schive (1978), Wade (1990), Winckler and Greenhalgh (1988), and Thorbecke (2000).

17. American TV manufacturers in the early 1960s initially invested in both Taiwan and Mexico, when wages in Taiwan were roughly half of those in Mexico (Levy 1981).

Chapter 2

1. Levy goes on to note: "Economies of scale based on changed factor proportions or changed input to output ratios do not appear to be particularly important. There is a substantial range of outputs for which automated production is the least cost method (although not all American firms are automated to the same degree). At very low levels of production, hand assembly and less division of labor are practiced. Many of the licensees of American firms, located in Central or South America, produce on this basis. Their parents, however, do not. It should be noted here that the key factor is scale of production rather than relative factor prices." See Lin (1986) for the wide range of firm sizes operating in Taiwan's protected television industry.

2. "Since the late 1980s, many export-oriented foreign firms pulled out due to the appreciation of the N.T. dollar and continuously rising wages. RCA (Taiwan) Ltd., which was the largest foreign company in Taiwan for many years, left in 1992. In 1991 Zenith Taiwan Corporation also announced its intention to withdraw from Taiwan. Among Japanese firms, the suspension of production by Orion Electric (Taiwan) had a great impact [in 1987, ORION accounted for 27.6 percent of Taiwan's color TV exports and 67.8 percent of its VCR exports]. Funai Electric of Taiwan also announced a shift of its production base for TVs and audio equipment to the People's Republic of China, while Dashen Electronic, a subsidiary of Mitsubishi Electric, discontinued production and became an asset management company" (Sato 1997).

3. Though most non-Japanese foreign TV producers left Taiwan by the early 1990s, Philips remained and both upgraded and diversified its operations. Parts producers such as General Instrument, Texas Instruments, and Motorola also innovated and remained, and joint-venture TV firms such as Matsushita, Sanyo, and Toshiba successfully restructured themselves (Chen et al. 1997).

4. According to Stan Shih, CEO of the Acer group, "Twenty years ago, all top-notch people in Taiwan worked in a foreign company. From the manufacturing view point, such companies trained the best operations people. Foreign companies can't survive in Taiwan now; they leverage investments with Taiwanese companies in the stock market. There are no stock options. RCA, Philco, DuPont, Bayer . . . they are all gone. But all top talent is from multinational firms" (Interview, March 2000). Acer got its start as a distributor of Apple Computers.

5. Another early market segment in Taiwan's electronics sector was the production of motors, and one of the "second movers" in this sector was Teco Electric and Machinery Company, Ltd. After its formation it almost immediately established technical cooperation with Japanese companies.

6. In general, Japan was the chief source of technical assistance in Taiwan's early phase of industrialization. One indicator of this is the origin of capital goods imports. Capital goods (defined as electrical and nonelectrical machinery) embody technology directly. Additionally they often involve long-term collaborative learning between buyer and seller. It is therefore significant that in 1970, *as much as 59.8 percent* of Taiwan's capital goods imports came from Japan, compared with 19.3 percent from Europe and 19.2 percent from the United States. Even Korea, another former Japanese colony, had a lower share of capital goods imports originating in Japan: 43.6 percent

compared with 30.8 percent from Europe and 24.4 percent from the United States (United Nations Conference on Trade and Development, various years), as cited in Amsden (2001).

7. See Chandler Jr. (1990) for the "three-pronged" investment in the case of first movers. See Amsden (2001) for the difficulties that latecomers had in making the "three-pronged" investment before World War II.

8. According to Borrus (1988, p. 82), "The consumer market [in the US] did prove to be a mass market for special calculator and watch ICs, but intense price competition and the vagaries of consumer product marketing forced most of the merchant firms to abandon their consumer product lines by 1977. The chief victors in the calculator wars were, of course, the Japanese."

9. Estimated by the Market Intelligence Center, Institute for Information Industry.

10. We discuss business groups in chapter 4. We include table 2.11 here because some electronics firms became groups (Acer, Tatung, and Teco), or/and some groups established electronics firms (Formosa Plastics).

