財團法人 中華經濟研究院
CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH
75 Chang-Hsing St., Taipei, Taiwan, 106
Republic of China
TEL : 886-2-735-6006
FAX : 886-2-735-6035

ISBN 957-9676-14-3

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

DEVELOPMENT OF THE SMALL- AND MEDIUM-SIZED MANUFACTURERS IN TAIWAN'S PC INDUSTRY

MOMOKO KAWAKAMI

DISCUSSION PAPER SERIES No.9606
November 1996

Discussion papers are intended to provide prompt distribution of CIER's preliminary research work to interested scholars and to invite their discussions and critical comments.

The opinions expressed in these papers are those of the authors and do not necessarily reflect the views of the CIER.

Any comment or communication, please write to: Publications Department, Chung-Hua Institution for Economic Research, 75 Chang-Hsing Street, Taipei, Taiwan 106, ROC.

財團法人 中華經濟研究院

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH
75 Chang-Hsing St., Taipei, Taiwan, 106
Republic of China
TEL : 886-2-735-6006
FAX : 886-2-735-6035

ISBN 957-9676-14-3

CHUNG-HUA INSTITUTION FOR ECONOMIC RESEARCH

DEVELOPMENT OF THE SMALL- AND MEDIUM-SIZED MANUFACTURERS IN TAIWAN'S PC INDUSTRY

MOMOKO KAWAKAMI

DISCUSSION PAPER SERIES No.9606
November 1996

Discussion papers are intended to provide prompt distribution of CIER's preliminary research work to interested scholars and to invite their discussions and critical comments.

The opinions expressed in these papers are those of the authors and do not necessarily reflect the views of the CIER.

Any comment or communication, please write to: Publications Department, Chung-Hua Institution for Economic Research, 75 Chang-Hsing Street, Taipei, Taiwan 106, ROC.

Discussion Paper Series No. 9606

Development of the Small- and Medium-Sized Manufacturers in Taiwan's PC Industry

by

Momoko Kawakami

Visiting Assistant Research Fellow
Chung-Hua Institution for Economic Research
&
Overseas Research Fellow
Institute of Developing Economies, Japan

November 1996

Chung-Hua Institution for Economic Research

75 Chang-Hsing St., Taipei, Taiwan 106
Republic of China

MOMOKO KAWAKAMI

Development of the Small- and Medium-Sized Manufacturers in Taiwan's PC Industry

I. Introduction

Taiwan's personal computer industry (hereafter abbreviated PC industry)[1] has attained an amazing record of expansion since the mid-1980s. Its international market share for several products in 1995 was as high as 65% for motherboards, 64% for scanners, and 57% for monitors.[2] As Taiwan was primarily exporting simple labor-intensive products such as textiles and plastic products until the mid-1980s, this outstanding achievement in the PC industry is often referred to as a successful case of the upgrading of the industrial structure in a developing economy.

The development of the industry has the following three main characteristics: (1) diversification of products, or a backward and upgrading production shift from labor-intensive products, i.e. from PCs and peripherals, to capital-

[1] In this paper, I use "PC industry" as an abbreviation for "personal computer-related industry" : manufacturing of personal computers and peripheral products, including monitors, scanners, motherboards, add-on cards, computer mice, etc. The term covers a wide range of products, but my field research focused mainly on the manufacturers of PCs, monitors, and motherboards.

[2] Including overseas production values.

and technology-intensive products and components, (2) heavy reliance on OEM/ODM export orders, and (3) dramatic growth of local small- and medium-sized manufacturers (SMEs), who took the place of foreign manufacturers (FMs) as the main producers within several years.

The author is especially interested in the third point, firstly because Taiwan's PC industry's competitiveness stems from the flexibility provided by the rise of these SMEs (Ernst, 1992). Second, and more important, this process is a typical example of the development path of Taiwan's manufacturing industries, where the role of foreign firms is no more than that of catalyst (Schive, 1992). As is also the case with other industries in Taiwan, it was the energetic entry into the market of local SMEs that brought about the dramatic rise of Taiwan as the world's third largest producer in the information industry.

This is in contrast to many other Asian developing economies, where FMs are likely to continue to dominate production activities in the electronics industries. Also, this differs from the cases of Japan and South Korea, where large local corporations have led the expansion of the industry. The questions, then, are: why were these local SMEs in Taiwan able to enter the industry and grow, in spite of their limited capital and technology? What were the economic and technological backgrounds that made the vigorous entry activities of SMEs possible? Are other developing economies likely to follow the same path to witness the development of their own local SMEs in the PC industry?

In this paper, I will explore these problems by studying the background of the industry in Taiwan. First, I try to show that the development of Taiwan's PC industry is not a sudden and unexpected phenomena, but rather a natural process that started on the basis of technology formation during the preceding period of the 1960s and 70s. Second, I will show that the subcontracting production network prevalent in the export-oriented industrialization of Taiwan played a critical role in the rise of SMEs in the PC industry in two respects: on the one hand, it transmitted the production experience acquired in the preced-

ing expansion of Taiwan's electronics industry, as well as carrying various spillover effects from relationships with FMs, while on the other hand it lowered the market entry barriers to the industry, and thus made the entry of local SMEs possible.

In this paper, I primarily focus on the early phase of the industry's development, in 1980-90, when SMEs were very actively entering the market and subcontracting production networks developed rapidly. In Section II, the process by which Taiwan's PC industry developed and the main characteristics of the industry in Taiwan are summarized. Section III studies the activities of FMs and their impacts on the development of local SMEs. Section IV studies the basic conditions for the development of local PC manufacturers, the preceding development of the electronics industry, and the subcontracting production arrangements of the PC industry. The analysis is based on my interviews with 17 manufacturers and two informants, the list of which appears in Appendix 1. Emphasis in this section will be put on the critical role of the well-organized subcontracting production network in Taiwan, which evolved as an organizational response by SMEs to the environment. Section V is the conclusion.

II. Development of Taiwan's Local PC Manufacturers

1. Development of the PC Industry: Chronology

In Taiwan, production of PC-related products started around 1979, when a few American manufacturers began to produce terminals and monitors on the island (IDB Annual Report, 1982-83). Tables 1, 2, and 3 show the export value of the main products (1981-86), the annual production and export value

Table 1. Export Value of Taiwan's Major PC-Related Products

Unit: Million US$

Items	1981	82	83	84	85	86
Microcomputers	0.4	2.0	12.0	152.2	240.0	393.0
Terminals	3.8	21.2	96.7	207.1	225.0	317.0
Monitors	8.6	33.6	130.8	318.9	303.0	500.0
Magnetic Disk Devices	0.0	0.4	15.2	85.7	42.0	71.0
Printers	0.1	4.5	12.0	22.9	45.0	41.0
Peripheral N.E.S	0.9	2.0	22.0	124.7	256.0	44.0
Product total	13.9	63.7	288.7	911.5	1111.0	1366.0
(Share of products)	13.1	40.0	69.1	89.0	91.1	66.2
(Share of M+T+M/Prod.Ttl)	92.6	89.2	83.0	74.4	69.1	88.6
Computer parts	91.8	95.6	128.9	113.0	109.0	697.0
(Share of computer parts)	86.9	60.0	30.9	11.0	8.9	33.8
Total	105.6	159.2	417.6	1024.5	1220.0	2063.0

Source: *IDB Annual Report*, 1981-86.
Original Source: Market Intelligence Center (MIC), Institute for Information Industry.

Table 2. Annual Production and Export Value of Taiwan's Hardware Information Industry

Unit: Billion US Dollars

Year	1981	82	83	84	85	86	87
Production of information industry	n.a.	n.a.	n.a.	n.a.	1.26	2.13	3.84
Export of information industry	0.11	0.16	0.42	1.00	1.22	2.06	3.70
Export/output ratio (%)	n.a.	n.a.	n.a.	n.a.	96.83	96.67	96.41
Year	1988	89	90	91	92	93	94
Production of information industry	5.32	5.48	6.15	6.91	8.39	9.57	11.58
Export of information industry	5.15	5.24	5.87	6.55	n.a.	n.a.	n.a.
Export/output ratio (%)	96.77	95.62	95.51	94.76	n.a.	n.a.	n.a.

Table 3. Annual Value of Taiwan's Export by FMs and Llocal Manufacturers

Unit: Million US Dollars

	1984	85	86	87	88	89	90
Production by FMs	572	708	908	1443	1800	1835	1762
(Share) %	57.0	58.0	44.0	39.0	36.0	35.0	30.0
OEM production by LMs	402	451	805	1518	2200	2269	2760
(Share) %	40.0	37.0	39.0	41.0	44.0	43.3	47.0
OBM production by LMs	30	61	351	740	1000	1140	1351
(Share) %	3.0	5.0	17.0	20.0	20.0	21.7	23.0
Total	1004	1220	2064	3701	5000	5244	5873

Source: Same as Table 2.
Original Source: MIC.

Note: FM stands for foreign manufacturers, and LM stands for local manufacturers.
OEM stands for original equipment manufacturing, and OBM stands for original brand manufacturing.

of the industry (1981-94)[3], and the annual export value of the foreign and local manufacturers (1984-90). As Table 1 indicates, the export of monitors and terminals increased remarkably, and the industry started to expand rapidly in 1982. In 1983, the export of microcomputers showed a sudden increase, and they became one of the primary export items of the industry. In 1984, total export value for the PC industry exceeded one billion US dollars, and as early as 1986, Taiwan recorded the 7th largest information industry production value in the world.

In 1989, however, the industry experienced a slowdown due to recession in the European, US, and Japanese economies. Although the industry's growth rate remained positive, the slowdown drove many local manufacturers, especially SMEs, out of the market. Also during the recession period of 1989-91, a sluggish world market, appreciation of the New Taiwan dollar, and a labor shortage on the island forced several FMs to discontinue their operations in Taiwan.

Starting in 1992, the industry picked up again. In this year, Compaq announced a bold price cut policy which led to worldwide price competition in the industry. Faced with intensified market competition, many FMs increased their OEM/ODM orders to Taiwan, and this led to a strong recovery of the PC industry in Taiwan.

Throughout this period of growth, Taiwan's PC industry was led by export growth. Table 2 reveals that about 95% of the total demand of the industry continuously came from the international market. OEM was the main source of orders for local manufacturers, with the share in total orders being 93% in 1984 and 67% in 1990 (Table 3). As for product composition, computer parts dominated at 87% of total exports in 1981, but declined very rapidly to 11% in 1984. Since then, the top three products, i.e., microcomputers,

---

[3] Figures for the hardware information industry are used. The elements of the "hardware information industry" basically correspond to those of the "PC industry."

terminals, and monitors, have continuously led the industry's development, with their combined share in production export being 92.6% in 1981 and 88.6% in 1986 (Table 1).

2. Characteristics

The development of Taiwan's PC industry summarized above has two conspicuous characteristics. First, a significant change in the attributes of the producers occurred over the course of the industry's expansion: FMs as leading producers came to be replaced by local producers by the early 1990s, as local manufacturers caught up with and substituted for these FMs (CIER, 1988, p.84).

Table 4 compares the annual values of exports by FMs and local manufacturers. In 1984, 57% of total exports was that of FMs. However, the position of FMs gradually faded through the 1980s, as local manufacturers successfully increased their production and exports. As a result, the export share of FMs fell to 30% by 1990. Unfortunately, detailed figures for the 1990s are not available, as MIC (the Market Intelligence Center of the Institute for the Information Industry), the information source, stopped collecting this data after 1990. But, unarguably, the decline of the production and export share of FMs accelerated after the slowdown in 1989-91, as American FMs such as Commodore stopped their production in Taiwan during this period. In 1995, the production share of FMs was as low as around 15% (Hwang, 1995, p.45). Kuo (1995, p.165) writes, "Taiwan's electronics industry has been transformed from a FM-dependent assembly industry to a self-sustaining, continually upgrading locomotive for Taiwan's industrial growth in the 1980s and beyond." This is mostly true in the case of the PC industry.

