The Development of Taiwan's Personal Computer Industry

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Abstract

This paper traces the development path of Taiwan's personal computer industry. Four groups of firms are identified: decedents of the TV industry in the early 1970s, decedents of the calculator industry in the late 1970s, new entrants that pioneered Taiwan's PC industry, and follow-up entrants that concentrate on PC peripherals. The technology roots of each group of firms are examined and their roles in the industry are discussed. Vertical disintegration and de-technology are two important strategies that allow small and medium enterprises to play a central role in the industry.

The Development of Taiwan's Personal Computer Industry

I. Early History

The development of Taiwan's personal computer industry has its root in the electronics industry. The history of Taiwan's electronics industry can be traced back to 1948 when some local merchants began assembling radios using imported vacuum tubes and other electronic parts. The quality of locally assembled radios was naturally mediocre. The government moved swiftly to protect this budding industry by putting radios under an import licensing control in 1950. Domestic sales expanded under protection and small assembly shops operated by local merchants soon turned into large-scale factories. Less sophisticated parts also began to be manufactured locally (IDIC 1968).

Taking advantage of their experience in assembling vacuum tube radios, Taiwanese firms quickly jumped on the bandwagon of transistor radios when these products were mature. Taiwan's first transistor radio plant was established in 1961 and in the following year it successfully exported 30,000 units of the new products (IDIC 1968). This was the turning point for Taiwan's electronics industry because a new market frontier had been discovered. At that time, Taiwan had just overhauled its economic policy from the orientation of import substitution to export promotion. Blessed with low wages, Taiwan attracted a large number of consignment orders to manufacture transistor radios for export, mostly from Japanese general trading firms (shogo-shosha). By 1966, Taiwan's exports of transistor radios exceeded 2 million sets, mostly destined for the U.S. market. This performance established Taiwan's reputation as a good site for assembling electronic products.

Taiwan's electronics industry expanded through the introduction of television. With technical assistance from Japan, the Taiwan government started television

broadcasting in 1962. Concomitant with television broadcasting, local manufacturing of monochrome TV sets sprang up. This was 16 years behind the U.S. (which invented TV and started formal production in 1946) and nine years behind Japan (which started TV production in 1953) (Levy 1981, p.190, Table 5-5). Local firms obtained technologies from Japan through technology licensing or joint venture arrangements. The major Japanese electronics firms like Matsushita, Sanyo, Sharp, and Toshiba formed joint ventures with local entrepreneurs while Sony and Mitsubishi licensed technologies to local firms without taking equity shares. All of them were geared to serve the local market.

Segregated from local and joint-venture firms was a group of multinational firms engaged in TV set production exclusively for export. Led by Philco in 1965, a series of direct investments to Taiwan were made by American firms including Admiral (in 1966), RCA (in 1967), Motorola (in 1970) and Zenith (in 1971). These firms either established bonded factories or chose to locate in export processing zones. They were allowed to import components and parts duty-free but were required to export all finished products. This facility allowed American multinational firms to take advantage of Taiwan's low wages to combat increased imports of Japanese TV receivers into the U.S. market. American multinationals in Taiwan specialized in small screen sets and re-exported them to the U.S. under the parent firm's brand names (Levy 1981, pp.261-7).

Taiwan's reputation as a competitive site for TV assembly also attracted multinational firms from other countries. Hitachi and Orion of Japan, Philips of the Netherlands and Grundig of Germany also established bonded factory operations in the early 1970s. Likewise they exported all finished products, mainly to the U.S. market. By the early 1970s, Taiwan had become a major exporter of TV sets in the world. In 1973, for instance, Taiwan exported a total of 3.8 million units of

monochrome TV sets, on top of a local consumption of 373,000 units (Schive and Yeh 1980).

With ample experience in monochrome TV production, Taiwan had little difficulty making the transition to the age of color TV. Like the inauguration of monochrome TV broadcasting, the beginning of color television broadcasting in 1969 by state-owned television stations was accompanied by the launch of the local production of color TV receivers. Although Taiwan was far behind the U.S. and Japan in initiating color TV production, it was virtually running neck-and-neck with European countries in entry into this new field. For example, the U.K., France and Germany started the production of color television receivers in 1967 and Italy started it in 1969 (Levy, 1981, p.191, Table 5-5). Domestic demand provided an initial boost to local production, but it was again the export market that paved the way for rapid growth of the local industry. In 1978, domestic production of color television receivers exceeded 1.3 million, of which only 486,000 were sold to domestic consumers, the rest were exported (Schive & Yeh 1980). Multinational firms remained the major players in the export drive, but indigenous and joint-venture firms which used to target the domestic market in the monochrome TV age also began to move into the export markets.