11. Reid (1984). For a summary, see Ruttan (2001).

12. Backyard-built illegal clones of the Apple II had emerged in the late 1970s (see "High-Tech Entrepreneurs Create a Silicon Valley in Taiwan," *Business Week*, August 1, 1983, and Daniel Burstein, "The Asian Micro Pirates," *Datamation*, May 15, 1984, as cited in Langlois 1992). Their role in the evolution of PC learning in Taiwan is probably similar to the role of hobbyists in the American microcomputer industry. Both are representative of the stage of a high-tech industry when production occurs in firms with low survival rates.

13. As cited in *Wealth Magazine* (March 2001).

14. In the case of heavy telecommunications equipment, such as digital switching systems, breakthroughs in the advanced countries (by companies such as Ericsson, NEC, and ITT) occurred in the early 1970s, whereas production, with extensive government support, began in Brazil, Korea, and India in the early 1980s (by 2000 Taiwan was behind these latecomers in developing this industry). See Goransson (1993). Possibly the shortest lag between a breakthrough at the frontier and latecomer manufacture was observable in Singapore's hard disk drive industry. It is estimated that the pioneer, Seagate Technology, was founded in the United States in 1979 and established operations in Singapore as early as 1982 (Wong 1999).

15. The high-tech parts and components that began to be produced in Taiwan after having been imported also tended to be mature, as in the case of CD ROMs. When production began in Taiwan (circa 1994), world output was already nearly 18 milliion sets, as discussed in chapter 3.

16. In the case of Delta Electronics, for example, Mr. Bruce Cheng and family controlled the group through a direct 18 percent equity ownership in the flagship entity, Delta Electronics, Inc. "Indirectly, Mr. Cheng is also believed to exercise a controlling influence over a number of companies, which were also major shareholders in Delta, i.e., Deltron Holding and Deico International" (Ong 2000, p. 70).

17. Taiwan's estimated number of returning professional engineers—11,706—are likely to have been trained and to have worked in all parts of the United States, if not all over the world. The Bell Labs club in Taiwan, for example, claimed about 250

members. There is nothing to suggest that a disproportionate number of total engineers came from Silicon Valley (Taiwan, National Science Council 2000).

18. Harvard Business School (1993, 1994) and Mathews and Snow (1998).

19. Teco does not rank among the top ten in table 2.12 after 1985 probably because the Teco group's sales are not consolidated; Teco Electric and Machinery is only one company in the group.

20. This was also typical of the conglomerate's head office in Europe, the United States, and Japan.

21. For an evaluation of ACER's management style—personal or professional—see Harvard Business School (1993).

22. For prices, see Taiwan, Council for Economic Planning and Development (various years).

23. Examples are production systems for magentics, from winding to assembly and testing, an automated in-line SPC production line, automated thin film and thick film transmission systems, automated material flow and warehousing systems, automated foil winding systems, and a fully automated production line for the manufacture of batteries.

24. Horizontal integration did not necessarily influence a firm's speed of ramp up. Therefore we have little to say about it here. But clearly such integration was on the rise. Business groups, including those based in electronics, increased their number of subsidiaries rather than the size of each subsidiary (as discussed in chapter 4). A company like Acer, for example, has been creating a wide range of horizontally integrated internet-based businesses.

25. The ratio of design engineers to total employees may have been higher in Quanta than in other Taiwan notebook companies insofar as Quanta was unusually specialized in notebooks, and all notebooks at the time were manufactured in Taiwan rather than abroad due to government controls, which mitigated in favor of a higher ratio of capital-to-labor than overseas production and, hence, a smaller size measured in number of workers (see table 2.7 for the globalization of IT production). Notebooks accounted for almost 95 percent of Quanta's total sales. On the other hand, because Quanta had one major customer, Dell, which accounted for between 40 and 60 percent of its notebook output, the number of design teams that Quanta dedicated to individual clients may have been smaller than on average (besides Dell, Quanta was an ODM supplier to Apple, Gateway, HP, IBM, and Siemens).

