The Taiwanese Personal Computer Cluster : An Analysis of Linkages between PC Manufacturers and Supporting Firms

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1 : Introduction

In the early 1980 s when the computer was not yet familiar to ordinary people, Taiwanese firms entered the new business as producers of Monitors and Terminals or as assemblers of fake Apple II computers or of IBM-compatible machines. By 1998, the total output of the Taiwanese information technology (IT) industry reached about US$ 34 billion and Taiwan became the third largest country in the production value of IT hardware, next only to the USA and Japan. The Taiwanese IT industry largely consists of personal computers (PCs) and related products, and so, it can be called the PC industry. Taiwan is included in the "Four Dragons" of East Asia. However Taiwan's success in the PC industry is remarkable even among these countries. For example, South Korea is highly competitive in the production of capital- and technology-intensive key parts/components such as Random Access Memories (RAMs), Liquid Crystal Displays (LCDs) and Cathode-ray Tubes (CRTs). But it is far from being a match for Taiwan in the production and design of PCs and peripherals, at least up to now. Singapore is also a major world supplier in the PC industry, but this is largely due to the production of Hard Disk Drives (HDDs) and PC systems, both of which are undertaken by foreign multinational companies. At a first glance, it looks strange that Taiwan which is so dependent on small and medium-sized enterprises (SMEs) out-competes these rivals in

a "high-technology" industry. In fact, at least in the early days, the production of PCs and peripherals did not necessarily need large initial investment in equipment and technological learning if they adopted the IBM architecture and only assembled final products without manufacturing necessary parts by themselves. With the original equipment manufacture (OEM) mechanism, Taiwanese manufacturers have avoided spending huge funds on marketing.[1]

Critical to the Taiwanese success story is that the production of PCs and peripherals can be dismantled into different production stages, with each stage being undertaken by independent firms. In addition, PCs and peripherals consist of a huge array of electronic parts, each one of which can be obtained from specialised suppliers. It is a major advantage of Taiwan that the majority of these supporting firms including parts suppliers and subcontractors as well as manufacturers of PCs and peripherals are located within a small area in the northern part of Taiwan. This can be recognised as an industrial cluster, defined as the geographical concentration of enterprises which are engaged in the production and related activities of a specific product. This facilitates an extensive division of labour and cooperation among different units. Under such condition, there

[1] OEM is a specific form of subcontracting, under which the supplying firms make a whole product (and not just one or several steps of the production process) according to the design specified by the buyer, with the product being sold under the buyer's brand name. Relying on OEM, local firms are through time able to accumulate product design capability as well as production skills. OEM that reaches this stage is called own-design and manufacture (ODM). Under ODM, the local firm carries out some or all of the product design, as well as production according to specifications supplied by the buyer. As with OEM, products are sold under the buyer's brand name (regarding Asian NIEs' industrial development through the OEM mechanism, see Hobday, 1995 ab, 1997 and Gereffi, 1996, 1999). It is said that Taiwanese PC industry advanced into the ODM stage around the end of the 1980 s.

is space for SMEs to attain competitiveness if they focus on one specific sub-product or one (or several) specific production stages, through relying on a thorough division of labour and dense networks among local supporting firms.

The recent literature on industrial development has emphasised that the clustering of enterprises contributes to their competitiveness and to the economic growth of their respective regions. Research on developing and newly industrialising countries in particular has shown that SMEs, on the basis of their collective efficiency, have been able to overcome growth constrains and reach distant markets.[2] Probably Taiwan is the most conspicuous success story of industrial growth based on clustering SMEs. Despite the existence of huge amount of literature on the Taiwanese PC or IT industry, it seems that there are not many detailed studies on the quality of inter-firm linkages among local PC producers and related actors (especially, parts suppliers and subcontractors) in the cluster.[3] In this regard, this paper tries to make some contributions. The main

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[2] Inspired by the literature on Italian and other European industrial clusters (e. g. Piore and Sabel, 1984; Pyke, Becattini and Sengenberger eds., 1990; Pyke and Sengenberger eds., 1992; Pyke, 1992, 1994), there have appeared a number of studies on developing countries' clusters (e.g. Schmitz, 1992, 1995 ab; Nadvi and Schmitz, 1994; Nadvi, 1995 ab, 1996; Rabellotti, 1995; Knorringa, 1996). "Special Issue: Industrial Clusters in Developing Countries" of *World Development* (September 1999) provides recent fruits of such studies (e.g. Bell and Albu, 1999; Knorringa, 1999; McCormick, 1999; Nadvi, 1999; Rabellotti, 1999; Schmitz, 1999; Tewari, 1999).

[3] There are several insightful works on this or related matters. Among these, Kawakami (1996, 1998) provides detailed analyses of the system of division of labour in the PC industry and the mechanism by which the flexibility and efficiency of production are achieved. In addition, although they do not necessarily focus on the PC industry, there are several notable studies of SME networking in Taiwan: for example, Ka (1993), Shieh (1992 ab, 1993), Chen (1994, 1998), Luo (1997), Commonwealth Magazine ed. (1993).

tasks of this paper are to : (a) examine the quality of inter-firm linkages between PC manufacturers and supporting firms (i.e. parts suppliers and subcontractors) in terms of belonging to arm's length market relations or inter-dependent network-type relations, (b) to pay explicit attention to inter-firm interactions which are connected with technological learning and innovation. Through a detailed examination on these matters, I try to shed light on the secret of Taiwan's success in the PC industry characterised by rapid technical change and large market fluctuation.

The structure of this paper is as follows. In section 2, an overview of the Taiwanese PC cluster is provided. Section 3 examines the quality of inter-firm linkages between PC manufacturers and parts suppliers/subcontractors. Section 4 offers a detailed analysis of technological interactions between them. The summary of the main findings and concluding remarks are shown in section 5.