Although the growth in the assembly of radios and television sets was phenomenal, Taiwan's electronics industry would not have performed so well had it not had a solid foundation in the manufacturing of parts and components. Multinational firms played the role of catalyst in the parts and components sector, but it was the small indigenous firms that constituted the core of the industry and drove the growth.

The first major multinational firm to engage in Taiwan's electronic parts industry was General Instruments (GI) of the U.S. GI established a fully-owned subsidiary in

suburban Taipei in 1964 to operate the first-ever bonded factory in Taiwan. The plant was designated for the production of electronic parts such as transistors, tuners, deflection yokes, capacitors, etc. for shipment back to the parent company. Following GI's model, Philco's and RCA's operations in Taiwan also started with components production before they moved into TV set assembly.

Local firms which copied technologies from multinational firms or licensed technologies from them strove to get into exports in addition to serving the domestic market. Although the quality of their products was inferior, they targeted late-comers in the TV industry such as Southeast Asia, the Middle East and Latin America as their market focus and excelled at niche products with ultra-low prices. Exports enabled them to realize scale economies which improved production efficiency. Moreover, making money from exporting enabled them to invest in new-vintage equipment in which more sophisticated technologies were embodied.

A solid parts industry laid the foundation for Taiwan's successful entry into the production of calculators in 1972 and digital watches in 1975. Experience in the design and manufacturing of these primitive digital products, for example, circuit boards, laid the foundation for transition to the field of personal computers which blossomed in the 1980s. The largest calculator producer, San-Ai, was established by capital from a textile firm and technicians from the electronics parts industry. Two spin-offs from San-Ai, Inventec and Quanta became two leading notebook computer makers in the 1990s.

II. Development of the Personal Computer Industry

Taiwan's personal computer (PC) industry began in the late 1970s as some Taiwanese companies started assembling PC kits for domestic sales, using imported microprocessors from Intel, Zilog, Texas Instrument, etc. The industry was

subsequently boosted by a big boom of electronic games on the Taiwan market. During this boom, local game parlor operators imported game machines from Japan and contracted local electronics firms to replicate them in mass volume through direct copying or redesign. Electronics firms imported microprocessors from the U.S. and designed the circuit boards which constitute the core operating units of the machines. In its high times, producers of game machines had to wait in line for the delivery of main boards with cash in hand. The electronic game boom gave the initial impetus to Taiwan's PC industry, whereby some primitive design capabilities were established. For example, Taiwanese firms decomposed the programmable logic arrays (PLA) built inside the Japanese game machines through reverse engineering and redesigned them for local production. Some of these locally redesigned circuit boards were even exported to Hong Kong (Chou, 1996, pp.80-82). The electronic game boom came to a sudden finish when the government surprised the industry by banning electronic games in 1982, claiming that many of these games involve gambling. Electronics firms that were stuck with large inventory of expensive microprocessors were scrambling for outlets. They found that these microprocessors were also used in Apple II computers and started to make unauthorized clones of Apple II for resale. This was the beginning of Taiwan's export of personal computers. The Apple II clone was a hit on the U.S. market as it substantially undercut the price of genuine Apple computers with comparable quality. The Taiwan government was forced to crack down on such illegal clones in 1982-1983 under the pressure from Apple and the U.S. government. But the industry resurrected itself by starting producing IBM clones as IBM was willing to license relevant technologies, primarily BIOS technology, to Taiwanese manufacturers for the purpose of combating Apple's dominance.

In the early 1980s, PC industry in Taiwan was nonetheless dominated by American multinational firms. Companies like Atari, Wang, WISE were producing

PC-related products for export to the U.S. market to take advantage of Taiwan's low-cost labor and engineering capabilities. But local companies quickly seized the opportunities to join the market by serving as subcontractors and OEM producers for brand marketers.

Using its dense production networks developed since the 1960s, Taiwan competed successfully in the world's PC industry by separating the production of computers into small segments in which small firms developed their niche and prevailed. As a result of refined division of labor, there were hundreds of specialized producers in the field of mother boards, keyboards, monitors, mice, add-on cards, and so on. Each product was sold separately to system producers for integration, or was combined with other products to form a subsystem for resale in the international markets.