The second characteristic of the development process of the industry is the fact that it was not the growth of certain large-scale corporations but rather the vigorous market entry activities of SMEs that brought about the rise of local manufacturers as the main producers. All through the 1980s, news-

Table 4. Number of Manufacturers of Each PC-Related Product

	1983-84	84-85	85-86	86-87	87-88	88-90	89-90	90-91	91-92	92-93	93-94	94-95
Data-Processing Systems	2	9	-	11	7	9	17	18	24	23	21	19
Small-Business Systems (<$20K)	12	14	-	16	19	19	21	26	29	25	17	14
Small Systems ($20K-$100K)	5	5	-	15	20	19	19	22	25	21	18	17
Medium-sized Systems ($0.1-$1 Million	1	2	-	2	3	2	4	4	5	4	4	3
Large-sized Systems ($1M-)	1	-	-	1	1	1	1	3	5	7	6	5
Microcomputers & Minicomputers	4	3	-	5	10	18	23	30	29	25	18	9
Microcomputers	53	73	-	78	102	109	108	117	111	103	83	73
Minicomputers		2	-	7	12	15	19	21	23	64	46	33
16-bit and below	1	15	-	25	40	42	47	52	50	-	-	-
32-bit and below	1	3	-	4	20	22	27	33	35	-	-	-
Personal Computers		20	-	30	64	135	162	201	152	202	161	141
Laptop Type	-	-	-	-	-	-	-	-	22	22	19	12
Notebook Type	-	-	-	-	-	-	-	-	40	45	42	42
Pocket Type	-	-	-	-	-	-	-	-	2	4	6	6

Source: Member list of Taiwan Electric Appliance Manufacturers' Association.

Note1: "Buyers' Guide" (TEAMA) is used instead of TEMMA members' list for 1986-87, as the list for the year is lacking.

2: The census for "1983-84" was conducted in 1983. Similarly, "1994-95" covers the members in 1994.

3: According to the Association, data-processing systems refer to those designed for special business and engineering purposes, and minicomputers are relatively large-sized workstations.

Also, personal computers are defined as those whose designs are more standardized and are more mutually compatible compared with microcomputers.

4: The table is based on the self-assessment of products by manufacturers. While some manufacturers reported themselves as manufacturing the rough classification of "personal computers."

others chose a more detailed classification, i.e. "laptop type." Therefore, the number of personal computer manufacturers, for example, is obtained by adding up the number for all four categories.

papers continuously reported on the "overheated rush into the market" (*Central Daily News*, 1983.6.22), the "large number of small and medium manufacturers rushing into the information industry crazily" (*Economic Daily News*, 1986.10.7), and the "entry of a large number of manufacturers with small production scale and capital" (*United Daily News*, 1987.9.4).

Chen (1994) revealed that the electronics industry recorded the highest gross entry ratio[4] (18.7%) and the second highest net entrance ratio (9.5%) among 20 manufacturing sectors during the period 1983-89. Though the figures include non-PC industry manufacturers, and therefore remain only indirect evidence, they indicate the vigor with which PC-related manufacturers were entering the market. Further evidence is the decline of the export share of the 20 largest exporters; it dropped from 83.2% in 1983 to 53.7% in 1988. The government attributed the decline to the increase in the number of small-scale exporters during the period (*IDB Annual Report*, 1988).

Table 4 shows the number of manufacturers of each PC-related product that belong to TEAMA (Taiwan Electric Appliance Manufacturers' Association). Here, we can see clearly that the rush of manufacturers into the market was the main driving force of the industry's continuous growth. The number of personal computer manufacturers that belong to TEAMA increased by ten times during 1984-90 (from 20 in 1984 to 201 in 1990), while the number of PC units produced in Taiwan increased by four times (from 584,000 in 1984 to 2,381,000 in 1990).

Moreover, the table does not demonstrate the full extent of the market entry activity of local SMEs, as it covers only the members of TEAMA, and so does not necessarily include underground manufacturers. Indeed, the actual number of manufacturers grew much faster than it appears in Table 4. For

---

[4] Gross entry ratio, gross exit ratio, and net entry ratio is defined respectively as E_t / N_t, $(N_{t-1}-N_t+E_t)/N_t$, and $(N_{t-1}-N_t)/N_t$, where E_t is the number of new entry in the year of t and N_t is the number of manufacturers in the year of t.

example, a report claims that the number of microcomputer manufacturers increased from 10 in the early 1980s to 100 in 1983 (Institute for the Information Industry, 1990, p.6), while, according to Table 4, there are only 59 makers in that year.[5] This discrepancy seems to have originated from the fact that a large number of local SMEs were tiny underground manufacturers that engaged in subcontracting production. Some of the manufacturers I interviewed (M5, M7) observed that there were "numerous tiny subcontractors" in Taiwan in this period. The market entry of SMEs was much more vigorous than is indicated by the statistics.

By the mid-1980s, the problems caused by the number of SMEs swarming into the PC manufacturing business came to be recognized as a threat to the industry's sound development. The government, once concerned that most of the industry's exports were concentrated among the small number of large FMs (*IDB Annual Report,* 1985), came to ascribe the difficulty of the industry to the fact that manufacturers were too small in scale and too large in number.[6] In 1988, the number of companies engaged in the information industry, including software manufacturers and trading, jumped to 4,400 from 1,709 in 1985 (*IDB Annual Report*, 1988). The *IDB Annual Report* (1992, p.190) states:

> [These SMEs] have no other choice but to follow the market change and foreign large manufacturers. They all produce the same or similar products, hence bringing about vicious price-cutting competition. There is no way to maintain market order and possible profit.

Thus, the energetic entry of SMEs into the PC industry continued all through the 1980s. It is the background and mechanism of this energetic mar-

---

[5] Including manufacturers of microcomputers and minicomputers.

[6] The assistant director of ERSO (Electronics Research and Service Organization) of the Industrial Technological Research Institute also expressed his concern about the smallness of local manufacturers in the mid-1980s (*China Times*, 1984.2.22).

ket entry that will be explored in Section IV. But before proceeding to that analysis, we'll take a brief look at the impacts of the production and purchasing activities of FMs on the development of local SMEs in the next section.

III. The Role of Foreign Manufacturers

In general, the role of FMs in the postwar industrialization of Taiwan has been rather indirect, where FMs "served less as an engine of growth than as a catalyst to significantly facilitate the development process" (Schive, 1992, p.102). In the case of the PC industry, too, some authors conclude that "it is not through the technology transfer but through the introduction of new products, that foreign manufacturers showed the direction of development for local manufacturers" (CIER, 1988, p.84).

However, the role of FMs in the PC industry is undoubtedly far more important than in other industries. As we have already seen in Section II, the position of FMs was quite high both in the production and export segments of the industry in the early to mid-1980s (Table 3). Obviously, if there had not been local production by these FMs, Taiwan could never have risen to become a world-famous "PC Island" within only a decade.

FMs' other contribution to the development of Taiwan's PC industry came from their OEM/ODM procurement activities. In the PC industry, the change in products and technology is extremely rapid, and differentiation in products has a wide range. Many large PC manufacturers have resorted to OEM procurement in Taiwan in order to lower the cost of production and adjustment, and to respond to the rapid market change. Especially after the mid-1980s, when labor costs on the island rose and the New Taiwan dollar appreciated, several FMs began to take advantage of Taiwanese manufacturers' accumulated experience in mass production and in R&D rather than simply exploiting Taiwan's cheap labor. Thus, Taiwan came to be significant to

FMs as a foothold for OEM/ODM procurement rather than as a simple production base. This change is reflected in the rapid expansion of OEM export value (Table 3). These OEM orders provided local manufacturers with vast opportunities to expand production and accumulate experience without incurring marketing costs. At the same time, FMs extended various forms of assistance to local manufacturers in procuring OEM/ODM orders.

In this section, we study the significance of FM activities, including local production and OEM/ODM procurement, for the development of local PC manufacturers. The following three aspects are considered: (1) demonstration effects, (2) technology assistance and nurturing of human resources, and (3) stimulation of the components industry.

1. Demonstration Effects

At first, FMs played a critical role in introducing new products to Taiwan. They stimulated the development of local manufacturers by demonstrating the future possibility of this industry. Obviously, the successful expansion of exports by FMs in this period induced both existing and potential local manufacturers to pursue this profitable new market.

Similarly, OEM procurement by FMs showed local manufacturers not only the profitability of the industry, but also the fact that they had the capability to manufacture PC-related products. One example of the introduction of new products by FMs is power supplies, production of which was started by the two pioneers Vidar Sun Moon Star and Delta Electronics with OEM orders and technology assistance from IBM (interview with IBM).

2. Technology Assistance and Nurturing of Human Resources

Upon procuring OEM orders, FMs extended various forms of technology and managerial assistance to local manufacturers. This assistance played a

critical role in the development of local manufacturers. Let's take the example of IBM, the FM in Taiwan best known for its effectual assistance.[7]

IBM's procurement value in Taiwan grew from US$310 million in 1984 to US$580 million in 1995. In 1986, Taiwan ranked as its second largest OEM source in the world (*Commonwealth*, 1986.11.1). Almost all of the staff of the Procurement Division of Taiwan IBM are engineers with rich experience in production engineering. They routinely go out to the shopfloors of local manufacturers to keep a close eye on their production lines. In order to extend appropriate assistance, a previous career at other manufacturers is almost always a requirement for serving at IBM.

M1 developed an original monitor on the basis of its experience in TV production in 1980. But it was after M1 received OEM orders from IBM in 1981 that production started to expand rapidly. M1 admits, "IBM played a critical role in the technology formation process of our company. Their assistance was effective, and it was a typical process of learning." IBM points out that they contributed to M1 in two ways. First, they extended direct assistance in the R&D process for creating the monitors. Headquarters in the US and Taiwan IBM were both involved. Second, it supported M1 indirectly in accumulating production experience with its high volume of orders.

M2 is another large monitor supplier that grew with the support of IBM's procurement. Similar to the case of M1, M2 benefited from the large volume orders and assistance from IBM in the early to mid-1980s. Business with IBM terminated in the late 1980s. But it had provided M2 with a chance to enter the market and start to consolidate the technology from the initial phase of the industry's development (interview with M2).

Compeq, the largest PCB manufacturer in Taiwan, is another example of a local manufacturer nurtured under the assistance of IBM. It started to manu-

---

[7] The following is based on an interview with Taiwan IBM.

facture multi-layer PCBs in the early 1980s, as it was "forced by customers to do so" (*Commonwealth*, 1985.8.1). Taiwan IBM extended assistance in production engineering, and the company headquarters in the US assisted in R&D, and thus "made Compeq's 50 engineers try and experiment continuously"(*Commonwealth*, 1985.8.1), whenever a problem arose. Clearly, this technology assistance extended by OEM customers played a critical role in the technology formation process of these Taiwanese manufacturers.

Also many manufacturers indicate that they improved their quality control, design of their production line, and production design through assistance from OEM customers. One leading monitor manufacturer (M3) developed all of its products by itself. Still, it admits that detailed assistance in production technology and quality control extended by its Japanese customers improved its productivity substantially. The same thing was heard from other manufacturers (M14, M15). "Japanese customers are very nervous about quality control. We learned a lot from them, including how to tidy up the shopfloor."