2 : An Overview of the Taiwanese PC Cluster

PC systems consist of a lot of peripherals/components such as Monitors, Motherboards, Keyboards, HDDs, Floppy Disk Drives (FDDs), CD-ROM Drives, Mouse attachments, Power Supply Units, and so on. Each of these can be regarded as a relatively independent subsector. In Taiwan, it is normal that manufacturers focus on each of these sub-sectors as specialised suppliers, although advancing into other sub-sectors in order to diversify their business has become not rare since the late 1990 s. The assemblers of PC systems (including Desktop PCs and Notebook PCs) normally purchase necessary peripherals/components from specialised suppliers. According to an official statistical report from 1996, 88% of the establishment units of manufacturing in the PC industry are concentrated on the northwestern part of the island.[4] It is this area that I regard as the "PC cluster."[5]

Besides producers of PC systems and peripherals/components, specialized suppliers of electronic parts and subcontractors are indispensable actors for establishing a flexible and low-cost production system. The electronic parts industry developed accompanying the growth of the conventional electronic industry such as radios, TVs and pocket calculators in the 1960 s and 1970 s, and so, the rate of local supply of necessary parts was relatively high from the start of the PC industry. After the late 1970 s when labour costs increased and production plants for these conventional electronic products started to move to lower-cost countries, electronic parts producers shifted their principal clients to manufacturers of PCs and peripherals (KI 4). The electronic parts sector also has the tendency to cluster, and it overlaps spatially with the PC cluster to a substantial extent. For example, the percentage of the number of business units of the electronic parts and components industry located within the area which I regard as the PC cluster reached about 77 % of the total business units in this industry in 1996.[6] A solid supply base of electronic parts/components and geographical proximity to input suppliers have been a major advantage in the

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[4] Directorate-general of Budget, Accounting and Statistics, Executive Yuan, 1998, *The Report on 1996 Industry, Commerce and Service Census Taiwan-Fukien Area, the R.O.C., Vol. 3 Manufacturing.* Strictly speaking, the PC industry appears in the statistical report under the designation of "data storage media & processing equipment." It includes not only personal computers and peripherals but also other kinds of computers and calculators such as mini-computers, workstations and so on. But the products other than PCs and peripherals make up a very small portion of the total number, and so, it does not matter if we neglect it.

[5] It includes three prefectures (*Taipei, Taoyuan* and *Hsinchu*) and three cities (*Taipei, Keelung* and *Hsinchu*).

[6] Directorate-general of Budget/Executive Yuan, 1998, 1996 *Report of Industrial and Commercial Census Taiwan-Fukien Area, the R.O.C. (Volume 3. Manufacturing).*

Taiwanese PC industry since the early years. In addition, there are some parts which are partly or completely purchased from foreign suppliers (mainly from US, Japanese and Korean firms). But even when this is so, these foreign suppliers normally have plants or branch offices/agents within the cluster area, so enabling Taiwanese customers to easily keep in contact with them.

The well-developed subcontracting system is also considered to be one of the sources of Taiwanese competitiveness. The minute division of labour facilitated by the subcontracting system enabled local small firms to make highly productive use of very limited resources and to grow and innovate in the early stages. In the PC industry, subcontracting is largely concerned with the production of motherboards and other kinds of add-in cards (e.g. graphics cards, sound cards, etc.). The production of these electronic circuit boards consists of several stages such as the insertion of electronic parts on a Printed Circuit Board (PCB) by automatic insertion (AI) machine or by hand and soldering, surface mount technology (SMT) assembly, testing, repair, packaging and so on. All of these stages of production can be farmed out, and the amount and types of tasks that are farmed out change seasonally or depending on business conditions. Accordingly, there are various types of subcontractors. Some can take charge of all of the production stages and some can conduct one or a few stages. Some are specialised in the processing of Motherboards for PCs and some are engaged in the processing of other kinds of boards/cards too. Because of such circumstances, it is difficult to clarify the number of subcontracting units for each function or product. According to one Taiwanese analyst, there were about one hundred subcontractors as of 1998 including not only these in the processing of Motherboards but also in other kinds of cards/boards, among which relatively large ones counted 30~40 (KI 1). With few exceptions, they were located in the cluster area, espe-

cially in *Taipei* and *Taoyuan* prefectures. Within the area, it takes approximately one hour for them to visit one another by a car.

The subcontracting system in the PC industry developed rapidly in the latter half of the 1980 s, when a lot of small-scale firms entered into the assembly of PCs and peripherals and replaced large firms as the main driving force behind business expansion. Many of them specialised in one or several stages of the production process, farming out other stages. Some firms relied on subcontracting orders from other local producers. Because, unlike in the 1990 s when production automation was advancing, in the 1980 s the assembly of electronic circuit boards depended largely on manual work, the necessity for subcontracting remained high in order to utilise lower labour costs. In this manner, the system of a minute division of labour developed. But since 1989 such the system has become less popular. There are several reasons for this. First, producers increased in-house production in order to respond to situational changes such as stricter quality control (QC) requirements from OEM clients, enlargements in OEM orders, and the shortened life span of products. Second, the necessity to rely on the cheap labour of subcontractors decreased because of the introduction of foreign labourers and the moving of production plants to lower-cost countries (Kawakami, 1998).

3: An Analysis of the Quality of Inter-firm Linkages between PC Manufactures and Supporting Firms

The task of this section is to examine the features of inter-firm linkages between PC manufacturers and supporting firms such as parts suppliers and subcontractors. In the first sub-section, an analytical framework to investigate the quality of linkages is provided. The second and third sub-sections examine linkages with parts suppliers and linkages with subcontractors respectively by using this frame-

work. The analysis of this and the following sections is largely based on the information attained from my own fieldwork in Taiwan carried out mainly in 1998. Among many sub-sectors, I selected three sub-sectors as case study materials - the Motherboard ("MB" for short hereafter), Monitor and Notebook PC ("NB" for short hereafter) sub-sectors - and conducted interviews with more than ten firms from each of these.[7]

3.1 : Analytical framework

The presence of a critical mass of local-based, sophisticated (ideally internationally competitive) supporting and relating industries is one of the critical features of dynamic advanced clusters. Even in the global economy, it is indispensable for accelerating innovation as well as for lowering transaction costs and enhancing efficiency, to have close collaboration between them and downstream firms (Porter, 1998).