Many of Taiwan's small PC component suppliers had previous experience in producing consumer electronics and components (Dedrick and Kraemer 1998, p.147). When the TV industry came to a decline in the mid-1980s and many multinational firms withdrew from Taiwan, the engineers released from the TV industry was immediately absorbed into the computer monitor industry. The design and manufacturing capabilities transferred from the TV industry quickly made Taiwan the world's leading producer of monitors. Local CRT manufacturer, Chung-Hua Picture Tube, also adapted itself from making television tubes to monitor tubes. Capitalizing on the booming monitor industry, Chung-Hua Picture Tube has become the world's largest CRT manufacturer, surpassing such international giants as Hitachi and Philips. Among local firms that made the transition from making TV receivers to computer monitors were local companies, like Tatung and Sampo, as well as multinational firms like Philips and Matsushita. Local companies served as subcontractors for system producers such as IBM and Compaq. Their anonymity, while a fatal deficiency for

their endeavor to become a world-class producer of consumer electronics such as TV receiver, made them perfect partners for world-renown system producers which source components and parts globally to minimize the costs.

A strong and interwoven network of component producers constitutes the core competence of Taiwan's PC industry. For example, mother boards are supported by high-quality printed circuit boards (PCB) whose production was originally to serve the production of TV receivers, calculators, and other electronic devices. Switching power supply (SPS), in which Taiwan also tops the world in production, is supported by a strong transformer industry whose root can also be traced back to TV receiver production. In addition to the design and manufacturing capabilities developed during the previous experience of making consumer electronics, Taiwan's PC industry was aided by the technologies and skills acquired from overseas. Through the contact with Taiwan's overseas engineers and technicians working in Silicon Valley of the U.S.. Taiwan's PC industry was able to access the frontier technologies in the industry. Through repatriation of these overseas engineers, the industry was able to acquire scarce skills which are critical to the development of the key technologies. For example, there are more than thirty chipset makers in Taiwan, most of which are spin offs from the U.S. firm, Chips & Technologies (Dedrick and Kramer, 1988 p.159). Taiwan is the world's leading producer of scanner and mouse, of which major companies were established by ex-engineers from Silicon Valley.

In addition to indigenous technologies accumulated from the previous production experience and those acquired through government-sponsored R&D, Taiwan's PC industry also obtained critical technologies from multinational firms. This is achieved mainly through linkages to multinational firms with which Taiwanese manufacturers form a strategic relationship. For example, up to now the revolution of PC has been brought about by Intel through the introduction of new-generation microprocessors

(CPU). A close relationship with Intel would enable Taiwanese firms to access the data regarding the newest CPU and allow them to introduce new-generation products a step ahead of their competitors. This strategic relationship is built upon the trust that early access to the critical information by small Taiwanese producers, while useful for Intel in evaluating the performances of its new CPU, does not present a threat to upset the balance that Intel wishes to maintain among the world's major system producers.

Taiwan also took advantage of its manufacturing capabilities to form strategic alliances with multinational firms in an attempt to acquire critical technologies. For example, through the arrangement of ERSO, Taiwan's major PC manufacturers formed the Power-PC Alliance with Apple, IBM and Motorola in an effort to promote Power-PC computers to counter the monopoly power of Intel. Under the alliance, Apple, IBM, Motorola agreed to establish a research and support center in Taipei to support the consortium members. Although in the end, the alliance failed to present a credible threat to Intel, it strengthened Taiwan's linkages to multinational firms. For example, a member of the consortium, Umax, was licensed by Apple to produce Power-PC computers based on the Macintosh operating system (Macintosh compatible), first such a license ever awarded by Apple.

III. Vertical Disintegration and the Role of SMEs

Until recently, small and medium enterprises (SMEs) have played a central role in Taiwan's PC industry. There are two questions to be answered if we are to understand the predominance of SMEs of this newly emerged industry. One concerns how SMEs overcame the technology barriers to the supposedly high-tech (at least in the early 1980s) PC industry. The other question concerns the disadvantage of small scale of SMEs in international competition. The answers to both questions lie with the vertical disintegration of the PC industry in Taiwan.

First, about the technology barriers to entry. Vertical disintegration allows technology hurdles to be handled by a small group of specialists whereby SMEs can undertake the segment of production on which they choose to focus. The most technology-demanding part of PC manufacturing is circuit design, which is handled by a large number of design houses, typically very small and owned by experienced engineers. Most design houses were nurtured during the video-game era spanned from the late 1970s to 1982. These design houses re-engineered the programmable logic arrays originally made in Japan and redesigned the circuits to suit local preferences. They were typically very small with primitive design tools. They custom-designed the circuits for local producers of video-game machines, which then were sold to a market that was never explicitly legalized until it was formally banned. The market never had a chance to consolidate before it was pronounced illegal, and the small circuit design houses, together with game-machine makers, also never had a chance to grow big.