Another significant contribution of FMs has been their training and nurturing of employees, many of whom eventually left FMs to play an important role in information and technology diffusion from FMs. Some set up or joined local manufacturers after their employment at the FMs' local branches. Some exploited the experience they accumulated while serving as engineers at local OEM manufacturers. During field research, I came across many former employees of FMs who founded their own manufacturing operations, or were recruited as senior engineers or managers by local manufacturers. An industrial analyst comments, "Required experts for local manufacturers were supplied by FMs in the early to mid-1980s" (Informant 1).

A good example of the utilization of the engineers fostered by FMs is the case of a present leading monitor manufacturer, M4. On its entry to the field of monitors in the late 1980s, it adopted a strategy of starting from a multi-frequency model, a technologically more advanced product compared to the single-frequency model prevalent at that time. M4 intended to overcome its

disadvantage of late entry by jumping into this frontier market. For this purpose, it recruited a group of engineers from an American monitor manufacturer which was leaving Taiwan at that time, and succeeded in the new market through the continuous efforts of those engineers. Hwang (1995, pp.45-46) writes, "Foreign electronics companies nurtured the human resources which Taiwan's PC industry needed most during its rapid expansion... and if they had not left Taiwan at the appropriate time, Taiwan could have been faced with a lack of human resources." M4 demonstrates the unintended but well-timed contribution of FMs to the subsequent development of local manufacturers.

In the case of IBM, "there are several manufacturers set up by former IBM employees. As they understand our requirements and standards very well, we often do business with them" (interview with IBM).

Nevertheless, the critical key to success in realizing these spillover effects of FMs lay not in the technology assistance itself. Rather, it lay in the smooth transmission of market information and production experience from FMs to local PC manufacturers via the movement of Taiwanese production engineers, managers, and experts in component procurement. These human resources, together with the return of engineers who had studied and accumulated their experience abroad (mostly in the US), proved to be the most important asset to the subsequent rise of local manufacturers.

3. Stimulation of the Components Industry

Local production of FMs stimulated the PC components industry with its production volume, especially in the initial phase of the industry's development. FMs' large-scale procurement of components, together with their strict cost and quality requirements, stimulated the growth of the components industry (Informants 1, 2).

As we have seen above, the presence of FMs was very significant for the success of Taiwan's PC industry. However, as is indicated by the case of

ASEAN countries, where expanding inflow of FMs hasn't induced the emergence of local PC manufacturers, the mere inflow of FMs does not stimulate the growth of local manufacturers. In other words, the presence of FMs is only a necessary condition for the rise and growth of local SMEs, not a sufficient one. Therefore, in order to understand the critical key to the successful growth of local SMEs, we must explore the idiosyncrasies of the Taiwanese economy that made the rapid rise of local manufacturers possible. In the next section, we will take a look at some of the elements that formed the background to the rise of local SMEs.

IV. The Rise of Local SMEs

As we have seen in Section I, it was the vigorous market entry activity of local SMEs that brought about the rapid expansion of Taiwan's PC industry. Actually, this "swarming" phenomenon is not unique to this industry, but is a typical pattern of industrial development in postwar Taiwan. This can be seen partly from the fact that the most common description of the active market entry in the PC industry was that it was "just as the case of other industries" (*Commercial Times*, 1982.12.11). "The PC industry is the most conspicuous example of the very serious situation of bee-like swarming market entry in Taiwan" (*Central Daily News*, 1985.3.30).

In this section, I will try to clarify the basic mechanism through which local SMEs entered the highly competitive market of the PC industry, in spite of their limited capital and technology. First, we study the step-by-step process of technology formation in the consumer electronics industry during the 1960s and 1970s. It will be clear that it was strong human resources and the components industry, both of which were cultivated by the preceding growth of consumer electronics production, that facilitated the market entry of SMEs, as well as the expansion of Taiwan's PC industry. Second, we examine the relevance of subcontracting production arrangements for the market entry of

SMEs. By analyzing the results of interviews with the management of several local PC manufacturers, we can see that the minute division of labor of the subcontracting production network played a critical role in the industrial development of the local PC industry in Taiwan. It acted as a carrier for swift transmission of information and technology, while at the same time it lowered the market entry barrier for local SMEs.

1. Legacy from the Consumer Electronics Industry: Continuous Process of Technology Formation

In the early 1980s when Taiwan's PC industry started its rapid expansion, there were two types of local manufacturers on the island: the large-scale electronics manufacturers, and the petty manufacturers that started with "nothing in hand." The former started with monitors/terminals, as TV sets, one of their primary products, shared technological similarity with these peripherals. As for the latter type of manufacturers, many of them started from assembly or subcontracting production steps of PCs and peripherals, expanding step-by-step. Though these two types of manufacturers differed in their initial condition of entry, they benefited equally from the good industrial basis that was already established by the early 1980s. The purpose of this subsection is to show that the development of local PC manufacturers was an extension of the continuous development process based on the heritage of the electronics industry since the early 1960s. In the following, I will study the development of (a) the TV industry, (b) the calculator industry, (c) videogame machines, (d) fake-Apple computers, and (e) early entrants to the PC industry, with an emphasis on their significance for the subsequent development of the PC industry.

(1) The TV Industry: Consolidating the Foundation for the Electronics Industry[8]

Taiwan's electronics industry started in the 1960s,[9] when assembly production of transistor radios and black-and-white TV sets was started, mainly by foreign manufacturers. These two products dominated, comprising 80.6% of the total output of the electronics industry in 1966, and led the growth of the consumer electronics industry all through the 1960s to the early 1970s. The TV industry in particular became a significant milestone in the subsequent development of the electronics industry.

Figure 1 shows the change in the annual production of TV sets (1964-85). In 1962, several Japanese manufacturers, including Matsushita, Mitsubishi and NEC, set up joint ventures in Taiwan, and started production of black-and-white TV sets in 1963. The number of manufacturers grew from 1 in 1962 to 22 in 1979 for black-and-white TV sets, and from four in 1969[10] to 17 in 1979 for color TV sets. Among the 22 manufacturers operating in 1979, seven were 100% foreign manufacturers, four were joint ventures (all of them were with Japanese cooperation) and the remaining 11 were local manufacturers.

In this period, the government adopted an import substitution policy for the TV industry, with the intention of protecting local producers. A high import tariff rate for finished TV sets and various components, import controls, and local content regulation were adopted. At the same time, the government allowed export-oriented manufacturers to make good use of Taiwan's cheap labor without being affected by the protective policy adopted for the local

---

[8] The following description is based on Yeh (1980) and Liu (1987).

[9] Some manufacturers engaged in radio assembly in the 1950s, but "there was no such concept as industrial engineering; every product was assembled with numerous pieces of spare parts by one worker" (Lin, 1986).

[10] Production of color TV sets was started in this year.

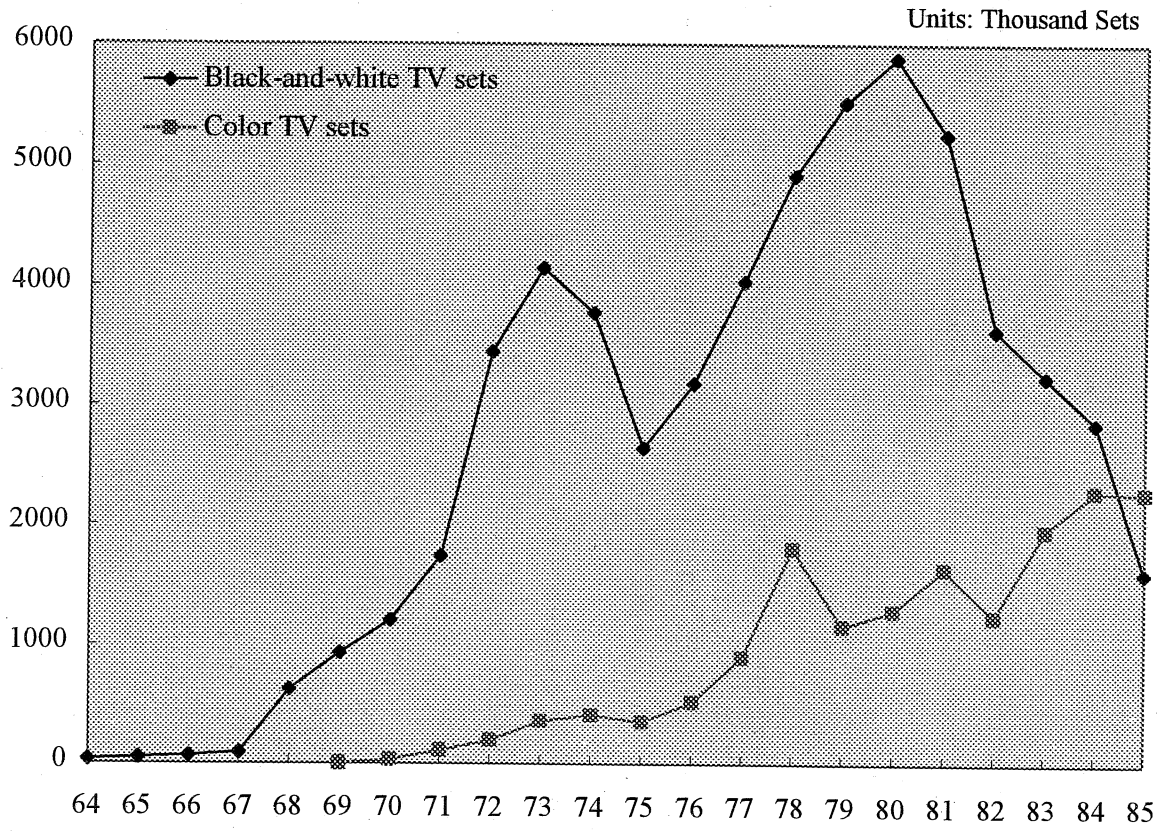

Figure 1. Annual Production Volume of TV Sets

market. While foreign manufacturers sold 99% of their products back to their parent companies, most of the local producers targeted the domestic market. As a result, foreign manufacturers, with a high export ratio, high volume of production and relatively low local content, and domestic manufacturers, with a low export ratio, small volume of production and high local content, coexisted on the island. It was this "dichotomy" (Satoh, 1996) between export-oriented foreign manufacturers and local manufacturers that made TV production an important step toward the PC industry.

On one hand, this dichotomy provided local manufacturers with "opportunities to learn foreign technologies and accumulate capital" (Yeh, 1980, p.182) by allowing them to engage in production for the protected domestic market. By conducting interviews with 40 manufacturers, Lin (1986) found that local TV manufacturers learned almost all of the production techniques, basic concepts of industrial engineering and quality control from their Japanese technology suppliers. But Lin's emphasis is on the fact that they acquired these borrowed technologies and new concepts through their own technological efforts to learn and master. She points out that color TV subcontract operations, once begun by taking advantage of cheap labor, turned into a channel for introducing new technology and technological concepts through the sincere "technology efforts" of local manufacturers.

Moreover, some of the local manufacturers avoided falling into the "trap of inefficiency" which often accompanies the import substitution policy, by gradually starting to export in the 1970s. Some exported for OEMs, and some exported to Asian and Latin American countries. The required local content ratio for black-and-white TV was as high as 90% in the early 1970s. This policy played an important role in stimulating the expansion of the components industry, including the manufacture of CRTs, PCBs, switches, flybacks, etc. Monitor manufacturers (M1, M2) emphasize that "the most important components of monitors, CRTs and flybacks, were developed by the growth of the TV industry. Sure enough, we owe a lot to the industry."