In developing countries too, relatively successful clusters display the improving quality of linkages with supporting firms. According to Schmitz and Nadvi (1999), who review several recent studies on developing countries printed in "Special Issue : Industrial Clusters in Developing Countries" of *World Development* (September 1999), through responding to enhancing pressure from the

[7] This paper is based on my own DPhil thesis submitted to Sussex University (Kishimoto, 2001 a). In the thesis, I conduct three sub-sector analyses - the Motherboard, Monitor, and Notebook PC sub-sectors. For the thesis, I conducted total 55 interviews : 17 with Motherboard firms (MB 1-17), 19 with Monitor firms (Mo 1-19), 14 with Notebook PC firms (NB 1-14), and 5 with key informants (KI 1-5). All of these interviews were conducted in cooperation with Dr. Luo Jar-Der (Associate Professor of the Graduate School of Information Sociology, *Yuan Ze* University - *Zhong-Li,* Taiwan) and his assistants (Mr. Yeh Yong-Zhu and Mr. Hsu Wei-Jie), and Mr. Su Zhe-Xian who joined in this survey as my assistant.

global economy, "*Vertical cooperation was high and/or increasing*... Co-operation with key suppliers and subcontractors increased on issues of quality and delivery and there was more flow of information up and down the chain" (Schmitz and Nadvi : 1508). There are a variety of experiences in the common trend, of course. For example, in a shoemaking cluster in Agra of India, while strong performers tended to subcontract more, they had not increased stability in their relationship with subcontractors (Knorringa, 1999). In the shoemaking cluster in the Sinos Valley of Brazil, cooperation with suppliers increased initially but the shoemakers' investment in specific suppliers diminished with time, because the prompt delivery of high -quality inputs has become more common (Schmitz, 1999). The overall conclusion from the recent literature, however, is that meeting the new quality and speed requirements requires more cooperation with suppliers and subcontractors.

This trend can be expressed as one of moving from arm's-length contractual relation (ACR) to obligational contractual relation (OCR). ACR and OCR are two ideal types of customer-supplier relationships conceptualised by Sako (1992). In ACR, transactions are conducted at arm's length, avoiding undue commitment, with neither party controlled by the other. OCR is pioneered by Japanese firms, which includes long-term commitment supported by intense communication. In order to establish an analytical framework to be employed in the following empirical analysis, I borrow Sako's distinction of ACR and OCR, but modify it as set out in Table 1.

Table 1 : ACR and OCR

	Arm's-length contractual relation (ACR)	**Obligational contractual relation (OCR)**
Transactional dependence	Buyer has multiple sources. Supplier has many clients. Low trust.	Both buyer and supplier have only one or a few partners. High trust.
Ordering procedure	Bidding takes place. Prices negotiated and agreed before an order is commissioned.	Bidding may not take place. Prices are settled after decision about who gets the contract.
Projected length of trading	Short-term commitment by both buyer and supplier.	Mutual long-term commitment.
Problem solving	"Exit strategy" (threatening to find new suppliers).	"Voice strategy" (to set up a communication system to let things work out with an original supplier).
Communication	Infrequent contact. A narrow channel between the buyer's purchasing department and the supplier's sales department.	Frequent contact regarding socialising as well as immediate necessary business matters. Extensive multiple channels, between engineers, QC personnel, top management, as well as between purchasing and sales managers.
Technological interactions	Little technical cooperation beyond circumstantial interactions.	Close cooperation over quality, efficiency and innovation.

Source : Made by the author based closely on Sako (1992) and partly on Helper (1993).

ACR and OCR have different kinds of advantages. In ACR, relations with suppliers are adversarial, characterised by mistrust, misinformation and conflict. But in the situation where the number of potential suppliers is large and there is excess capacity in the suppliers' industry, purchasers can lower material prices. In OCR, purchasers have a limited number of suppliers and they are connected through extensive channels of communication, which facilitates open exchange of information and joint problem-solving approach to quality improvement and flexible production. Stated simply, if companies compete mainly on cost for large market shares in standardised products, ACR is advantageous. If companies compete on quick response to clients, quality and shorter product development time, OCR appears superior over ACR. Recently global competition is increasingly won or lost on cost-effective quality and shorter product development cycles. To deal with these trends, OCR is more advantageous.

Considering the fact that Taiwanese producers have attained substantial success in the PC industry rich with such trends, it is expected that linkages between PC producers and supporting firms display many of the OCR features. This expectation is examined in this section and, regarding technological interactions, in the next section.

3.2: Linkages with parts suppliers

Taiwanese producers of PCs and peripherals normally purchase all the necessary parts/components from specialised suppliers. In my fieldwork in Taiwan, relations with parts suppliers were surveyed systematically for the Monitor and NB sub-sectors. Regarding the NB sub-sector, the result of survey is introduced in detail in other paper (see Kishimoto, 2001 b). This sub-section examines linkages with parts/components suppliers based on our survey on the Moni-

tor sub-sector.[8]

Monitors are composed of a lot of electronic parts and components such as CRTs, Flyback Transformers (FBTs), PCBs, Cases (i.e. outer frames), and various kinds of Integrated Circuits (ICs). According to one respondent, CRTs make up 60～65% of the total material cost. Other parts account for much smaller portion, for example, Cases account for 4%, FBTs 1.5% and PCBs less than 1% (Mo 13). Among these parts, CRTs are the most important. This is not only because the percentage of them in the total material cost is very large, but also because the function of CRTs largely determines the performance of Monitors.

Because Monitors are a relatively conventional product and Taiwan has a solid background of the production of TV-sets and electronic parts, most parts can be obtained locally. But the supply of CRTs is through Japanese and Korean companies to a substantial extent and most sample firms had dealings with foreign suppliers.[9] Even so, these suppliers also have agents or branch offices in the cluster area, and so, there is no inconvenience for Taiwanese customers.

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[8] We conducted interviews with a total of 17 Monitor producers for the questionnaire survey and conducted two in-depth interviews by using open questions. According to what I confirmed in the fieldwork, there were approximately 10 major producers as of 1998, whose combined output together accounted for more than 70% of the total output of Taiwanese makers. If one includes other minor producers, there were around 30 Monitor makers. Due to various reasons, we could not get sufficient answers in the questionnaire survey from several firms. But investigating more than ten sample firms is meaningful because it accounts for a substantial portion of the whole Monitor producers.

[9] There were approximately ten CRT suppliers in 1998. These include CPT and Philips of Taiwan (Philips is a Dutch company, but its CRT plant is located in Taiwan), Matsushita, Mitsubishi, NEC, Hitachi, Toshiba and Sony of Japan, Samsung, LG and Orion of South Korea.