The circuit designs made by these small designers were then forwarded to a large number of printed circuit board (PCB) manufactures who imprinted the circuits and inserts the electronic components on them. In fact, the PCB imprinting operation is segregated from the components-insertion operation to become a distinctive industry. The PCB-imprinting segment requires some sophiscated equipment, particularly in the drilling process, where thousands of small holes of different sizes have to be drilled on each layer of the circuit board to enable electrical connection through bondage. The industry find a way to disintegrate by establishing specialized drilling mills that undertake the most capital-intensive part of the PCB production process, hence allowing small PCB imprinting operators to survive without these expensive machinery. They usually concentrate their work on circuitry development, etching, and copper plating to make a bare board. The bare boards are then forward to components-insertion factories for assembly. The components-insertion process can

be further separated into three parts: automatic insertion, surface-mount insertion, and hand insertion. The former two parts, which are more capital intensive as they require computer controlled machinery, can also be segregated from the hand-insertion operation that is labor intensive (Kawakami 1996). In addition to capital requirement, the drilling operation and automatic and surface-mount insertion processes are also technology intensive as the machinery is programmed to reach a high-level of precision. The processes can also be de-technicalized as the programs can be contracted to independent programmers who specialize in computer-aided manufacturing (CAM) designs.

The presence of independent circuit designers allow small PC producers or traders to enter the industry without possessing substantial technological capabilities. Gradually, there emerged an industry that combine the designers with PCB manufacturing, known as the "motherboard" industry. The industry designs and produces motherboards for use in the PC and sell them to system producers or traders, who in turn, sell motherboards to DIY (do-it-yourself) consumers. The emergence of the motherboard industry illustrates a "de-technology" process of the industry development that allows free entry to the industry and creates a "swarm" (Schumpeter 1944) of entrants. In the 1980-1988 period, the three largest motherboard producers were ARC, Autocomp and Elite, among which only Elite was established by a group of engineers. ARC and Autocomp were swept away during the industry consolidation of the late 1980s due to the lack of technological competence.

Even within the motherboard industry, de-technology process takes place. The circuit design houses have developed a large set of design modules that perform specific functions. A design based on an old CPU can be made quickly by combining several modules with proper modifications to suit the customer needs. A design based on a new CPU is more challenging as it has to accommodate new functions and new

configurations. At this juncture, the designers rely on the chip-sets produced by specialists like Chip & Technologies (C&T). C&T takes the central processing units (CPU) provided by Intel and design some key integrated circuits (ICs) that drive the CPU. The CPU and these auxiliary ICs are collectively fabricated as a single chip-set for the motherboard designers who design the remaining circuits. The availability of a chip-set greatly reduces the complexity of the design because the framework for design is established. Initially, the chip-sets were monopolized by C&T, but later the technologies were diffused to Taiwan where more than 30 local chip-set producers are competing provide even faster service to the motherboard industry. The ability of the chip-set producers to provide the service at proximity is due to the existence of capable foundry service providers, such as TSMC & United Microelectronics.

Outside Taiwan, motherboard industry only exists in the US temporarily. The US Micronics was, in fact, a pioneer of the motherboard industry and dominated the industry for a while because of its first access to Intel's data about new CPU designs. Micronics failed to market competition in 1998 (Chou 1999).

Taiwan's motherboard industry not only served the local industry well, it also exports. Traditionally system producers like IBM or Compaq made their own motherboards, which are considered the core technology of the PC production. These companies, however, eventually discovered that out-sourcing motherboards from Taiwan is more economical. As a result, Taiwan's motherboards, initially only served the overseas DIY markets, started to penetrated the brand-name markets. Today, Taiwan's motherboards account for over 70% of the world market share. It clearly demonstrates the merit of specialization. The dominance of the motherboard production also gives Taiwan a tremendous advantage in its access to frontier technologies, particularly those related to CPUs.

Vertical disintegration also solves the scale economies problem for Taiwan's PC

industry. Scale economies are important only in the capital intensive production process as it requires large investment in capital equipment. The dominance of SMEs in the labor-intensive and technology-intensive segments of production allows capital-intensive producers such as PCB drilling and surface-mount insertion operators to become independent subcontractors whose size is often larger than their clients. They can pool together the demand from small producers to realize economies of scale. A PCB-drilling operator, equipped with high-precision, computer-programmed drilling machines can serve all kinds PCB producers for all kinds of boards, including those for PC, cellular phones, PDA, and VCD.