On the other hand, this "dichotomy" allowed foreign manufacturers to expand their Taiwan-based production without being affected by the protective policy. Eventually, these large-scale manufacturers contributed to the local economy with their huge volume of production by nurturing the local components industry and human resources. Foreign manufacturers trained hundreds and thousands of engineers and managers, who then set up local assemblers and component makers. A magazine article once noted, "GI [General Instruments] and TI [Texas Instruments] are training centers for Taiwanese engineers, and RCA trained many shopfloor leaders." In 1985, the number of manufacturers set up by ex-employees of GI exceeded 100 (*Commonwealth*, 1985.3.1).

In addition, the technological similarity between TVs and monitors/terminals allowed several local TV manufacturers to enter the PC industry in the very early phase of its development.[11] Although M1 and M2 stress that the resolution requirement for monitors was much higher, they admit that they made good use of the accumulated technology from R&D in the TV industry when they started to develop monitors.[12] If these manufacturers had not been able to exploit their technology and production experience in the TV industry, Taiwan would have missed the critical time of entry into the PC industry. In this way, the TV industry paved the way for the rise of the PC industry in various respects.

Nevertheless, to the extent that the TV industry was technologically mature and key components always had to be imported, Taiwan's TV industry could never break the foreign manufacturers' technological control over the

---

[11] As Lin (1986, p.13) points out, "medium and high resolution monitor and terminal manufacturing are actually a technological extension and upgrading of the TV receiver manufacturing technology."

[12] Both of them received OEM orders from IBM in the early 1980s and used the opportunity to grow.

industry.[13] As Liu (1987, p.262) indicates, the industry by this period had attained its rapid growth through "being incorporated into the international system of division of labor of Japanese and American multinational corporations." It was through the emergence of new products that this situation changed.

(2) The Calculator Industry

Beginning in the early 1970s, the manufacture of new products, i.e., calculators, telephones, and tape recorders started to expand rapidly. To the extent that they were developed on the basis of the components industry and the manpower developed by Taiwan's TV industry, manufacturing of these products began from the industrial foundation laid by the TV industry. But these new industries were different from the TV industry in several ways. Here, we look at the example of the calculator industry, from which some manufacturers jumped into the PC industry.

Satoh (1996) points out that Taiwanese manufacturers of calculators and telephones had the following common characteristics; they were ① mainly local manufacturers, ② highly export-oriented, ③ highly dependent on OEM orders, and ④ mainly SMEs that made use of the local production network. Obviously, these attributes are different from those of Taiwan's TV industry, where foreign manufacturers continuously occupied an important position, where local manufacturers were large in scale, and where the subcontracting operations were limited (Lin, 1989). This difference seems to have stemmed from the following two factors. First, the entry barrier was much lower in the calculator industry than in the TV industry, both in terms of the required technology level and capital. M5 says, "At the time calculator production was relocated to Taiwan by American and Japanese buyers, the technology was

---

[13] As many as 66 technological assistance agreements were signed between Taiwanese and foreign manufacturers between 1965-1978.

already quite simple. Basically, it was an assembly production of 10 to 20 components. Certainly, calculators were much easier to manufacture than TV sets." Also fixed and liquid capital required for the manufacturing of calculators was much smaller. "The availability of CPUs sometimes formed an entry barrier" (M5), but compared to the huge amount of capital required for TV manufacturing, the requirements to enter the calculator industry were much lower. Second, the industrial development of the whole economy, the upgrading of the educational level, and the increase in the number of engineers and managers with backgrounds in electronic engineering during the 1960s had produced a large number of potential founders of SMEs by this time.

Of particular relevance to the present paper's concern is the development of a subcontracting production system in the calculator industry. One leading manufacturer (M6) was established by a group of engineers in 1973. It notes that it once had as many as 40-50 subcontractors in the 1970s. M6 describes its subcontractors as follows: "Most of the subcontractors engaged in a small number of production steps, usually 2-3 steps only. Larger makers had 40-50 employees, but there were many minor subcontractors with only 4-5 employees. Workers in these tiny manufacturers were often housewives, who couldn't work in factories as they had to look after their children, but who could engage in some simple job in nearby house factories. Some of these subcontractors were established by our former employees. The production cost was quite cheap in these tiny manufacturers, as their overhead cost was very low."

Another manufacturer (M5) points out that there were two critical factors in the rise of subcontracting production in the calculator industry: a labor shortage and market fluctuations. M5 was established in 1973 and executed all of the assembly production steps in-house at first. But the labor shortage gradually forced M5 to subcontract out an increasing number of production steps. M5 says, "It's hard to recruit 100 workers, but it's easy to subcontract out to 5 subcontractors each with 20 workers." According to M9, "Calculator production in the 1970s involved many labor-intensive routine tasks, like placing plastic keys on a board. Development of subcontracting production

was almost inevitable." Also, subcontracting ensured flexibility in production. "If an order exceeded our capacity, then we subcontracted it out. If orders decreased, then we took the subcontracting work back and did it in-house. We made adjustments in this way" (M5).

In their comparative study of Korean and Taiwanese keyboard and PC industries, Levy and Kuo (1991) found that Taiwanese manufacturers were small in size at entry, and expanded gradually through continuous investment. They called this strategic orientation of Taiwanese SMEs a "bootstrap strategy." Clearly, the two calculator manufacturers I studied followed the "bootstrap strategy," and can be regarded as forebears of the same pattern of development in the PC industry.

Last, as in the case of the TV industry, the calculator industry's technological similarity to the PC industry provided several manufacturers with good starting points in the PC industry. M6's founders were strongly interested in the PC industry when they started operations, but as the PC industry's technology was still immature, they decided to start with calculators (*Commonwealth*, 1984.5.1). Later, when they started manufacturing terminals in 1985, they were able to fully exploit the technological similarity between these two products.

(3) Videogame Machines: A Cradle of Fake Apple Manufacturers

During 1980-82, Taiwan experienced a boom in the manufacture of videogame machines, with exports amounting to US$130 million in 1982. A high profit ratio of 15-20% led to a swarm of new makers.[14] In 1982, however, there arose a "save our children" movement, and the government finally announced a ban on the production of videogame machines due to social pres-

---

[14] An article described the sudden increase of manufacturers as, " walk three steps and find one maker, walk another five steps and find another maker, turn the corner and again find one maker" (*Commonwealth*, 1982.5.1).

sure. According to a newspaper article (*Commercial Times*, 1983.12.21), about three-fifths of the videogame machine manufacturers managed to survive the ban. Most of them rushed into the production of Apple II clones as a way out, because the basic technology of design and manufacturing of that product was quite similar to that of the videogame machine (*Commercial Times*, 1983.12.21). By early 1982, the swarm of new entries into the PC market became so huge that the existing PC manufacturers became concerned that the rush of former videogame machine manufacturers would ruin the industry's market order (*Commercial Times*, 1982.3.16). Clearly, videogame machine production played a significant role as a cradle for small local PC manufacturers.

Another contribution that videogame machine production made to the PC industry came from the induced expansion of the components industry. An article in *Commonwealth* magazine (1982.3.11) pointed out that the videogame machine industry had improved the components procurement conditions for the PC industry. For example, Taiwan enjoyed IC purchase prices 10% below average international prices, owing to the huge demand from videogame manufacturers. This certainly benefited PC manufacturers, too. Also, the number of domestic printed circuit board (hereafter abbreviated as PCB) manufacturers increased from 2-3 to 50-60 by the early 1980s, with half of their production absorbed by videogame manufacturers. In addition, the videogame industry nurtured a large number of programmers. According to an article in the *Commercial Times* (1982, 1982.3.11), "the videogame machine industry nurtured thousands of microcomputer engineers within a year." Rich human resources in circuit design and production engineering, and a good basis in the electronic component industry were good preparation for the rise of Taiwan's PC industry.

(4) Fake Apple Computers

Stimulated by the boom of Apple II PCs in the United States during 1980 to 1983, manufacturers in Taiwan flocked into the production of fake Apples,

illegal clones of Apple IIs, in the early 1980s (*Commercial Times*, 1982.12.8; 1982.12.11). Market entry was further accelerated by the collapse of videogame machine production. As the capital and technology required for manufacturing Apple clones were small (M7, Informants 1,2), many minor manufacturers leaped into the market, and the number of manufacturers jumped within a few years from around 10 to 100 by 1983. Many manufacturers improved the hardware and software of the original Apple II and developed a Chinese language word processing system as well. As a result, these clones "exceeded the original Apple II in function, and in cost performance exceeded the Apple IIe" (*Commercial Times*, 1983.12.21). However, fake Apple production collapsed, as Apple took decisive measures against imitators and charged several Taiwanese manufacturers with counterfeiting by 1983.

In spite of its short duration, the Apple II boom proved to be an important technology learning step toward the present success of Taiwan's PC industry, as it bridged the gap between the technology needed in this new industry and the capability of design and production engineering that manufacturers had accumulated by that time.

Another significance of Taiwan's fake Apple production is that local manufacturers could start accumulating technological capability from the very beginning of the industry's product cycle, owing to the foothold they got with Apple clones. PC manufacturers could start their efforts in design, production engineering, and organizing subcontractors from the very beginning of the industry's product cycle. Compared to the case of the TV manufacturing industry, this was very fortunate for local Taiwanese PC manufacturers. In the case of the TV industry, mature technology from Japan[15] was transplanted from abroad with 8-12 years' lag. In contrast, engaging in the production of

---

[15] The lag with Japan was 12 years for black-and-white TVs, and 8 years for color TVs.

Apple clones, which was still immature technologically, made the technological independence of Taiwan's PC manufacturers possible. No matter whether they were small or large in scale, most of the manufacturers I interviewed developed their products without technological assistance from abroad. Taiwan's PC industry seems to owe its independence to the early manufacturers of Apple clones.

As Apple clones demonstrated the profitability and future possibility of the industry, the entry rush continued. From around 1984, IBM 16-bit PCs replaced 8-bit Apple II PCs. As early as the mid-1980s, "horrible competition" (*Economic Daily News*, 1986.10.7) and "bad competition" had already appeared in the market. Vigorous market entry by local PC manufacturers continued all through the 1980s.

(5) Earliest Entrants to the PC Industry

In this way, both categories of Taiwan's local PC manufacturers in the early 1980s, traditional consumer electronics manufacturers and small new manufacturers that leaped into the market, arose on the basis of the preceding development of the consumer electronics industry. Thus, the rise of the PC industry in the early 1980s was not sudden and unexpected, but was a natural extension of the preceding industrial development.

Of the two categories, the large-scale electronic appliance manufacturers played an important role in the early phase of the industry's growth. In the early 1980s, these traditional manufacturers such as M1 and M2 received OEM export orders for low-end terminals and monitors from abroad.[16] By exploiting their experience in TV set production, these manufacturers expanded their production volume quickly. The role of these traditional electronic manufacturers in the early 1980s was very important, as the rapid in-

[16] They had manufactured heavy electric machinery, electric home appliances, and other industrial electric products in the past.

crease of their production of terminals and monitors provided Taiwan's PC industry with important initial momentum.

However, the presence of these consumer electronics makers gradually faded out through the 1980s, as "their organizations were so huge that they couldn't always keep up with the rapid market change of the PC industry" (Informants 1, 2). Thus, the small manufacturers that rushed into the market came to replace the large manufacturers and became the main force of the industry's expansion by the mid-1980s. Some of them were established by engineers who applied their knowledge, design capability, and experience in industrial engineering to this new market. There were also some manufacturers that jumped into the market starting with subcontracting tasks. They were often so small that they could take on only a few production steps.