In our questionnaire survey, we examined relationships with parts suppliers by focusing on four key parts (CRTs, FBTs, PCBs and Cases). The result of our survey is presented here basically following the form of Table 1 : ACR and OCR.

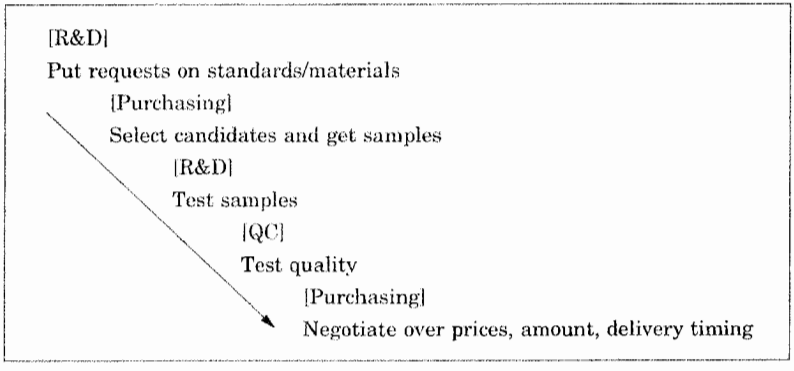
Transactional dependence : Monitor producers normally have dealings with several suppliers of each part, but in many cases the main source is one or two suppliers. The grasp of key parts is one of the crucial factors which decide the business contest. This is especially the case with CRTs. When a shortage develops, it is possible that minor Monitor producers cannot get enough CRTs. According to one respondent, when world leading PC companies such as IBM and Compaq select OEM partners, they tend to prefer Monitor firms that produce CRTs internally or keep a good hold on CRT sources. Taiwanese major Monitor makers keep good relationships with CRT suppliers although most of them do not produce CRTs by themselves (Mo 18).

Ordering procedure : Personal connections often play an important role in many industrial sectors in Taiwan. However, in the PC industry, producers basically get acquainted with suppliers through firm-to-firm direct contact in the open markets, without depending on particular informal connections. Smaller firms possibly tend to depend on personal connections. One respondent said that suppliers were largely sought through personal connections of the boss in the early years, but after the company grew to a certain large size, the adoption of suppliers was decided according to an institutionalised procedure (Mo 3). As far as I discovered in the fieldwork, the selection of suppliers was usually decided according to a fair and open procedure. If a candidate does not meet the conditions required by a Monitor maker, then regardless of personal connections it cannot not get orders.

Here I show an example of the adopting process. According to

one respondent (Mo 14), the adoption of a new part is decided based on a specific standardised procedure as the following : (1) the research and development (R&D) staff decide a proper standard and material for parts ; (2) the purchasing staff select candidate suppliers and get samples from them based on the opinion from the R&D department ; (3) the R&D staff check the samples; (4) the QC staff also test it in terms of quality ; (5) finally, the purchasing staff negotiate with the supplier over prices, the amount of dealings, and delivery timing. If there is not any problem, they start dealings in earnest (see Figure 1). Several firms expressed this as their procedure.

Figure 1 : Adopting Process of Parts Suppliers



Source : Made by the author based on information from Mo 14.

Projected length of trading and problem solving : In the questionnaire survey, we asked : "If you feel discontented with your suppliers over important issues such as quality, price, delivery timing and so on, how do you deal with partnership?" The result is shown in Table 2. No respondent said that they immediately stopped the partnership. Generally speaking, when a serious prob-

lem occurs, they have a meeting with a supplier to discuss a solution. It is possible that dealings are stopped if a partner is dishonest or problems continue to occur. However, because most suppliers are willing to improve, it is rare that a partnership is broken off. One respondent said : "Chinese basically prefer to have a long-term partnership" (Mo 11). But as Table 2 indicates, the majority of respondents said that they reduced the amount of dealings with suppliers that caused problems. Monitor producers may carry out periodical evaluations of their suppliers. According to one respondent, they make an evaluation of suppliers every three months, and change the amount of orders according to their performance. When there is a serious problem, the firm gives a supplier a caution and the grace period of three months, and then, they cancel working with the supplier if it does not show improvement (Mo 6).

Table 2 : Ways of Coping with Serious Problems (Sample : 11)[1]

Means	Immediately stopping partnership	Reducing dealings	Giving time to make improvement[2]	Improving cooperatively	No answer
CRT	0	7	1	0	3
FBT	0	9	0	0	2
PCB	0	8	0	1	2
Case	0	8	1	0	2

Source : Author's survey.

[1] We conducted interviews with a total of 17 Monitor producers for the questionnaire survey. But there are only eleven sample firms for this and several other questions, because these questions were added halfway.

[2] Two respondents gave the answer of "reducing dealings or giving time to make improvement" to all four parts. In this table, these answers are regarded as "reducing dealings." If these are classified into "giving time to make improvement," each part gets two more points in this category.

Communication : I also enquired : "How often do your staff contact the counterparts of suppliers over technological issues such as R&D and QC as well as price and time of delivery?" Table 3 displays the result. Three respondents gave the answer of "Often to Occasionally" to all four parts. In the table, these answers are listed as "Occasionally." If these are regarded as "Often," the score of "Often" gets three more points in each kind of parts. Considering this, we can say that the majority of sample firms said that they kept frequent and multi-channelled communication with suppliers of all main parts. Besides periodical meetings, the purchasing and QC staff are usually in contact, and the R&D staff need to be involved when a new part is adopted or any technical problems arise (Mo 7, Mo 11, Mo 13 and Mo 17). Keeping in constant communication with partners is also indispensable in order to construct the common understanding of the business environment (Mo 5). In addition, there may be social contact between the top level management of each firm.

Table 3 : Frequency of Communication with Suppliers of Each Part (Sample : 11)

Communication	Often	Occasionally	Rare	No answer
CRT	5	5	0	1
FBT	7	3	1	0
PCB	7	4	0	0
Case	7	4	0	0

Source : Author's survey.