Vertical disintegration also serves the purpose of managing price fluctuations. The PC industry is characterized by unstable demand and key components such as CPU or DRAM manifest the drastic price movement. If a PC is to be shipped from Taiwan to the US in a month, price changes in CPU or DRAM can eat up the slim price-cost margin, hence imposing a tremendous risk on the manufacturer. One way to reduce the risk of price-movements of key components is to defer the incorporation of key components into the final products until the last minute. This can be done by producing a barebone computer without CPU and DRAMs, and shipping it to the market destination where a simple assembly line will add these components onto the barebone moments before the delivery. It is not surprising that the vertically-disintegrated PC industry in Taiwan also invented the barebone computers. A motherboard can be combined with the outer case, power-supply, and various connectors of a PC for shipment.

IV. Technology Accumulation and the Role of Large Firms

Although SMEs dominate Taiwan's PC industry until today, large firms also had an important role to play in the industry, particularly in terms of transforming

accumulated technologies into new applications. This was particularly evident in the computer monitor sector in which technologies developed in the previous experience of TV manufacturing was successfully converted into the making of monitors. Taiwan's TV industry was mature in the 1970s and by the early 1980s, had consolidated into several major producers, including Tatung, Sampo, and Teco. All had close ties to Japanese technologies with Tatung licensing technologies from Toshiba, Sampo from Sharp, and Teco from Mitsubishi. Taking advantage of the experience accumulated during the process of TV production, these TV producers turned to produce computer monitors for PCs or terminals for mini-computers. They usually served as subcontractors for American or Japanese firms that engage in cut-throat price competition. For example, Tatung produced monitors for IBM, allowing IBM to compete with its rivals such as Apple and Commodore. Table 1 lists the top producers of computer monitors and terminals in 1985, former TV producers like Tatung, Teco, and Sampo played a significant role in exporting these producers. Besides these indigenous companies, the exports of computer monitors and terminals were dominated by foreign firms such as Zenith, Philips, Wang and WISE. This stands in sharp contrast with the exports of PCs, which were dominated by newly emerged companies such as Acer and Mitac, in addition to foreign firms.

Established TV producers had the advantage in the production of computer monitors and terminals because they had mastered the mass-production technologies with the aid of an army of component suppliers who provide low-cost components. The component suppliers of power supply, diodes, or passive components quickly diversified into the monitor industry with an extension of existing technologies.

The transition form the production of TV receivers into computer monitors was precipitated by large subcontracting orders from American and Japanese PC producers, a replication of the TV history of the 1970s. These orders allow Taiwanese monitor

producers to realize scale economies. The large-scale production nurtured a sophiscated production networks, encompassing components and parts suppliers ranging from cathay-ray tubes (CRTs), transformers, PCB, and all sorts of passive components. From the beginning of the PC industry, monitors have been sold separately as an independent device. Taiwanese producers quickly emerged as the world's leading suppliers of computer monitors, capturing over a half of the world market share as early as 1990. The dominant position of the monitor production also allowed Taiwan to capture the upstream market for CRT. Chung-Hua Picture Tubes, a subsidiary of Tatung, seized this opportunity to become the world's largest supplier of monitor-used CRT. The transformation of the TV industry into computer-monitor industry also caught up with multinational firms operating in Taiwan. Philips, one of the largest TV producers in Taiwan, also became the largest monitor producer. Mitsushita, which made TV receivers for the local market up to the 1980s, also switched to produce computer monitors for export to the Japanese market.

Despite the dominance of large producers in the monitor industry, SMEs still had some room to operate as small local PC producers and traders prefer to deal with small suppliers. Because technology was mature, entry barriers to the industry were low. There were three major new entrants in the 1980s without previous experience in TV production, Liteon, ADI and Chuntex. Liteon was a diversification from the LED industry, and ADI a diversification from the shoe-manufacturing industry while Chuntex was a newly established firm. Chuntex specialized in system design and out-sourced components and parts from the local networks. Another two major entrants appeared in the 1990s: Delta and Viewsonic. Delta, a major producer of switching power supply, diversified into monitor production in the early 1990s and inaugurated first production in its Thailand subsidiary. Viewsonic, a design house based in California, organized production and sourced everything from Taiwan. Delta

served as an OEM suppliers, working mainly for Japanese PC producers such as Sony, who just began to out-source computer monitors. Viewsonic positioned itself as an independent monitor supplier, promising the highest quality products.