The significance of the subcontracting production arrangement to the rise of SMEs is the focus of the next subsection.

2. The Subcontracting Network

The main purpose of the present subsection is to show that the subcontracting production network, which developed as an organizational response by small local manufacturers to overcome the constraints facing them, played an important role in the successful rise of Taiwan's PC industry. Its significance was especially obvious in the early phase of the industry's development. On the one hand, the subcontracting production arrangement relieved small manufacturers of fixed costs and dispersed their risk, and thus made their "bee-like" market entry activities possible. On the other hand, the same arrangement provided manufacturers with the competitive qualities of flexibility and speed, as well as effectiveness of specialization, and thus attracted many OEM customers to Taiwan.

I first report on the structure and background of the well-organized subcontracting production network in Taiwan. Then its relevance for the rise of the PC industry is examined. Also, I look at the relevance of the subcontract-

ing production network for the shift of competitive edge of the industry; it lay in "flexibility and speed" stemming from the subcontracting production network in the early to mid-1980s, but has since shifted to a strong capability in design and production engineering. The primary source of information is my interviews with 17 manufacturers, and two other informants.

(1) Structure

Several previous studies have pointed out that the well-organized division of labor is a conspicuous characteristic of Taiwan's PC industry. Ernst (1995, p.4) points out that "an extreme form of specialization" and "a focus on multiple, volatile and short-term links that involve only limited financial and technology transfers" are observed in Taiwan's PC industry. Lee, Wu and Wu (1995, p.17) report that, "the edge of cheap labor and the industry network that naturally formed among middle-size and small manufacturers built the solid export capability of Taiwan." Also, most of my interviewees indicated that the close cooperation among numerous manufacturers in the Taipei-Hsinchu area is a critical key to the strength of Taiwan's PC industry.

On the development of the subcontracting production system in Taiwan's postwar industrial development, a series of studies by Shieh (1989, 1992a, 1992b, 1993) provides the most detailed and insightful analysis. His study is based on his participant observation and his interviews in a wide range of export-oriented industries, and his scope of analysis covers the production organization within and among units of production, unit trajectories along the subcontracting network, and the social background of the formation of the system. Also Ka (1993) studies in great detail the subcontracting production organization and social network among minor manufacturers and traders in an apparel industry community. A study by Chen (1994) is rich in detailed description of the SME's world, and reveals its socio-economic basis. Satoh (1996) provides a comprehensive analysis of the subcontracting production system.

In the PC industry, subcontracting production is typically observed in the assembly of PCBs, i.e., the process of inserting components into PCBs. The assembly of PCBs for monitors consists of three main steps: auto insertion process, surface mounting device (hereafter abbreviated as SMD) insertion process, and manual insertion process. PCB assembly for PCs consists of the SMD and manual insertion steps only. The basic characteristics of the subcontracting production arrangement observed in my case study are as follows.

(a) Minute Division of Labor

First of all, the subcontracting production arrangement is characterized by minute division of labor and specialization. Based on his interviews with 17 SMEs (each with fewer than 20 employees) in the apparel industry and 29 SMEs in the electronics industry, Shieh (1991) wrote, "small-scale enterprise is a characteristic of Taiwan's industrialization. Every step of production, and production of every component has a corresponding unit of production. And every unit of production has a corresponding boss." Shieh takes the example of the process of manufacturing PCBs, and explains the division of production steps into material preparation, holing, and printing, each of which is done by a different manufacturer. Similarly, my case study revealed that the production steps of PCB assembly can be executed by different units of production in Taiwan. Many cases of fragmentation of production steps and distribution of the tasks among minor subcontractors were observed in my case studies.

Figure 2 illustrates a possible pattern of fragmentation of production steps and distribution of tasks among manufacturers in PCB assembly production. In the case of PCB assembly, a typical specialization pattern is the division of labor into R&D — auto insertion (in the case of monitors only), SMD insertion — manual insertion — testing and packaging. Besides PCB assembly, miscellaneous tasks are often subcontracted out to house factories and houseworkers. For example, M8, a small manufacturer of power supplies with 30 employees, subcontracts out some tasks such as screwing, bonding switches, inserting plates, etc. to family workshops. M8 says, "Some housewives quit

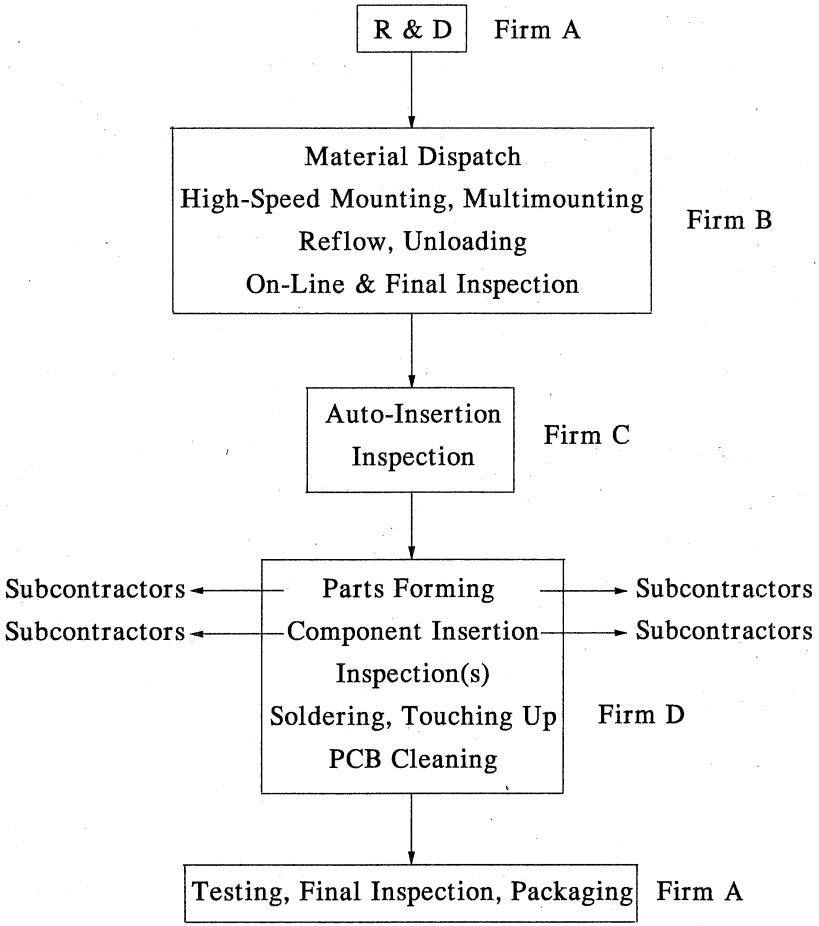

Figure 2. A Pattern of Fragmentation of Production Steps Among Manufacturers

Note: The figure indicates a possible pattern of division of labor among SMEs, and is based on the findings of the author's field research. In this case, Firm A specializes in R&D, final testing, and packaging, and subcontracts out all the assembly work. Some part of the work, such as parts forming and insertion of smaller components etc., are again subcontracted out by Firm D.

our factory to take care of their children. But they are familiar with the task, so we keep in contact with them, and ask for their help when we need them. Sometimes we subcontract simple jobs, like sub-assembly of heat-radiators, out to these houseworkers." Thus, a variety of manufacturers, including houseworkers, participate in this production system.

One important category of manufacturers that organize the subcontracting network is the "factory-less" or "fabless" manufacturers: those engaging in design, testing, packaging (and often marketing) only. A factory manager at M9 comments, "I once worked at this kind of manufacturer. Probably there are hundreds of manufacturers of this type in Taiwan. Their offices are often located in small apartments in Taipei. They specialize in design and quality control, and set up their own sales offices abroad and do marketing."

M10 is a typical example of a "factory-less" manufacturer. On its establishment in 1981, M10 engaged only in component trading. A few years later, it started design, testing and packaging of add-on cards, and subcontracted all the assembly production steps out. All through the 1980s, M10 grew rapidly and started "production" of scanners, motherboards, and PCs. It also set up offices in the US, Germany, the UK, etc., to promote sales. But it was only after 1991 that M10 introduced SMD equipment; in other words, M10 depended on subcontracting for PCB assembly and final assembly until as late as 1991. "Unarguably, subcontractors played a critical role in our development" (M10). Another motherboard manufacturer with 20 workers also specializes in design, testing and packaging only, and subcontracts out all the assembly production processes to five subcontractors. The very existence of the large number of "factory-less" manufacturers demonstrates the efficiency of division of labor among the highly specialized manufacturers on the island.

Besides the subcontracting based on fragmentation of production steps, there is another type of subcontracting arrangement, "horizontal subcontracting" (Shieh, 1992a, pp.53-54), where orders and tasks are exchanged between fellow manufacturers. This arrangement was observed in my study too. This

type of subcontracting arrangement has two subcategories; irregular horizontal subcontracting and regular horizontal subcontracting. The former is an arrangement where over-capacity orders are temporarily put out to other manufacturers. "When we are running out of time, we call on them for help. It's good for both of us. They can make money and we are helped by them" (M13). In the case of regular horizontal subcontracting, the order is subcontracted out to the most appropriate unit of production. For example, "We are a medium-sized subcontractor with 40 employees. In order to make full use of our manpower, we only take orders for products with more than 80 components. Otherwise, we subcontract the order out to smaller manufacturers" (M9). In the case of M12 , "We started from a small subcontracting factory. But now we have 600 workers, including 60 R&D staff members, and our competitive edge is shifting toward high-end products. We produce 17-inch monitors ourselves, and subcontract out 14-15-inch monitors to smaller manufacturers. They are more suited to production of these standard products, as their overhead cost is smaller." In this way, "horizontal" subcontracting promotes a distribution of appropriate tasks among the members of the network and improves the overall efficiency of the industry.

(b) Flexibility and Irregularity of Subcontracting

The second characteristic of subcontracting production observed in my study is the flexibility and irregularity associated with specialization. Most of the interviewees distinguish between "regular" and "irregular," or long-term and one-time contracting/subcontracting. Still, the distinction is quite vague. "We have several subcontractors who can help us when we are in hurry to finish the order" (M11, M13). "I have a list of possible subcontracting partners. When I need help, I make phone calls to them to find the guy who can help us" (M7). In these cases, the potential subcontracting relationship lasts for a long period, but the actual business relationship is irregular.

Even with subcontractors whom they regard as "regular" partners, many manufacturers maintain a free hand to stop doing business with them. Al-

though several manufacturers emphasize that "we become friends as we go on with the subcontracting relationship, and I feel too sorry to stop subcontracting out to them," most of the manufacturers admit that they stop subcontracting out orders when the demand declines. "We can put orders out when they grow and exceed our capacity for a certain period of time. But when the demand decreases, we have to take the production steps in again." This kind of flexibility and irregularity is natural, as these attributes are the very reason that a large number of manufacturers utilize the arrangement. As we will see in the next subsection, many manufacturers regard the subcontracting production arrangement as a "safety valve" for market fluctuations.