Finally, in view of the high offshore production rate in this subsector,[10] I should mention the overseas development of cooperative networks with parts suppliers. As production sites have been moved to foreign countries, mostly Southeast Asia or Mainland China, parts suppliers cannot help moving together or establishing a plant there in order to reduce production costs and to respond quickly to partners' demands. Some Monitor firms do not have their own plants in Mainland China, but have contact with suppliers and subcontractors located there (Mo 4, Mo 14). It is worth noting that many of the Taiwanese PC related plants, including Monitor producers, are concentrated in several districts in Mainland China, especially on *Dongguan* city in *Guangdong* province (near Hong Kong). *Dongguan* has a well-developed base of input suppliers and subcontractors which is the best in Southeast Asia outside Taiwan (Mo 3, Mo 4). It is necessary that suppliers have a plant within or around the cluster in Taiwan, because most Monitor producers conduct R&D in Taiwan. In addition, some of the suppliers establish a subsidiary plant in Mainland China and other foreign countries following the partner's request. One respondent said that about 80% of their suppliers had a plant in Mainland China (Mo 3). Another respondent said that the firm made it a requirement for suppliers that they have a plant in Taiwan, Mainland China and Thailand respectively (Mo 4). It seems normal during their early years that Monitor firms requested and encouraged suppliers to establish offshore plants. However, nowadays this is not necessarily the case, because there have already been ten to twenty thousand

[10] The offshore production rate of Monitors reaches 55% (of the total production value) and 71% (of the total number of products) in 1998 (MIC, 2000, *1998 Yearbook of the Information Technology Industry* ; MIC, 1998, *Retrospect and Prospects of the Information Technology Industry, 1998-99* ; both written in Chinese).

suppliers (it seems to be concerned with the whole PC industry, and not limited to the Monitor sub-sector) in Mainland China, and so, it is easy to find suitable partners there (Mo 3). Even if Monitor firms persuade suppliers to set up an offshore plant, they do not necessarily guarantee enough orders for them. It is normal that they give only a tacit promise and allow their suppliers to get orders from other Monitor producers in compensation for it (Mo 1, Mo 4).

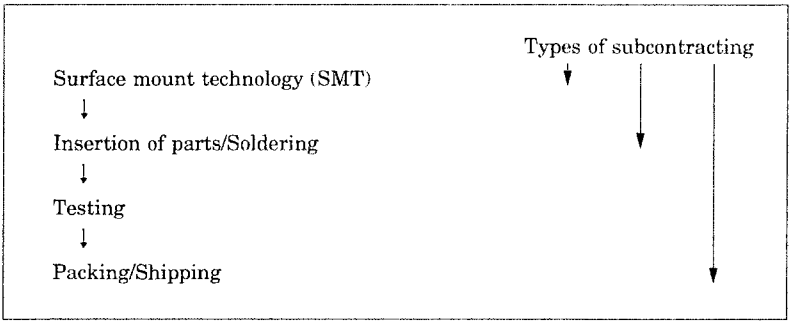
3.3 : Linkages with subcontractors

The purpose of this sub-sector is to investigate in detail inter-firm linkages between producers of PCs/peripherals and subcontractors. The importance of the subcontracting system for the prosperity of the SME-based PC industry in Taiwan has been pointed out by many researchers. For example, Levy and Kuo (1991) say that the presence of many subcontractors, as well as traders, facilitates risk-taking behaviour by providing : "the channels for rapid, incremental expansion of a new business venture, even in the absence of heavy investments in plant and equipment" (Levy and Kuo : 367).

Besides facilitating small-scale entrepreneurial trials by enabling SMEs to save heavy additional investment in production facilities, subcontracting is indispensable in order to : (a) respond to seasonal fluctuations in orders, (b) respond to urgent orders, and (c) deal with exceptional situations such as plant removal, the breakdown of own equipment and the production of special products. According to our survey, the majority of sample firms farm out one or some of production stages in all three selected sub-sectors, and subcontracting is more important in the MB sub-sector than other two sub-sectors, because the MB sub-sector is accompanied by a larger fluctuation of demand than other two sub-sectors. In the fieldwork, a detailed survey on linkages with subcontractors was conducted by focusing on the MB sub-sector.

The production process for MBs is spread out over many stages but can be simplified into several main stages as follows in Figure 2.

Figure 2: Main Production Stages of MBs and Main Types of Subcontracting



Source : Made by the author based on an interview with KI 1.

SMT differs from the insertion of parts and soldering because the former enables electronic parts to adhere directly to the surface of PCBs while the latter solders the terminals of electronic parts from the reverse side. SMT is considered a more advanced technology because it is suitable for fine pitch assembly and can also be done on both sides. In MB production, most electronic parts are loaded by using SMT equipment, but there still are some parts that need automatic or hand insertion and soldering.

According to an analyst of the PC system and MB sub-sectors (KI 1), subcontracting in MB production takes on roughly three types, as follows : (1) just doing SMT, (2) SMT + insertion of parts/soldering, and (3) SMT + insertion of parts/soldering + testing + packing/shipping (see the right-hand column of Figure 2). Type three is uncommon. One other respondent said that it was possible to farm out most of the production stages respectively (MB 16).

The features of linkages between MB producers and subcontractors are examined here basically following the form of Table 1 : ACR and OCR.

Transactional dependence : MB producers usually keep contact with one or several subcontracting units in order to cope with seasonal fluctuation in demand. They usually rely on subcontractors for about 30% of the total production capacity (*DigiTimes*, 13 August 1999). In regard to subcontracting units, the types of production stages they can undertake and the number of clients they have differ amongst subcontractors. But it seems that partnership is usually not exclusive, namely, subcontracting units are allowed to receive orders from two or more clients.

Ordering procedure : There may be different patterns to the ordering procedure. According to one respondent, applicants try to make contacts voluntarily only if the MB firm leaks a rumour that the MB maker is seeking subcontractors. After screening candidates by examining their papers, the staff of production control, QC and R&D departments inspect them, and if a candidate firm meets the required standards on quality, output and delivery timing, the firm is adopted as a partner. The relationship between the bosses (or the heads of related departments) of both firms is generally very close. But when a subcontractor does not meet required standards, it cannot be adopted even if there are special connections. After starting dealings, subcontractors who have special connections may receive more orders if there is no problem with quality and delivery timing (MB 16). With seasonal downturns, subcontractors encounter difficulties. When a subcontractor also deals with other kinds of products, fluctuations are easier to cope with, because the business cycles of other products are different. But if the subcontractor only deals with MBs, business cycle fluctuations can have harmful consequences. In this case, there is possibly the tacit promise that in

seasonal downturn a contracting unit spares some orders for a subcontractor and in prosperous season the subcontractor undertakes more jobs from the contracting unit in return (MB 18). Prices are renegotiated from time to time.