The monitor industry went into a process of consolidation in the early 1990s. Acer Peripheral (a subsidiary of Acer), Philips, Liteon and Tatung became the top-four monitor manufacturers, capturing over a half of Taiwan's total production. Acer Peripheral and Tatung also embarked upon foreign production as early as 1989. Acer first established a plant in Malaysia and later in China, while Tatung invested in Thailand and China. Globalization of production by major producers, whereby products are horizontally differentiated, foreclosed the market opportunities for small firms. Since 1990, there were few new entrants to the monitor industry; only diversification investments like that of Delta took place.

V. Niche Technologies and Peripheral Producers

One characteristics of SMEs in Taiwan's PC industry is that they focus on a small segment of technology, which is often neglected by market leaders, and develop it into peripheral products that complement with the main system. This strategy offers two advantages. First, a single niche technology enables a small start-up to enter the industry that was dominated by technological giants, such as IBM. Second, the products based on this niche technology is often peripheral products that add value to the PC system and therefore can leverage on the main producers without presenting a threat to them. This "alliance" strategy works well for the Taiwanese industry.

The strategy was manifested by Taiwanese firms' venturing into computer mice and scanners. Computer mouse was first invented by an American company named Mouse System in 1982. It was designed for program simulation. Neither Mouse System nor the major PC makers consider it a significant add-on device to the system.

Some Taiwanese companies, notably KYE and Primax, venture into this industry by improving the capabilities of the device through their own R&D. It was gradually accepted by the consumers. When Microsoft introduced the software Windows, mouse was "designed in" as a key apparatus that moves the pointer with the capability of making data entry and execution instructions. It later became an indispensable device for graphics as it allows the pointer to draw curves, dominating the functions of a keyboard which only allows movements horizontally or vertically. It also enables the editing and compilation of images which lies beyond the reach of a traditional keyboard.

Because of the decisive entry of Taiwanese firms and their small and cumulative innovations, Taiwan almost monopolize the production of computer mice with nearly 90% of the world's market share. The only challenger to Taiwanese dominance came from the late-established Swiss firm Logitec. But Logitec undertakes the entire production of computer mice in Taiwan. The Swiss operation is limited to design, and today, even the design function is largely shifted to Taiwan.

The other computer peripheral in which Taiwanese firms excel is the scanner used in image procession. Although image-processing has been considered a major part of data storage and processing by the PC industry from the very beginning. One of Taiwanese firms, Microtek, have entered the field early and succeeded in making major technological break-throughs. In 1986, Microtek introduced the first desk-top scanner capable of making image entry into a computer for processing and storage. This was followed by Mustek and Umax which introduced similar products. Unlike the computer mouse, Taiwan failed to dominate the scanner industry as it faced with stiff competition from a major player, namely HP. As a market leader in printers, HP embraces extensive technologies in image processing. HP introduced a desk-top scanner in 1987, soon after Microtek, and bundled the scanners with its printers in

sales promotion. Unable to match up with HP's marketing power, some Taiwanese scanner producers have since succumbed and serve as subcontractors for HP. Some choose to specialize in niche markets, such as scanners catered to hospitals and publishers rather than to offices, to avoid head-on competition with HP.

In addition to mouse and scanner, there are other kinds of peripherals such as CD-ROM drives, modems, video cards, sound cards, etc. A common feature of the peripheral makers is a limited scope for growth. Even if they become the leading producer in the niche market in which they specialize, they tend to remain a small player in the PC industry because the value of their products only account for a small fraction of the PC system. If they want to move into the mainstream of the industry, they have to pursue an aggressive strategy of diversification and that often entails a large amount of capital. One of the few firms that have succeeded in growing into major companies in the industry is Acer Peripheral. Initially specialized in the production of monitors and keyboards, Acer Peripheral diversified into scanners and CD-ROM drives, and more recently into cellular-phone handsets. From the beginning, Acer Peripheral served as an OEM subcontractor to major PC makers such as IBM and HP. Being a subsidiary of Acer, it had little difficulty raising funds for expansion and diversification. In addition to the back-up from a resourceful parent company, Acer Peripheral also succeeded in promoting itself to the position of a major supplier of monitors in the early 1990s along with Philips and Tatung and CD-ROM drives in the mid-1990s. Large production base allows it to devote to R&D to exploit new product frontiers, notably cellular-phone handset.