The flexibility and irregularity of the subcontracting arrangement naturally leads to multiplicity and mutual dependence among the manufacturers. My study found that the division between "subcontractors" and "contractors" is quite vague, especially among SMEs. "If an order exceeds our capacity, then we put it out. If we are not busy with our orders, then we can help other manufacturers to finish their orders" (M7, M8, M13). In this case, one cannot call the manufacturer either "subcontractor" or "contractor"; it is both a "subcontractor and contractor. " Also, the growth of a manufacturer doesn't necessarily accompany the upgrading of its status from subcontractor to contractor (M12, M13, M14). Nor does it lead to decreasing reliance upon subcontractors. As the case of M10 demonstrates, some manufacturers attain growth by making intensive use of subcontracting.[17]

(2) Factors in the Rise of Subcontracting Production Arrangements

(a) Motivation for Contractors

As we saw above, the subcontracting production arrangement observed in Taiwan's PC industry is characterized by the minute division of labor, and a very flexible arrangement of specialization among the members. The next

---

[17] This finding is in agreement with that of Levy & Kuo (1991).

questions are: Why do manufacturers make intensive use of the subcontracting production arrangement? Why do many manufacturers do subcontracting tasks, though they complain that "our profit rate is low, and we are vulnerable to market changes" (M7, M10)?

On the part of contractors, three main reasons for making use of subcontracting arrangements can be pointed out. First, this arrangement developed in order to solve the difficulty of recruiting factory workers, just as it did in the case of the calculator industry. M13 pointed out that the labor shortage is the primary reason for the development of the subcontracting system in the industry. "We cannot recruit enough workers in-house. But it's easy to find subcontractors." As we saw in the previous section, labor shortages led to the development of subcontracting production in the calculator industry as early as the 1970s. In order to solve the problem, it was natural for PC manufacturers to make use of subcontracting production's decentralized mobilization system of manpower from the very start of the industry's growth. "Especially, many manufacturers preferred to subcontract out labor-intensive production steps such as manual insertion of components and miscellaneous tasks " (Informant 1).

Second, the very flexibility associated with the subcontracting arrangement is the strong point of subcontracting production network. In Taiwan, SMEs have mainly engaged in export since the 1960s.[18] All through the export-oriented development of the postwar Taiwanese economy, how to deal with market fluctuation, how to disperse the involved risk, and how to realize the lowest cost, have been the primary concerns for SMEs. And it was this concern that made the specialization of the subcontracting production arrangement a desirable arrangement for SMEs (Shieh, 1992a; Chen, 1994). The subcontracting production arrangement is an organizational response on the part of SMEs to these fluctuations and risks, for it allows a manufacturer to

[18] Please refer to Abe & Kawakami (1996).

increase and decrease production volume without incurring substantial capital cost. In the case of M7, "it's not always cheaper to subcontract out, but we rely on subcontractors, as they save us investment in equipment" (M7). "They ensure us flexibility of production. By adjusting the order volume to put out, we can control the production" (M4).[19]

Third, specialization reduces the overhead cost to individual manufacturers and allows them to make full use of their equipment. Possible utilization of subcontracting arrangements enables a group of engineers to set up a "factory-less" manufacturer and concentrate on design and testing. This condition was critical for the growth of PC manufacturers, as most SMEs are continuously faced with capital constraints.

Last, subcontracting production allows individual manufacturers to exploit the merit of specialization. M9 points out that "each task we put out is quite simple, like simple soldering and bonding of wires. But workers accumulate experience in each job, and it does make a difference." M8 states, "Take the example of the work of bonding switches. Subcontractors do work for at least 2-3 contractors' orders simultaneously. So those housewives working at the subcontracting units are quite skillful. If we do the same bonding in-house, the cost might be higher by as much as 35-40 % at the initial stage."

(b) Motivation of the Subcontractors

Many subcontractors display dissatisfaction with "the low profit rate and limited opportunity" of simple subcontracting, when asked about their self-

---

[19] Here, it is noteworthy that the adjustment cost associated with stopping subcontracting business is substantially lower than the cost involved in in-house adjustment, i.e., dismissal of workers and idle equipment in Taiwan. In other words, the behavior of Taiwan's PC industry manufacturers reveals that the adjustment cost among production units is lower than the adjustment cost within a unit. For the relevance of the low transaction cost of Taiwan's economy for the growth of Taiwanese SMEs and the industrial development led by them, please refer to Levy (1991).

esteem. Why, then, do such a large number of manufacturers leap into this business?

The primary reason is the low risk and low fixed cost associated with subcontracting production. As for the required capital and technology to set up a PCB manual components insertion workshop, M13 says, "At present, 1.5 million NT dollars, several years' experience in production engineering, and a middle level knowledge of electronics will be enough." Of course, the smaller house workshops are even easier to establish. In the early 1980s, many engineers started subcontracting factories with NT$100,000 to 150,000 raised in the informal money market or borrowed from relatives (M7). Besides the low initial set-up cost, another merit of subcontracting is the smaller requirement for liquid capital. "Price fluctuation in key components is quite wild in this industry. But subcontractors do only assembly, and all the materials are procured by contractors" (M9, M10). Thus, the subcontracting production arrangement is not only a system of division of labor among manufacturers, but also a risk-sharing mechanism between differently sized manufacturers; the risk associated with the procurement of components is borne by the larger manufacturers in exchange for a high profit rate, while the risk-averse minor manufacturers offer their cheap labor and accept a lower profit rate in compensation for their low risk.

Related is the second reason for manufacturers to engage in subcontracting tasks, which is the prospect of stepping up "along the subcontracting network" (Shieh, 1992a, p.69). Indeed, it is this prospect that induces numerous manufacturers to leap into this network, despite the low profit rate. For example, M7 intends to "invest in SMD machines and 'step up' within a few years."

M13 is a typical case of "development along the subcontracting network." It was set up in 1986 as a small manual insertion subcontractor. As its customer expanded production rapidly, M13's subcontracting business expanded greatly, and it introduced SMD in 1994, then auto insertion equipment in 1995.

The number of employees expanded from eight in 1986 to 160 in 1995. Its next aim is to cultivate its own R&D capability. Another success story is the case of M12. It started as a subcontracting factory where employees of a PC manufacturer gathered after work and engaged in manual insertion production jobs "that were not profitable for large manufacturers." Through eight years' continuous investment, the firm grew into a monitor assembler with 600 employees including 50 R&D experts.

These manufacturers all follow the "step-by-step" expansion trajectory, gradually integrating the fragmented production steps and expanding capacity. "In general, we start as a small subcontractor. Sometimes the first goal is to integrate inspection and packaging in-house, as this means that we can do quality-control ourselves. Then we'll try to integrate more capital-intensive production steps" (M9). The next goal is to start to procure necessary components. "As long as we do simple subcontracting, our future is limited. It's risky to procure components by ourselves, but the business will be much more profitable" (M9). Another goal is "to start direct OEM business with foreign customers" (M13). The subcontracting production arrangement provided each manufacturer with the opportunity to "step up" at a small initial cost.

(3) Relevance of the Subcontracting Production Arrangement for the PC Industry's Development

In concluding this section, it is this arrangement of subcontracting production that has enabled and induced the market entry of SMEs. Also, almost all of the interviewees emphasized that "flexibility and speed of specialized manufacturing"[20] associated with close cooperation among manufacturers is the main source of competitiveness of the industry.

At the same time, many manufacturers point out that the significance of

---

[20] *Youth Daily News*, 1986.1.3, reports that "Taiwanese manufacturers' merit lies in the speedy response and flexible development capability."

the subcontracting production system has decreased substantially in the last four to five years (M14, M15, Informant 2).[21] My case study has revealed that the newly set up manufacturers are not as dependent on subcontracting production as are older ones. Also relatively old manufacturers are less reliant on subcontracting production.

One reason for the gradual disappearance of subcontracting is the stricter quality requirements of OEM customers. Though "many manufacturers still subcontract out to smaller ones in secret" (M9), the intensified competition among large OEM customers has led to an increase in in-house production by large OEM manufacturers, and narrowed the room for subcontracting. Also, severe price competition and rapid expansion of the market in the last several years has accelerated the trend of production concentration among large manufacturers. Finally, the production shift to Southeast Asian countries and mainland China, as well as introduction of foreign labor, have replaced the cheap local labor power mobilized through the subcontracting production arrangement.

As the importance of subcontracting has gradually decreased, the primary competitive edge of Taiwan's PC industry has shifted from the low cost and production flexibility ensured by the subcontracting network to strong capability in design and production engineering by specialized manufacturers.

In the following, the relevance of the subcontracting network in achieving flexibility and speed is first explained. Second, I will point out that the shift of the competitive edge toward strong design capability reflects the economy's successful accumulation of human resources and production experience, which was facilitated by the subcontracting arrangement.

---

[21] The recession during 1989-1991 was a turning point. Many SMEs exited the market and production concentration started, as the growing OEM orders from large American and Japanese buyers brought about the industry's recovery.

(a) Relevance of "Flexibility and Speed" to Specialized Manufacturrs

I have already revealed the relevance of the subcontracting production arrangement for production flexibility. The arrangement was the very apparatus that allowed local SMEs to adjust to market changes with flexibility and speed.

Another outcome of the subcontracting production arrangement is the large number of highly specialized manufacturers.[22] Whereas the PC industry of South Korea is led by large conglomerates, Taiwan's manufacturers are characterized by high specialization. Indeed, "specialization" is a key word for understanding the Taiwanese PC industry. A look at TEAMA's member list reveals that most of the PC industry manufacturers are concentrated in the production of a small number of products. This is partly because these manufacturers were established by engineers exploiting their technological backgrounds. Through the interviews, I formed the impression that Taiwanese manufacturers are bold when expanding their business in their "own direction," but are rather conservative about going into "unfamiliar spheres" (M2, M14). Also, as active market entry caused severe competition, manufacturers came to concentrate on a small number of products and production steps. The step-by-step manner of expansion and continuous capital constraints facing these SMEs made investment within the range of "one's own business" relatively profitable.

This specialization is also reflected in the organization of the components industry, of which Shieh (1993, p.100) said, "production of every component has a corresponding unit of production." Many interviewees pointed out that

---

[22] In her comprehensive study of the economic development process of postwar South Korea, Amsden (1989, p.127) pointed out that Korean conglomerates, the engine of the development of the economy, tend to diversify widely rather than specializing in certain fields, as their level of experience in particular industries does not enable them to upgrade and move into a higher quality niche.

the strength of specialized component manufacturers is one of the main factors that enabled local FMs to grow rapidly. "Almost all of the components are available at very reasonable prices in Taiwan. Without these components, we could never have grown as rapidly as we did" (M10).

(b) The Shift in Taiwan's Competitive Edge and the Decreasing Reliance on Subcontracting

Most of the interviewees indicate that strong design capability and experience in mass production are the two areas in which Taiwan's PC industry has the main competitive edge at present. For example, a leading motherboard manufacturer says, "Once a customer hands us a specification for a new motherboard, we can develop a correspondent sample within only a month" (M14). "Our capability of designing production lines and products in a way that minimizes the model-change cost is the source of our competitiveness" (M4). Taiwan IBM also points out that the main competitive edge of Taiwan's PC industry has already shifted to strong capability of design and production engineering. As for the latter, "Taiwanese production engineers can manage to produce 3-4 models in one line a day"(M3).

The significance of this shift in competitiveness is outstanding, when we compare it with the preceding cases of the electronics industry and other labor-intensive industries, where Taiwan's competitive edge continuously lay in "low cost and flexibility." How and why did the PC industry succeed in upgrading its technology capability?