26. The same tendencies toward rationalization began to occur in the Taiwan automobile industry and some other transportation and machinery sectors.

27. Flextronics was a Singapore-based company that specialized in providing manufacturing services to other firms.

28. For the ranking of these computer companies, see table 2.12. First International (FIC) is part of the third-ranking Formosa Plastics group (see table 2.11).

29. Given the indivisiblity of a computer and given shorter and shorter product cycles, a critical mass of engineers had to be assembled to specialize simultaneously in integrating the many different parts and components of a model as quickly as possible. Additionally, because of the high probability that any one design would fail, several teams worked simultaneously at a given moment; the more teams, the greater was the

probability of success. Given the need to assign one design team to each customer (i.e., to each ODM contractor supplying a basic design), and given the potential to modularize certain parts of any design (including the software), the greater the number of teams in operation, the greater was the payoff from modularization.

30. In Argentina, Brazil, and Mexico, where national enterprise in manufacturing is weaker vis-à-vis foreign enterprise than it is in Taiwan, globalization (outward investment) is also weaker (Amsden 2001).

31. The survey was sent to firms that had once applied for an FDI approval. About 2,000 firms responded, with about an 81 percent response rate.

32. Data that discriminate between firms with 500 to 999 workers and firms with 1,000 or more workers are only available for calculating R&D as a percentage of sales, not for other calculations.

33. See Sato (1997) for later concentration ratios in TVs and VCRs.

34. Dedrick and Kraemer (1998).

35. Interview, Jessy Chen, executive vice president, Realtek, August 2000.

36. By 2000, M&As in the cell phone industry had already begun: Compal, a leading notebook manufacturer, had acquired Trinity, which had been set up in 1999 by Mr. Ching Shan-yang, formerly the head of the mobile phone division of Acer Communications. Compal was believed to hold a 56 percent stake in Trinity (Ker 2000).

Chapter 3

1. For a formal treatment of geographical agglomerations, see Fujita et al. (1999).

2. By comparison with the electronics industry of Korea, Taiwan's electronics exports in 1992 were concentrated in computers and parts (70.9 percent versus only 22.2 percent for Korea). Electronics exports of Korea were concentrated in integrated circuits (47.3 percent versus only 14.6 percent for Taiwan). See Chen and Ku (2000).

3. Bicycles and motorcycles carry the official industrial classification of transportation equipment, not machinery. Formally, therefore, they are not an exception to the rule of small firms and little mass production in the nonelectrical machinery sector. We include bicycles in our discussion because of the dense network of parts and components suppliers that characterizes their output globally and in Taiwan.

4. To our knowledge, source material on this subject, whether in English or Chinese, is nonexistent.

5. Information on the sewing machine industry is from Schive (1990), unless otherwise specified.

6. Information on the bicycle industry is from Chu (1997, 2001), unless otherwise specified.

7. Wu (1995) and Wen (1984).

8. Technologically, Taiwan's largest nationally owned sewing machine company, Lihtzer, out-performed Singer in two respects by the end of the 1970s. First, Lihtzer implemented a new method of manufacturing aluminum arms, leaving Singer behind.

Second, Lihtzer introduced the first free-arm sewing machine. At one point Singer considered acquiring its arms from Lihtzer. Lihtzer went bankrupt in the late 1980s after a fire.

9. *United Daily*, July 23, 2000.

10. According to the Directorate General of Budget, Accounting and Statistics, in 2000 Taiwan remained in fourth place in terms of patents approved within the United States, behind (by a good distance) the United States, Japan, and Germany. The US government granted Taiwan 5,806 patent rights, up 1,280 from the previous year's level.

11. The two ratios are somewhat different because they are estimated by different methods. The import ratio is based on input-output (IO) data and takes into account all intermediate inputs including services. The self-sufficiency ratio looks only at parts and excludes services. When I-O data are being used, imports of parts are divided by a larger base that includes services. Hence the import ratio tends to be lower than the self-sufficiency ratio. In 1996, for example, the import ratio for bicycles was 19 percent, whereas the self-sufficiency ratio was 72.5 percent (implying an import ratio of 27.5 percent).