Size appears to be an important foundation of diversification. The advantage gained from a large scale in the production of mature products, such as monitor and keyboard, lies mainly with the bargaining power in the procurement of components and parts. From the technological perspective, a dominant market position also

suggests the firm's superiority in managing mass production. The risks of diversification are reduced by the low-cost supply of components and parts, and by the ability to engage in the mass production of new products. The nature of the production process that Acer Peripheral diversifies into is similar to the ones that it has excelled. As long as the technological barriers can be overcome, the diversification incurs only a small risk. Recently some scanner producers diversified into the production of digital cameras because they knew how and where to obtain high-quality lens.

Because of narrow specialization of Taiwanese firms, particularly in the area of computer peripherals, there seems to be little evidence of technology synergy in diversification, however. No firm in Taiwan stands close to the caliber of IBM which embraces a wide range of technologies with immense potential to create synergy effects. Taiwanese firms are so thinly focused, they only stand out in a small area of technologies. The benefits of technology development comes from a leverage with technology leaders rather than synergy. Because of the lack of synergy, these peripheral producers rarely became the targets of merger and acquisition by major PC makers.

VI. Technology Jump of Calculator Makers

A major development of Taiwan's PC industry is the emergence of notebook computers in the 1990s. It seems logical that the manufacturers of desk-top PCs will naturally make a transition to notebook computers. But it turned out that the dominant force of notebook computer sector is composed of former calculator makers. Among four largest producers of notebook computers, Quantas, Acer, Compal, Inventc, only Acer made the transition from desk-top production, the other three had been absent in PC manufacturing. Compal engaged in the production of monitors but never

experienced the integration of the whole PC system. Incidentally, Quantas, Compal and Inventc were all spin-offs of Taiwan's pioneer calculator maker in the 1970s, San-Ai. The ability of the calculators to jump the technology divide was partly explained by the availability of the relevant technologies from the public institution. In 1992, the Taiwan government organized a research consortium on notebook computers, with government funding and technological assistance from the state-own research institution, ITRI. More than 40 private firms, many of which SMEs, participated in the project. The consortium successfully developed a prototype notebook PC and the relevant technologies were dispensed within the participants. This initiative produced a large number of new entrants to the notebook PC production, creating a new industry almost instantaneously. Stiff price competition ensued following the massive entry despite various technological difficulties encountered by each competitor in the process of commercialization. In the end, three former calculator producers seized the top positions of the industry.

Unlike the desk-top computers where the assembly of parts into the final products is by no means a critical part of production, the assembly of parts is essential to the quality of notebook PCs. The assembly of major devices, including data input, storage, processing, and display devices into a compact housing is a demanding task, where technological requirement is high in the areas of compartments interface and heat control. The making of calculators faces the same technological requirement, although to a much lesser extent. More importantly, the production of notebook PCs entails effective coordination among the design and supply of various parts and components. Most parts of desk-top PCs are modulized with standard designs and can be outsourced with a small effort of coordination. In contrast, notebook PCs are not yet standardized and functional alignment and mechanical compatibility among various parts is critical to the quality of the products. This gives the calculator makers

a competitive advantage because they are used to working with a large number of suppliers under the cut-throat price competition. They are good at cost control as well as quality control. The production networks that they have established in the previous working relationship turned out to be a big asset for their competition in the PC industry.

Calculator makers were used to contract manufacturing, so they continued to play that role, and this time for major system producers like Dell, Compaq, and HP. Contract manufacturing guarantees these companies a large scale of production, which in turn, allows them to exploit the bargaining power as a dominant buyer in the supplier networks. They pushed the price of components down to the lowest level and required instant on-site delivery of components and parts to the production lines. Just-in-time system of supply is adopted by them to drive down the inventory cast and to drive up the flexibility of production. Consolidation quickly took place in the mid-1990s as technological bugs in mass production were overcome and SMEs were subsequently driven out of the market. In 1996, the top-four makers accounted for 61.9% of the market share (Chen et. al 2001). SMEs could not survive because there was not a good way of depriving the technologies embodied in mass production.

VII. Conclusions

In conclusion, four groups of firms led the development of Taiwan's personal computer industry. The first group consists of new entrants to the industry in the early 1980s. Except for a few firms such as Acer and Mitac, most of them remain SMEs throughout the 1990s. SMEs overcame the technological barriers to entry through vertical disintegration and a de-technology arrangement whereby the most technology-demanding tasks are outsourced from specialists who serve as independent contractors. Economies of scale are realized through the pooling of work

orders in the capital-intensive segment of production.