The successful shift in Taiwan's competitive edge in the PC industry is a result of the fact that local manufacturers caught up technologically with the industry leaders. As we saw in section II, a large number of engineers and specialized managers have been fostered in the electronics industry since the 1960s. The product shifts in the 1970s and 1980s from TV manufacturing to videogame machines and Apple II clone production accompanied the gradual improvement in local manufacturers' technological level. In other words, the gap between the technology required for a particular industry and the capabil-

ity of local manufacturers in that technology has narrowed over the course of industrial development since the 1960s.

Again, the subcontracting production network played a central part in facilitating the swift technology spillover and information dissemination. It was mainly via the turnover of engineers and managers who acquired expertise with one company, then set up new manufacturers, that these spillover effects were realized. M2 comments, "M2, M1, RCA, and another large local manufacturer were very much like four central training centers for the manpower of Taiwan's PC industry, because a large number of manufacturers spun off from these makers." When I asked to interview the engineers who did the R&D for monitors in the early 1980s, I was told that "they are all gone," " almost no one has remained here, for some of them set up their own business, and others moved to newer firms."

It is a conspicuous characteristic of Taiwan that the technology spillover and information dissemination occurred not within a firm, but primarily between manufacturers. And the subcontracting system, together with the strong cultural inclination to start one's own business in Taiwanese society, enabled capable engineers and managers to "stand alone," and promoted the continuous diffusion of technology and information. The subcontracting production system has played the role of a "carrier of spillover effects" over the course of the industry's development. The same arrangement spurred the diffusion of technology from FMs that produced PC products on the island in the early 1980s, and let local manufacturers get into the market at a good time.

It was this successful accumulation of human resources, as well as the return of engineers from abroad in the 1980s, that has enabled the industry to upgrade its competitive edge toward the more technology-oriented sphere.

V. Summary and Conclusion

In this paper, I have explored the background of the rise of SMEs in Taiwan's PC industry, with a focus on the factors that made their active market entry in the 1980s possible. I have studied the issue from the following two viewpoints: (1) technology accumulation by local manufacturers during the preceding expansion of the electronics industry, and (2) the subcontracting production arrangement.

My study found that both of these factors substantially contributed to the SMEs' growth. The step-by-step technology accumulation of local manufacturers is observable since the 1960s. The TV industry consolidated the basis of the electronics industry by introducing basic technology concepts and production engineering. It also fostered a large number of engineers, and stimulated a local components industry. In the following development of the calculator industry, the relatively low entry barriers allowed a large number of SMEs to enter the market. To the extent that an extensive subcontracting production network developed among the SMEs, this industry displayed a pattern of development similar to the PC industry. In the early 1980s, there occurred a boom in the manufacturing of videogame machines and Apple II clones. This produced a large number of engineers with experience in circuit design and the application of microcomputers. These two products also provided SMEs with opportunities to enter the PC industry in the initial phase of its development. This timely entry of SMEs was important for the later technological upgrading of PC manufacturers. All of these preceding industries brought about a gradual narrowing of the gap between the required technology level for a certain product, and the technological capability of the local manufacturers, thus lowering the technological entry barrier to the PC industry for SMEs.

Also, the subcontracting production network was significant for the rise of local SMEs in several ways. On one hand, it lowered the market entry bar-

rier for SMEs. On the other hand, it encouraged numerous engineers and managers to spin off from FMs and large local manufacturers, thus promoting the diffusion of information and technology in the economy. It also facilitated the upgrading of the competitive edge of the industry toward its current strong capability in design and production engineering. In this way, the rise of Taiwan's PC industry was not sudden and unexpected, but rather a natural extension of the preceding development of the electronics industry.

Finally, I would like to touch on the implications of the case of Taiwan's PC industry for the promotion of SMEs in other developing economies. Are other economies likely to experience a similar growth of SMEs to replace FMs and large local conglomerates in high-tech manufacturing?

Unarguably, Taiwan provides a good example of successful growth by SMEs. The PC industry in particular is full of success stories: venture businesses of two to three engineers growing into world-famous manufacturers in several years, petty subcontracting factories developing into makers with thousands of employees and strong R&D capabilities, and so on. However, what deserves emphasis is that Taiwanese SMEs could overcome entry barriers and grow rapidly mainly because there was an organized production system in Taiwan that allowed SMEs to enter this highly competitive market: the risk-sharing and cost-saving mechanism of the subcontracting production network. And this network was neither an arrangement developed under the leadership of large manufacturers, nor was it a result of a promotion policy by the government. Rather, it is a natural organizational response that SMEs developed in order to overcome the labor shortage and to reduce risk. The diffusion of education and an equal income distribution in Taiwan are preconditions of the arrangement, too.

In contrast, the conditions that gave rise to Taiwan's subcontracting network are usually lacking in the developing economies: we are more likely to find that oversupply of labor, domination by existing conglomerates, and unequal income distribution hinder the formation of a subcontracting produc-

tion arrangement among SMEs. In this respect, the development of the subcontracting production arrangement and the rise of SMEs in Taiwan are not simple, transferable experiences for other economies. Rather, they are a reflection of Taiwan's socio-economic conditions, and are the fruit of its overall economic development.

Still, economic development is a continuous process of catching up. Taiwan's electronics industry, which was only a simple production base with abundant unskilled labor in the early- to mid-1960s, came to earn Taiwan the sobriquet "PC Island," with its rich engineering and production capability, in just one decade. This fact itself should encourage the small manufacturers of the developing countries considerably.

References

1. English:

Amsden, Alice H., 1989, *Asia's Next Giant: South Korea and Late Industrialization.* New York: Oxford University Press.

Ernst, Dieter, 1995, "New Opportunities and Challenges for Taiwan's Electronics Industry — the Role of International Cooperation," Working Paper 78, The Berkeley Roundtable on the International Economy, University of California at Berkeley.

Kuo, Cheng-Tian, 1995, *Global Competitiveness and Industrial Growth in Taiwan and the Philippines*. Pittsburgh: University of Pittsburgh Press.

Lee, Jen Fang, Wu, Ching-Sung, and Wu, Se-Hwa, 1995, "The Strategic implications of Alliances and Networks in the Process of Taiwanese Industrial Development," paper Presented at Symposium on Development and Future Trend of Science and Technology, Taipei: Industrial Technology Information Services (ITIS), May.

Levy, Brian and Kuo, Wen-Jeng, 1991, "The Strategic Orientations of Firms and the Performance of Korea and Taiwan in Frontier Industries: Lessons from Comparative Case Studies of Keyboard and Personal Computer Assembly," *World Development*, 19(4): 363-374.

Levy, Brian, 1991, "Transaction Costs, the Size of Firms and Industrial Policy: Lessons from a Comparative Case Study of the Footwear Industry in Korea and Taiwan," *Journal of Development Economics*, 34:151-178.

Lin, Yeo, 1986, "Technological Change: a Microeconomic Study of the Consumer Electronics Industry in Taiwan," Ph.D Dissertation, Northwestern University, Evanston, Illinois.

Schive, Chi, 1990, *The Foreign Factor: the Multinational Corporation's*

Contribution to the Economic Modernization of the Republic of China. Stanford, California: Hoover Institution Press.

Shieh, Gwo-shyong, 1992a, *"Boss" Island: the Subcontracting Network and Micro-entrepreneurship in Taiwan's Development.* New York: American University Studies, Peter Lang.

Wang, Chien-Nan, 1994, "The Development and Strategy of Taiwan's Information Technology Industry," Occasional Paper Series No.9405, Taipei: Chung-Hua Institution for Economic Research, June.

2. Chinese

Chen, Chaonan, 1985, "The Entry, Exit and Growth of Electronic Firms in Taiwan Area," *Academia Economic Papers*, 13(1): 47-89, March.

Chen, Jeng-Chang, 1994, "Firm Entry and Exit in Taiwan Manufacturing Industries," *Journal of Social Science*, Vol.42: 199-234.

Chen, Jieh-Shyuan, 1994, *"Cooperative Network and Structure of Life: a Socio-Economic Analysis of Taiwanese Small and Medium Scale Manufacturers.* Taipei: Lien-Chin Publishing Co.

Ka, Chih-Ming, *1993, "Market, Social Networks, and the Production Organization of Small-scale Industry in Taiwan — the Garment Industries in Wufenpu.* Taipei: Institute of Ethnology, Academia Sinica.

Hou, Chi-Min & San Gee, 1988, "Upgrading of the Industrial Structure of R.O.C through Introduction of Foreign Capital," Completed Research Project, Chung-Hua Institution for Economic Research, 1988,

Yeh, Ryh-Song, 1980, "An Analysis of the Development of Taiwan's TV Industry from a Viewpoint of Product Cycle Theory," *Quarterly Bulletin of Bank of Taiwan*, 31(2): 156-205.

Shieh, Gwo-Shyong, 1989, "Black-Hands Becoming Their own Bosses: Class Mobility in Taiwan's Manufacturing Sectors," *Taiwan: A Radical Quar-*

terly in Social Studies, 2(2): 11-54, Summer.

Shieh, Gwo-Shyong, 1991, "Network Production Organization: Subcontracting System of Export Industries of Taiwan," *Bulletin of the Institute of Ethnology, Academia Sinica*, No.71: 161-182.

Shieh, Gwo-Shyong, 1992b, "Invisible Factory: Subcontracting Points and Homeworkers in Taiwan," *Taiwan: A Radical Quarterly in Social Studies*, No.13: 137-160, November.

Shieh, Gwo-Shyong, 1993, "Tasks, Bosses and the Activation of Entreprenuerial Niches: A Study on the Establishment and Managing of the Small Manufacturing Units in Taiwan," *Taiwan: A Radical Quarterly in Social Studies*, No.15: 93-129, November.

Institute for Information Industry, 1990, *General Survey on PC Industry of Republic of China*, Taipei.

Hwang, Chin-Yeong, 1995, *Taiwan — the Republic of Computers*. Taipei: Commonwealth Publishing Co.

Industrial Development Bureau (IDB), Ministry of Economic Affairs, *Annual Report on Industrial Development*, Taipei.

3. Japanese

Abe, Makoto and Kawakami, Momoko, 1996, "Chapter 5. Distribution of Size of Firms in Korea and Taiwan," in *Development Mechanism of Korea and Taiwan*, Edited by Hattori, Tamio and Satoh, Yukihito, Tokyo: Institute of Developing Economies, IDE Research Series No. 464.

Satoh, Yukihito, 1996, "Section III. Case of the Electronics Industry" in "Chapter 6. Comparative Analyses on Industrial Development in Korea and Taiwan," in *Development Mechanism of Korea and Taiwan*, Edited by Hattori, Tamio and Satoh, Yukihito, Tokyo: Institute of Developing Economies, IDE Research Series No. 464.

Satoh, Yukihito, 1996, "Chapter 3. Government and Firms in Taiwanese Economic Development," in *Development Mechanism of Korea and Taiwan*, Edited by Hattori, Tamio and Satoh, Yukihito, Tokyo: Institute of Developing Economies, IDE Research Series No. 464.

Liu, Jin-Ching, 1987, "The Electronics Industry of Taiwan and Investment by Japanese Firms," in *Foreign Direct Investment of Japanese Electronics Industry*, Edited by Sasaki, Takao and Esho, Hideki, Tokyo: Hosei University Press.