12. The decline in the export ratio probably was due to the fact that many parts manufacturers had moved production to China.

13. Company information and Chang et al. (2001).

14. Following the Leontief input-output analysis, the input matrix is defined as $A = A_d + A_m$, where d denotes domestic input factor and m for imported input fractor, and a_{ij} = the amount of the *i*th commodity required for producing one dollar value of the *j*th commodity. Thus $\sum_{i=1-n} A_{mij}$ and $\sum_{i=1-n} A_{ij}$ represent the value of imported inputs and total intermediate inputs required for producing one dollar value of the *j*th commodity respectively. (The economy has *n* sectors.) The ratio of the two gives us the percent of intermediate inputs imported for the *j*th goods. $\sum_{i=1-n} A_{ij} + VA_j = 1$ (or \$1 of the *j*th goods).

15. Small, specialized parts makers may be expected to outsource nonspecialty processes such as heat treatment.

16. Semiconductors also had a high in-processing rate, as was to be expected, given that Taiwan's semiconductor industry was comprised of foundries that were designed to manufacture for other firms.

17. In the case of Inventec, it began to produce electronic calculators in Malaysia in the late 1980s, and it did, in fact, carefully select its best 20 out of 300 Taiwan-based suppliers to co-invest with it. Its invitation included a promise of future orders. (Inventec also persuaded its Japanese supplier of LCDs, Seiko Epson, to build a plant close to Inventec's site, although Seiko Epson was planning to produce overseas irrespective of Inventec's plans.) By contrast, when Kinpo (a part of Compal, a notebook manufacturer) moved its calculator production to Thailand, it did not invite any of its Taiwan-based suppliers to go with it. Its intentions were to purchase its inputs globally. Ultimately Taiwanese firms operating in China remain dependent on Taiwanese suppliers—between 1995 and 1998, the average reliance ratio was estimated to be around 70 percent (Ku et al. 2000).

18. For the concept of "trust" in networking, see Humphrey and Schmitz (1998).

19. The Act for the Recruitment of High-Caliber Scientists, promulgated in 1983 and "vigorously implemented by the National Science Council, . . . attracted top talent from both indigenous and overseas Chinese to research projects in eight strategic priorities specified by the (government's) science and technology plan" (Liu et al. 1989, p. 30).

20. By 1998, there were ten ASEAN countries (Association of Southeast Asian Nations): Indonesia, Malaysia, Thailand, Philippines and Singapore (admitted in 1967), Brunei (admitted in 1984), Vietnam (admitted in 1995), Laos and Myanmar (admitted in 1997), and Cambodia (admitted in 1998).

21. ITRI refers to the Industrial Technology Research Institute.

22. ITRI, 2001, ITIS (Industrial Technology Information Service) reports posted on ITRI Web site: *Http:/www.itisdom.itri.org.tw/itisnews.nsf.*

23. Taiwan's annual trade deficit with Japan grew in US dollars to about ten billion in 1991 from only two billion or three billion in the first half of 1980s. Japan was the only trading partner against which Taiwan persistently ran a large trade deficit. Nevertheless, the *share* in these years of Taiwan's imports from Japan out of total imports was relatively stable; it remained at around 30 percent. Import dependence on Japan was thus probably a better indicator of Taiwan's technological dependence than its trade imbalance. Arguably, therefore, the passage of the Development of Critical Components and Products Act had less to do with trade structure than with industrial upgrading.

24. Information on CD-ROMs is derived from the following sources: Taiwan Industrial Development Bureau (various years), Taiwan Industrial Technology Research Institute (1997), Taiwan Electronics Research and Service Organization (1994), Hsiao (1994) and Taiwan Market Intelligence Council (various years).

25. Firms involved that we interviewed included BTC, Inventec, Acer, U-Max, and Lite-On. BTC and Lite-On were also involved in the project to develop the CD-ROM pickup head.

26. Information on the LCD (liquid crystal display) industry is from: Wong and Matthews (1998), Linden et al. (1998), Taiwan Industrial Technology Research Institute (1999, 2000).