Projected length of trading: Length and stability of partnerships differ amongst MB firms. Some large MB/PC firms simply quit dealings with subcontractors when they expand their own production lines and do not need to rely on subcontractors. Some firms prefer to keep long-term relationships and try to make their orders as stable as possible. Some firms keep contacts with an excessive number of subcontractors and allot orders among these in relation to the situations. Contracting units may give main partners priority and give orders to other partners only when the main partners have enough orders. Generally speaking, there is the tacit agreement between contractors and subcontractors about avoiding a sudden cancellation of dealings, although it may be accepted that the partnership is gradually fading away. If a contracting unit breaks its agreement, the reputation of the firm is injured (MB 16, MB 17).

Problem solving and communication: Subcontractors usually keep in close contact with a contracting unit involving both technical and managerial staff, and if there is any problem on technology and/or quality, a meeting is held or technicians from the contracting unit may be dispatched to assist improvement. If subcontractors fail to meet the standard of quality and delivery timing for several weeks, they are excluded and forbidden to be a partner again (MB 14, MB 16).

In the future, the room for subcontracting units to survive in Taiwan is expected to decrease. There are several reasons for this. First, as the profit in MB production has dropped, MB producers try to enhance it by internalising previously farmed out production stages, and so realise scale merits. Specifically, recently many MB

firms have started to try to gain OEM orders from leading world computer companies. In order to get orders, the production capacity must reach a certain large standard. In addition, this tendency is spurred by the fact that many MB producers (and PC related firms as a whole) start to make preparations for listing shares and must have their own production capacity at a certain level within Taiwan (MB 18).

Second, overseas production, especially in Mainland China, has become larger and larger in order to cut costs and to expand production capacity. It is not rare that a group of subcontracting units establish foreign plants accompanying the overseas investment of contracting units (MB 16).

Third, MB firms tend to withdraw subcontracting orders in order to respond to stricter QC demand, because QC is conducted better when done internally. One respondent reported thus : "if a quality problem occurs, the cost of repair may become higher than the profit of farming it out. Thus, we sometimes prefer to postpone an order or quit it rather than expand output too much" (MB 17).

4 : Technological Interactions between PC Manufacturers and Supporting Firms

Clustering may promote the vertical disintegration of production processes based on process and product specialization, which leads to an expanding and deepening range of input suppliers, subcontractors and other service providers. Each specialised firm is able to focus its energies on technological and managerial developments specific to its activities. This leads to deepening of the technological capabilities of each firm.

Learning may also be facilitated by rapid flows of technological information, interaction and consultation regarding technical and design specification among main producers, input suppliers and

subcontractors. These interactions and information flows are more easily realised in clusters than among dispersed entities. According to Lundvall (1988), when technology is standardised and reasonably stable, geographic clustering is not indispensable for information exchange. But when technology is complex and ever changing, the geographical and cultural proximity and the frequency of the interaction between users and developers are crucial. One of the best examples of this accelerated innovation mechanism is found in the Silicon Valley in the USA. Many of the new Silicon Valley computer firms specialise in a limited number of core capabilities and establish close partnerships with key input suppliers and contract manufacturers, through which they can introduce complex new products rapidly and alter their product mix continually (Saxenian, 1994).

We know from the literature that clustering facilitates interactions but is no guarantee that it takes place, nor that it is of a kind that enhances efficiency and innovation. In general, in the global economy, it is expected that in successful dynamic clusters, relationships between the main producers and supporting firms display the feature of OCR, namely, maintaining close communication and cooperation on quality, efficiency and innovation as well as prices. Key partners may be involved in new product design and development processes, and their relations should be reciprocal being based on each speciality. Contrastingly, in unsuccessful static clusters, it is thought that supporting industries have not developed well and that the quality of goods and services provided by them are often below necessary standards. Their relations with main producers have the ACR feature, namely, more price-driven than quality-driven and entailing limited technical cooperation that goes beyond unconscious circumstantial interactions.

The analysis of the previous sections shows that the well-

developed supporting industry has been an important source of competitiveness for the Taiwanese PC industry and that relationships between PC producers and parts suppliers/ subcontractors possess many OCR features such as high-trust, long-term commitment, voice strategy for problem solving, and frequent contact through multiple-channels. This section examines how significant technological interactions are and to what extent such interactions contribute to learning and innovation. Technological interactions with parts suppliers and with subcontractors are investigated in the first and second sub-sections respectively. The third sub-section offers an analysis of the technological competitiveness of Taiwanese PC producers, shedding light on in-house technical effort by individual firms too.

4.1 : Technological interactions with parts suppliers

In the questionnaire survey, the importance of various extra-firm information sources is examined. I focus on knowledge flows into PC producers from other actors in connection with new product (or new model) design and development. Table 4 shows the result of the questionnaire survey.

Table 4: Number of Respondents who Regard Each Knowledge Source as Very Important for New Product Design and Development (except in-house R&D)

Knowledge sources	Motherboard (Sample : 13)	Monitor (Sample : 16)	Notebook PC (Sample : 12)	Total (Sample : 41)
a) Local informal social gatherings	2	1	1	4
b) Key parts suppliers	10	8	7	25
c) Foreign clients	7	7	5	19
d) Domestic clients	2	1	0	3
e) Taiwanese rival firms	3	2	3	8
f) Foreign rival firms	1	3	3	7
g) Traders/dealers	1	0	0	1
h) Exhibitions	3	3	2	8
i) Foreign subsidiaries	1	1	0	2
j) Specialised publications	5	2	3	10
k) Trade associations	0	0	0	0
l) Public supporting institutions such as the MIC	0	0	0	0
m) Public research institutes such as the ITRI	0	0	0	0
n) Workers from other firms	0	0	1	1

Source : Author's survey.

In our interview, we asked a respondent to classify the knowledge sources into four categories : "very important," "important," "moderately important" and "not important." A numeral in each cell is the number of respondents who chose each knowledge source as a "very important" one.