The second group consists of established large firms who had accumulated relevant technologies through the experience of making TV receivers in the 1970s. They made technological transition and took advantage of a sophiscated supply networks that they have helped orchestrated to break into the computer monitor production. Their dominance eventually foreclosed the participation by SMEs in this sector and new entry only occurred through diversification by other established firms. Economies of scale are realized by OEM contracts with multinational firms.

The third group consists of small start-ups who established themselves with niche technologies and concentrate their production in computer peripherals. They leveraged their technologies with those of system makers and manufacture products to add value to the PC systems. They continued to innovate in order to maintain their leading position in a narrow field, and made necessary diversification to keep the company growing. Nevertheless they rarely grew into a major company in the entire PC industry.

The fourth group consists of some established, medium-size companies who had experience of making calculators in the 1970s. This group of firms excelled in the production of notebook PCs. They made a jump over the technological divide with the assistance from the public-sponsored R&D. They came to dominate the notebook PC industry in the 1990s by exploiting the production networks that they have mastered in managing. They maintained a competitive edge over their rivals in terms of cost control and work coordination and this edge can best be realized through large-scale production. The dominance of these companies also left no room for SMEs in the industry.

There is a common thread tying four groups of firms together, that is, alliance. Whoever succeeds in the management of alliance excels in the industry. The first

group of firms emphasize technological division of labor which leads to the prevalence of SMEs. The second group emphasizes alliance with foreign firms to gain economies of scale, whereby international division of labor is practiced. The third group emphasizes the niche technologies that are considered of secondary importance by the market leaders, whereby alliance between the core and the peripherals is formed. The fourth group excels with an ability to manage the supplier network whereby alliance between a system integrator and components and parts suppliers is formed. The benefits of this traditional type of division of labor are again magnified in large-scale production in which SMEs find it hard to compete. The relationship in this type of alliance is also asymmetric.

Table 1

Top Exporters of PCs, Computer Monitors and Terminals, 1985.

PCs	Monitors	Terminals
Atari**	Tatung*	WISE**
Wang**	Teco*	Digital**
Acer Peripherals	Zenith**	Compal
Acer	Philips**	ADI
WISE**	Wang**	Ampre**
Digital**	Sampo*	Kuo-Feng
Mitac	Yu-fu	Tatung*
Shinta	ADI	Teco*
Microtek	Kaion**	Hui-Chao
	Kyozai**	Yu-Fu

Source: Institute for Information Industry, *Information Industry Yearbook*, 1986.

Note: * are former TV producers, ** are foreign corporations.

References

Branson, Jack, 1970, "Technology Transfer through the International Firm", *American Economic Review* (papers and proceedings), vol.60, pp.435-40.

Chen, Tain-Jy, Shin-Horng Chen and Meng-Chun Liu, 2001, "Implications, Challenges and Prospects for Taiwan in the Knowledge-based Economy," in Ng Chee Yuen and Charla Griffy-Brown (eds.) *Trends and Issues in East Asia 2001*, Tokyo: International Development Research Institute.

Chien, Jui-Ch'ang, 1988, *Den Tze Ling Tso Chien Yeh Fa Chan Ch'e Lieh Yen Chiu Pao Kao* (Development Strategy of The Electronic Components Industry) (Project Report), Taipei: Taiwan Institute for Economic Research.

Chou, Cheng-Hsien, 1996, *Shi Cheng-Rong Te Den Nou Chuan Chi* (Legends of Stan Shih) Taipei: Lien-Ching Press.

Chou, Fen-Wan, Legacy of Austek, Taipei: Shiang-Hson publishing Co. (in Chinese)

Dedrick, Jason and Kenneth Kraemer, 1998, *Asia's Computer Challenge*, New York: Oxford University Press.

IDIC (Industrial Development and Investment Center), 1968, "The Electronics Industry in Taiwan", *Industry of Free China*, vol. 29, no. 3, pp.32-44.

Levy, Jonathan, 1981, *Diffusion of Technology and Patterns of International Trade: The Case of Television Receivers*, Ph. D. Thesis, Yale University.

Liu, Tai-Yin, 1985, Jih Shang :Lai Hua Tou Tzu Tui Wo Kuo Ching Chi Chi Yin Shiang (Economic Impacts of Japanese Investment in Taiwan), Taipei: Project Report to Research and Development Council, Executive Yuan.

Schive, Chi and Ryh-song Yeh, 1980, "Direct Foreign Investment and Taiwan's TV Industry", Economic Essays, vol.9, no.2, pp.261-91.