27. An LCD is the best known example of the microelectronic flat panel display used in electronic calculators, laptop computers, and other applications.

28. The joint venture between IBM and Toshiba, founded in 1989, ceased making LCDs for computers in May 2001. Toshiba will use its Japan facility to make LCDs for cell phones and IBM will use it for ultra-high-resolution applications such as medical devices (*Nikkei Weekly* 2001).

29. ERSO, the Electronics Research Service Organization, is a part of ITRI. VLSI refers to very large-scale integration.

30. Ultimately UMC adopted TSMC's strategy and became less vertically integrated, assuming the structure of a foundry.

31. ERSO started a Multi-Project Chip program with the National Science Council in 1983 to help build up IC design capabilities in Taiwan's universities (Chen and Sewell 1996). Mosel and Vitelic merged in December 1991 and now manufacture and market

worldwide dynamic random access memory chips (DRAMs) and other products. Revenues were US$880 million in 2000. Quasel is no longer in business.

32. Ministry of Finance Web site: *http://www.mof.gov.tw/statistic/trade.*

33. "Seventy percent of VC (venture capital) investments have been in computer-related and electronics sectors. The rest occurs in communications, industrial products, and medical/biotechnology. The concentration by Taiwan's VC on technological rather than traditional industries, which is similar to the case of Singapore and South Korea, can be explained by the tax incentives which channel VC towards technological enterprise investments" (Wang 1995, p. 86).

34. The Ministry of Finance introduced a 1983 statute (Regulations Governing Venture Capital Investment Enterprises) that stipulated guidelines for the organization of venture capital firms, their minimum capital requirements, and rules for the management and supervision of their funds. The first venture capital company to be created was Multiventure Capital Corporation (1984), a cooperation between Acer and Continental Construction. Then a joint venture was founded in 1986 between an American venture capital firm (Hambrest and Quest) and various government agencies—49 percent of the firm's minimum capital requirements came from the government's Development Fund, the Executive Yuan, and a quasi-development bank, Chiao-Tung (see Tzeng 1991; Taiwan Venture Capital Association, *http://www.tvca.tw*).

35. The funding of start-ups by the venture capital industry may have been more important in the 1980s than in the 1990s. It has been estimated that of the 80 firms operating in Hsinchu Science Park in 1987, as many as 43 were financed by venture capitalists (Liu et al. 1989).

36. "The achievements of VCs in directing technological enterprises about how to go public with their stock are considerable" (Wang 1995, p. 90). Public offerings were the major exit strategy of venture capital investors.

37. See also Chang (1992), Xue (1997), Yang (1998), and Taiwan, Hsinchu Science-Based Industrial Park (2000).

38. Taiwan, National Science Council, table on source of R&D funds (various years) and Hsiao (1994). Besides Acer, many of the second movers examined in chapter 2 participated in government-funded research. ITRI's Communications Laboratory (CCL) alone made nine technology transfers to Accton, five to Z-Com and U-Max, three to Delta, two to Lite-On, and one to D-Link (Taiwan, Ministry of Economic Affairs, various years).

39. For the role of the IDB in promoting Taiwan's new economy, see Mathews (1997) and Chu (1998).

40. Unless otherwise stated, information in this section is from Taiwan, Industrial Technology Research Institute (2000a, b), Taiwan, Center for Public Administration (1999) and Taiwan, Corporate Synergy Development Center (2001).

41. The number of electronics firms, 160, with 500 or more workers was provided by the Directorate-General of Budget, Accounting, and Statistics.

42. CMOS stands for complementary metal oxide semiconductor. For this decision, see Chiang (1990) and Chang et al. (1994).

43. For a general discussion of performance standards in the success of government intervention in late industrialization, see Amsden (2001).