MIC = Market Intelligence Centre of the Institute for Information Industry (III)

ITRI = Industrial Technology Research Institute

Table 4 reveals that key parts suppliers and foreign clients are critical as knowledge sources for new product design and development, while public and private supporting organisations (i.e. trade associations, public supporting institutions such as the MIC, and public research institutes such as the ITRI) are lowly rated in this field. Anyway, key parts suppliers are the most important source in all three sub-sectors. This is most prominent in the overwhelming influence of the suppliers of Central Processing Units (CPUs) and Chipsets in the MB sub-sector.[11] Here I introduce the result of our survey on this matter.

MBs consist of various kinds of electronic parts such as CPUs, RAMs, Chipsets, PCBs, Condensers, Connectors, Resisters, Switches and so on. Among these, CPUs and Chipsets have a crucial influence on the business trend of the MB sub-sector. First, these are important because of their large proportion of the entire material cost of MBs. Chipsets account for around 30~40% of the material costs (CPUs have no influence on the material costs, because MBs are usually shipped without being loaded with CPUs) (KI 1). Second, CPUs and Chipsets are very important in terms of technology. The performance of MBs (and PCs) is basically determined by CPUs and Chipsets. Recently more and more functions have been incorporated into the semiconductor chips. These key parts are provided by a limited number of specialised suppliers (Intel has a predominant position among them).[12] It is often said that business trends in

[11] CPU is the "brain" of the PC. It accumulates the basic functions of computers - basic processing units, main storages, control storages, input-output control units and so on - on a semiconductor chip. Chipset is a kind of Large Scale Integration (LSI) unit that delivers and translates electronic signals between CPUs and other components.

[12] The share of Intel in the world total supply was about 77% in CPUs and 75~80% in Chipsets in 1998 (*DigiTimes*, 7 October 1999, 11-13 March 2000).

the MB sub-sector are largely initiated by CPU/Chipset suppliers rather than MB producers and end-users. Therefore, the key concern in the MB business is to respond to CPU and Chipset technology upgrading, and to bring a new MB model to the market as quickly as possible and ideally before competitors. Getting technological information and marketing strategy information about new CPUs and Chipsets from Intel as early as possible is crucial in the process of new model development.

Due to the predominant position of Intel in the supply of CPUs/Chipsets, Taiwanese MB (and PC) producers cannot help adopting the so-called "follow Intel" strategy. Traditionally it has been the custom in the MB industry that every time Intel develops new products, MB producers have to adjust a product line-up according to it. One respondent said that because MB producers could not change the content of these key parts, the R&D of MB firms in reality did not involve profound technologies and there was no major difference in MB design among producers (MB 11). In addition, CPU/Chipset suppliers, like other parts supplier, have intermittently reduced the price of products. The production and sales schedule of MB firms must be adjusted in relation to this, because it influences the value of parts in stock as well as the price of final products.

The suppliers of CPUs and Chipsets offer information on new technologies to MB producers. Suppliers explain the technical features of products and give instruction and recommendation on good design. Such technological data were definitely necessary in the R&D of MBs, as one respondent reported (MB 11). The following are ways of supplying information :

- sending information through Internet automatically to the club members (MB 11) ;
- holding seminars to announce new products or to train MB engi-

neers (MB 11, MB 6, MB 4);
- technology transfer and formal/informal cooperative R&D with selected MB firms (MB 4).

The relation between Intel and MB producers is not unilateral but rather bilateral. Considering the strength of Taiwan in the world MB market,[13] it is no wonder that Intel has intended to spread its products by making good use of Taiwanese firms. For several years Intel has maintained a cooperative relation with several top Taiwanese MB and PC producers (MB 4). Intel offers these partners samples of CPUs and Chipsets when a trial product is developed and makes their Taiwanese partners conduct the reliability test for it (MB 16). These selected partners not only receive detailed technological information but can also obtain more samples of new trial products. For example, selected cooperative firms are supplied one or two hundred samples but other minor partners are given less than ten samples. Because CPUs are burned, damaged or lost during testing process, this process is limited by being allotted fewer samples (MB 4). The partners are classified into three categories according to their importance for Intel, namely, red, yellow and white, which derives from the colour of the cover of internal technical reports. "Red cover" is the most detailed and the promptest. "White cover" is the opposite. "Yellow cover" is between them. Formerly there was only one red cover partner: ASUS, which is the top MB maker of Taiwan. Now there are four firms classified

[13] For example, in 1998, Taiwanese MB/PC firms manufactured 84 % of the total world output (this excludes the portion that the world top ten PC makers produced by themselves or farmed out to contract manufacturers). If you consider only clone markets (namely, MBs sold to the non-top ten PC producers), the share for Taiwan reached 95% (MIC, 1998, *Retrospect and Prospects of the Information Technology Industry 1998-99*).

as red cover firms (MB 4). In industrial sectors with fast technological and product turnover, the earlier a firm brings a new model to market, the more profit it can attain. This is one of the reasons why ASUS has reported an extremely high profit margin.

The important partners are in direct communication with Intel, while other less important firms normally get in contact with Intel through agents. Recently Intel has begun to try to co-opt more promising MB firms, due to the dominant position of Intel being eroded. But entering into the direct communication circle gives MB firms disadvantages as well as advantages. As mentioned above, it offers advantages such as getting technological support, detailed and prompt information on new products and technologies, and the plentiful number of samples. But it also has burdens, such as being forced to accept more number of products when the product does not sell well and causing difficulties in dealing with other CPU/Chipset suppliers. On account of this, one red cover firm intentionally keeps contact with Intel through an agent. Moreover, the time lag in bringing a new model to market between red cover and other minor partners is becoming less and less. During the fieldwork, this time lag was reduced to one month or less because the life span of a MB model itself was becoming shorter and shorter (about half a year or less) (KI 1).[14]

But such predominant influence of CPU/Chipset suppliers in the MB sub-sector is rather exceptional. In other sub-sectors, relationships with suppliers of some key parts are critical but less so.

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[14] One respondent said that this is also due to the speed of R&D in small firms being faster than that of large firms. Speed and flexibility are the main competitive advantages of small firms (MB 11). But according to another respondent, it is not the case that the R&D of small firms is speedier. He argues that the competitiveness of small firms consists in focusing on a specific range of product and in advancing into niche markets (KI 1).