Appendix 1 List of Informants

Manufacturers

	Year of Establishment	Number of Employees	Main Products
M1*		27500	motors, home electric appliances, monitors, terminals, etc.
M2*		3926	motors, home electric appliances
M2		1750	monitors, terminals
M3	1981	1500	monitors
M4	1984	1040	monitors
M5	1973	33	calculators
M6	1973	1650	calculators
M7	1975	38	manual assembly of PCB for motherboard, add-on cards
M8	1984	30	power-supplies
M9	1989	40	manual assembly of PCB
M10	1981	290	PCs, add-on cards
M11	1989	20	add-on cards
M12	1988	650	monitors
M13	1986	160	assembly of PCB for monitor, add-on cards
M14	1987	530	motherboards
M15	1982	900	keyboards, add-on cards, power-supplies
M16	1983		PCs
M17	1985	20	add-on cards, motherboards

Note: Numbers of employees of M1 and M2 include those of heavy electric machines, home electric appliances, and other products. As for M2, I visited both M2 and the subsidary it established in 1989 that specializes in the PC industry.

Other informants

Informant 1	Industrial analyst of a stock company
Informant 2	Industrial analyst of the Market Intelligence Center, Institute for Information Industry

Discussion Paper Series

1. Kang Chao and Ellen S. S. Chien. "The Relative Real GDP and Price Structure of Mainland China," 1981. ***(No.8101)***
2. Kang Chao. "Economic Readjustment in Mainland China," 1981. ***(No.8102)***
3. Mingshu Hua. "The Inflationary Effect on the Structure of Trade," 1981. ***(No.8103)***
4. Kang Chao and P. C. Chang. "A Study of Regional Factor Productivities in Chinese Agriculture," 1982. ***(No.8201)***
5. Chun-yuan Wang. "The Spillover Monetary Effect of Devaluation: A Disequilibrium Interpretation of the Cooper Paradox and the 'Reversed'," 1982. ***(No.8202)***
6. Chihwa Kao. "Second-Order Efficiency in the Estimation of Heteroscedastic Regression Models," 1984. ***(No.8401)***
7. Chihwa Kao. "An Em Algorithm for the Heteroscedastic Regression Models with Censored Data," 1984. ***(No.8402)***
8. Hak Choi. "Methods of Generating Demand Functions - A Tabular Review," 1984. ***(No.8403)***
9. Chihwa Kao. "Robust Regression with Censored Data," 1984. ***(No.8404)***
10. Chihwa Kao. "The Bootstrap and the Censored Regression," 1984. ***(No.8405)***
11. San, Gee. "The Early Labor Force Experience of College Students and Their Post-College Success," 1984. ***(No.8406)***
12. Chihwa Kao. "Small Sample Studies of Estimating, the Regression Models with Multiplicative Heteroscedasticity: The Results of Some Monte Carlo Experiments," 1984. ***(No.8407)***
13. San, Gee. "Student Financial Aid, In-School Employment, and Educational and Labor Market Outcomes," 1984. ***(No.8408)***
14. An-loh Lin and Scott A. Monroe. "The Structure of Gasoline Demand Across the United States," 1985. ***(No.8501)***
15. Hak Choi. "Why the EEC-ROC Trade Remains Unimportant," 1985. ***(No.8502)***
16. Hak Choi, J. Chou and D. E. Nyhus. "A Disaggregated Exports Forecasting Model for Taiwan," 1985. ***(No.8503)***

17. Diagee Shaw. "On-site Samples' Regression: Problems of Nonnegative Integers, Truncation, and Endogenous Stratification," 1987. ***(No.8701)***
18. Li-min Hsueh and Su-wan Wang. "The Implicit Value of Life in the Labor Market in Taiwan," 1988. ***(No.8801)***
19. Chien-hsun Chen. "Modernization in Mainland China: Self-Reliance and Dependence," December, 1990. ***(No.9001)***
20. Tain-jy Chen and Wen-thuen Wang. "The Effects of Production Quotas on Economic Efficiency: The Case of Taiwan's Canned Food Industry," December 1990. ***(No.9002)***
21. Ya-hwei Yang. "The Influence of Preferential Policies on Strategic Industries: An Empirical Study of Taiwan," December 1990. ***(No.9003)***
22. Solomon W. Polachek and Charng Kao. "Lifetime Work Expectations and Estimates of Sex Discrimination," January 1991. ***(No.9101)***
23. Ke-jeng Lan. "Inflation Effects on the Labor Market: A Transition Rate Model," April, 1991. ***(No.9102)***
24. Hui-lin Wu, Quen-leng Miao, and Ke-jeng Lan. "Wage Differentials: Among College-and-Above Graduates in Taiwan," April 1991. ***(No.9103)***
25. George J. Y. Hsu and Tser-yieth Chen. "Uncertainty and Asymmetric Information in the Modelling of Electric-Utility Tariff Regulation," May 1991. ***(No.9104)***
26. Ya-hwei Yang. "An Analysis on the Structure of Interest Rate in the Banking Sector, the Money Market and the Curb Market," June 1991. ***(No.9105)***
27. Jiann-chyuan Wang. "Quota Restriction Policies and Their Impact on Firms' Quantity Setting Decision Under 'Learning-By-Doing'," June 1991. ***(No.9106)***
28. Jiann-chyuan Wang. "Cooperative Research in Taiwanese Manufacturing," October 1991. ***(No.9107)***
29. Mo-huan Hsing. "The Empirical Relevance of the Orthodox Demand Theory," October 1991. ***(No.9108)***
30. Hui-lin Wu and Ke-jeng Lan. "Labor Shortage and Foreign Workers in Taiwan," October 1991. ***(No.9109)***
31. Ji Chou and De-min Wu. "The Cost of Capital and the Effective Tax Rate in Taiwan: 1961 - 1985," October 1991. ***(No.9110)***
32. George J. Y. Hsu, Pao-long Chang, and Tser-Yieth Chen. "Industrial Outage Costs in Taiwan: Estimation from a Proposed Curtailable Rate Program in Taiwan," January 1992. ***(No.9201)***
33. Charng Kao, Solomon W. Polachek, and Phanindra V. Wunnava. "Male-

Female Wage Differentials in Taiwan: A Human Capital Approach,'' Feb. 1992. ***(No.9202)***

34. Lee-in Chen Chiu. ''The Economic Reunion of Taiwan and the Mainland China: The Impact on Industrial Development,'' May 1992. ***(No.9203)***
35. Yi Chou, Pao-long and Chyan Tuan. ''TQC Chinese Style and Its Management Implication -- Taiwan V.S. Mainland China,'' June 1992. ***(No.9204)***
36. Chung-hua Shen and Lee-rong Wang. ''Testing Efficiency of the Coffee Futures Market -- A Markov Switching Model,'' June 1992. ***(No.9205)***
37. Tain-jy Chen and Hsien-yang Su. ''On-the-Job Training as a Cause of Brain Drain'' July 1992. ***(No.9206)***
38. George J. Y. Hsu, Pao-long Chang and Tser-yieth Chen. ''A Priority Service Program and Power Outage Costs: The Case of Taiwan's Cement Industry,'' October 1992. ***(No.9207)***
39. George J. Y. Hsu and Ai-chi Hsu. ''Energy Intensity in Taiwan's Industrial Sectors: Divisia Index vs. Laspeyres Index,'' October 1992. ***(No.9208)***
40. Lee-in Chen Chiu. ''Regional Differential of Enterprise Efficiency and Labor Productivity in Coastal China,'' December 1992. ***(No.9209)***
41. Chi-ming Hou and Chien-nan Wang. ''Globalization and Regionalization -- Taiwan's Perspective,'' March 1993. ***(No.9301)***
42. Yi Chou. ''The Practice Beyond Property Right Boundaries -- Quality Management in Chinese State-owned Enterprises and Rural Enterprises,'' March 1993. ***(No.9302)***
43. Tzong-shian Yu. ''Economic Development in Transition -- The Case of Taiwan,'' June 1993. ***(No.9303)***
44. Tzong-shian Yu. ''An Analysis of the Effects of Economic Policies on Taiwan's Economic Growth and Stability,'' June 1993. ***(No.9304)***
45. Ke-jeng Lan. ''An Evaluation of the Effectiveness of Government Automation Promotion Schemes in the Electrical Component Industry,'' June 1993. ***(No.9305)***
46. Yi Chou. ''Measurement of Technical Efficiency and Its Management Implications -- The Example of Taiwan Sugar Corporation,'' June 1993. ***(No.9306)***
47. Chien-nan Wang. ''On the Choice of Exchange Rate Regimes,'' June 1993. ***(No.9307)***
48. Yi Chou and Chyau Tuan. ''Quality Management of Chinese Township Enterprises in Inland and in Coastal Areas,'' November 1993. ***(No.9308)***
49. Lee-in Chen, Chiu and Jr-tsung Huang. ''Improvement of Capital Productivity

and Technical Efficiency via DFI: Evidence from the Industrial Interaction between

50. An-loh Lin. "Trade Effects of Direct Foreign Investment: The Bilateral Case," February 1994. ***(No.9401)***

51. Jiann-chyuan Wang and Homin Chen. "The Impact of North American Economic Integration on Taiwan," March 1994. ***(No.9402)***

52. Joseph S. Lee. "Is There a Bona Fide Labor Movement in Taiwan?" April 1994. ***(No.9403)***

53. Jiann-chyuan Wang and Kuen-hung Tsai. "An Evaluation of the Effect of Government Research and Development Promotion Schemes in the Electrical Component Industry," June 1994. ***(No.9404)***

54. Anthony H. Tu. "The Dynamic Self-Hedged Behavior During the Period of 1987 Crash: Evidence from the U.S. Stock Market," August 1994. ***(No.9405)***

55. Ji Chou, Yun-peng Chu and Shiu-tung Wang. "Effects of Trade Liberalization on Taiwan -- A Computable General Equilibrium Analysis," October 1994. ***(No.9406)***

56. Ya-hwei Yang. "Economic Crime and Business Cycles in Taiwan," January 1995. ***(No.9501)***

57. Jiann-chyuan Wang and Homin Chen. "An Evaluation of the Effectiveness of Government R&D Tax Credits," March 1995. ***(No.9502)***

58. Tzong-shian Yu. "Policies for Industrial Development and Evaluation of their Achievements in the Republic of China on Taiwan," April 1995. ***(No.9503)***

59. King-min Wang. "Grazig Management and Rehabilitation of Degraded Rangeland in Western Australia," August 1995. ***(No.9504)***

60. Hui-lin Wu, Chia-hui Lin, and Ke-jeng Lan. "An Empirical Study of Youth Mobility in Taiwan," November 1995. ***(No.9505)***

61. Mo-huan Hsing. "A Demand System with Homothetic Utility Function: Measurability and Empirical Relevance," November 1995. ***(No.9506)***

62. An-loh Lin. "Dummy Functions in the Koyck Distributed-lag Model," December 1995. ***(No.9507)***

63. An-loh Lin. "Estimation of the AR(1) Model Containing a Dummy Variable," January 1996. ***(No.9601)***

64. Ya-hwei Yang, Yenpao Chen, and Tzung-ta Yen, Ying-yi Tu. "The Financial Aspects of Taiwanese Investment in South China," March 1996. ***(No.9602)***

65. Jiann-chyuan Wang, and Kuen-hung Tsai. "Success Factors in Cooperative Research in Taiwan," May 1996. ***(No.9603)***

66. Lee-in Chen Chiu. "Toward an Interregional Integration of Habitat,

Production and Ecosystem — Developing Taiwan into a Regional Operations Center,'' September 1996. ***(No.9604)***

67. Sze-Yueh Wang and Lee-in Chen Chiu. ''The Impact of Mainland China's Open Door Policy on Regional Industrial Development,'' November 1996. ***(No.9605)***

68. Momoko Kawakami. ''Development of the Small- and Medium-Sized Manufacturers in Taiwan's PC Industry,'' November 1996 ***(No.9606)***