Chapter 4

1. A business group (*guanxiqiyie* in Chinese) was typically owned and controlled by a single family, at least through the second generation of its life, with each generation being measured by approximately 20 years. Usually a group was characterized by some form of holding company at the top, which controlled the various subsidiaries, even if the equity shares of a given subsidiary were traded on a stock exchange. Like conglomerates in advanced countries, the corporate headquarters of groups were small. As indicated in chapter 2, groups in Taiwan based mainly in electronics, such as Teco and Lite-On, had barely a dozen professionals and family members presiding at the top and taking key strategic decisions on expansion.

2. For groups in Taiwan, see also Amsden (2001), Chu and Hong (2002), Fields (1995), Gold (1988), Hamilton (1991), Lai (1990), Numazaki (1986), Numazaki (1997), Schak (1999), and Taniura (1989).

3. The share for 1999 was as high as 73 percent! This jump, in contradistinction to the jump between 1996 and 1998, is likely to have been due to a change in government accounting requirements that forced groups to declare all their subsidiary holdings. This increased consolidated reporting, however, may have led to biases if groups committed double counting (assuming vertical integration, the inputs of one subsidiary are double counted in the sales price of another subsidiary that used that input). Thus the data for 1999 and 1998 may not be strictly comparable.

4. The diversification pattern of smaller groups was similar to that of China Steel, as in the case of USI Far East Corporation, a producer of petrochemicals.

5. Long-term investments, in which a company has less than 20 percent of a subsidiary's paid-in voting share capital, or in which it has no ability to exercise substantial influence over the subsidiary's management, are usually calculated using a *cost accounting* method. Investments in which ownership interests exceed 20 percent, or in which a company exercises substantial management influence, are usually calculated using an *equity accounting* method. In either case, unless the sales and employment of such subsidiaries are consolidated into a company's overall balance sheet, the company's total sales and employment tend to be understated.

6. A possible difference between the re-investments of business groups and those of electronics companies, as suggested by our interviews, concerns business objective. In the case of groups, most re-investments had only to meet the criterion of profitability. In the case of electronics companies (e.g., Teco and D-Link), increasingly re-investments had to meet the criterion of "strategic." That is, they had to increase the long-run profitability of a company's core business (in the capacity of an input of some sort—technology, a part, or a product line enrichment).

7. In the first quarter of 2001, Far Eastone reported a 180 percent year-on-year revenue growth. Its revenues per user were estimated to be 23 percent higher than those of Taiwan Cellular (Culpan 2001).

8. In preparation for entry into the World Trade Organization, the Taiwan government liberalized banking regulations. In June 2001 it passed a law that allowed local and foreign financial holding companies to acquire existing local banks. The law gives a company leeway to bypass another regulation that stipulates that any institution cannot hold more than a 25 percent share of a bank.

9. The sales composition of retail trade in 1999, according to monthly commerce statistics, was as follows: department stores, 31 percent; super stores, 24 percent; convenient stores, 19 percent; supermarkets, 14 percent; and others, 12 percent (*Wealth Magazine* 2000).

Chapter 5

1. See Chandler Jr. (1990).

2. For an analysis of company-level financial policies for governmental consideration, see Lessard (2002). This is part of a study being undertaken on Taiwan's globalization by the Massachusetts Institute of Technology.

3. For the low level of R&D of foreign-owned companies in Singapore's electronics industry, and the measures undertaken by the government to promote more advanced research, see Amsden and Tsang (2003).

4. In the case of USI Far East, a group that ranked among Taiwan's top 100 but not 30, it diversified by acquiring other local petrochemical companies with different specializations for purposes of expansion and market rationalization. After bringing these acquisitions to profitability through improved management, USIFE used the proceeds to re-invest in service companies unrelated to chemicals. USIFE's big worry was globalization; it had failed for political reasons to expand production facilities in the Philippiines and was waiting for approval by the Taiwan government to operate in China.

5. The Biomedical Engineering Center of ITRI organized a forum in 2001 that brought together 24 experts from the United States, Australia, Japan, Hong Kong, China, and Taiwan. The strategic purpose of the forum (and a tour of the US biotech industry by Taiwanese business people and government officials) was to connect Taiwan's well-established information technology with the development of biotechnology, with a specialization in bio-chips, bio-information and bio-pharmaceuticals.

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