For example, as mentioned above, CRTs are the most important among key parts in the Monitor sub-sector. But the influence of CRT suppliers on the technological trend of the Monitor sub-sector is much less prominent. One of the reasons is that CRTs are a matured product and they involve relatively stable technological change. Another reason is that there are more than ten suppliers of CRTs in the world and none of them has as much power as Intel has in CPUs.

In the fieldwork, this issue was discussed with several respondents. Because CRTs are supplied mainly by Japanese and Korean firms, Taiwanese Monitor producers more or less cannot help depending on them regarding technological issues (Mo 1). Although CRT technology is substantially matured, some innovations take place. Sometimes CRT suppliers can lead the development trend of the Monitor industry (Mo 7). But in comparison with the MB sub-sector, it seems that CRT suppliers do not have the kind of overwhelming influence on the design of Monitors that CUP and Chipset suppliers have. According to one respondent, users' demands, not innovation of key parts suppliers, lead the development trajectory of this industry. CRT suppliers innovate according to market demands and the prospect of future trends. Monitor makers can simply select an appropriate CRT from the existing product line-up of suppliers. They make R&D following clients' demands, not following CRT innovation (Mo 5).

In the NB sub-sector, CPUs and LCDs are especially important among key parts. Suppliers of CPUs/Chipsets, especially Intel, have considerable influence on the design and development of NBs too. But this is diluted, because NBs include several other important parts such as LCDs and HDDs. LCDs are crucial, because LCDs account for 30~40% of the total material costs of NBs. The design and development of a new NB model is influenced by not

only the upgrading of CPUs/Chipsets but also the upgrading of other key parts.

In the questionnaire survey, we examined how significant technological cooperation between PC producers and key parts suppliers was. We asked whether or not there was explicit technological cooperation such as cooperative R&D, technology transfer and cooperative training of engineers, in connection with partnership with CRT suppliers in the Monitor sub-sector and partnership with LCD suppliers in the NB sub-sector. Unexpectedly, few respondents have such kinds of technological cooperation with key parts suppliers, if any, it is not of a substantial nature that is conducive to deep innovations of each party. One respondent stated: "it is normal that there is not substantial technology transfer except when we are in the same business group or have a strategic alliance agreement" (Mo 13). This is the case in relations with suppliers of other key parts too.

In conclusion, despite close communication with key parts suppliers, it seems that there are few technological interactions that have a profound influence on the innovation of either party, except that technical data and instruction offered by CPU/Chipset suppliers (especially Intel) are crucial in the design of MBs and NBs. As specialisation has progressed, producing parts has become a totally different kind of industry from producing the final product of PCs and peripherals. As mentioned above, the upgrading of PCs and peripherals is initiated by the upgrading of key parts to a substantial extent, and key parts suppliers are considered the most important knowledge source for new product design and development. But it seems that technical interactions with suppliers are more concerned with routine model changes than with fundamental innovations.

4.2: Technological interactions with subcontractors

Technological interactions between PC manufacturers and subcontractors were investigated in detail during the survey of the MB sub-sector. Relatively large MB firms may have a specialised team for providing technical support to subcontractors. Contracting units may request subcontractors to accept a specific production control procedure, but generally speaking there is no deep technical interaction except QC (KI 1). Subcontracting units must meet a certain quality standard to survive. For example, one respondent pointed out that passing ISO 9002 was the minimum condition (MB 15). Furthermore, technical assistance is not necessarily provided by contracting units for subcontractors. It is not rare in Taiwan that a contracting unit which has undertaken only R&D and sales receives technical assistance from its subcontractors or purchases their plants when the contracting unit advances into the production sphere. But, as confirmed by our fieldwork, interaction with subcontractors has no importance as a knowledge source for product design and development.

4.3: Technological competitiveness of Taiwanese PC producers

In the PC industry, technological trends are initiated by key parts suppliers rather than by PC manufacturers. Also, in spite of close communication, technological interactions between PC producers and parts suppliers are not of a substantial nature except the case of CPU/Chipset suppliers. The question to be examined here is what the source of technological competitiveness of Taiwanese PC manufacturers is.

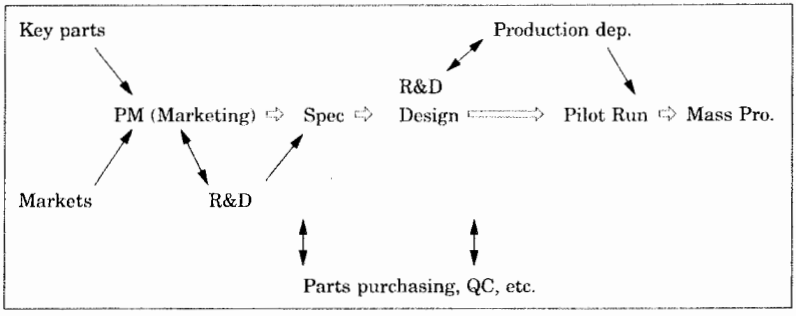
According to one Taiwanese analyst of the PC system and MB sub-sectors (KI 1), the main competitive advantage of Taiwanese firms is found in the speed of product design and development, flexibility, and low production costs. Such kinds of strength coin-

cide with the key success factors of the middle and down streams of the IT industry. It cannot be applicable to upper-stream industrial sectors (for example, the semiconductor industry) even among the IT industry.

These kinds of strength are derived from in-house effort of individual PC manufacturers as well as cooperation with supporting firms. The remainder of this section examines this issue in detail.

The speed of product design and development : In the PC industry, product innovation mainly means the development of new models, rather than entirely new products. We investigated the whole in-house process from new model design and development to mass production in the MB sub-sector. There are many stages but a simplified figure is shown in Figure 3.

Figure 3 : From Product Design and Development to Mass Production of MBs



Source : Made by the author based on interviews with KI 1, MB 16 and MB 17.

The explanation of each stage is the following. First, depending on the analysis of new key parts (especially CPUs and Chipsets) and the market situation, specifications are made. This task is carried out by the product manager (PM - sometimes conducted by the

marketing manager) consulting the R&D staff. In small firms that have only the sales department (without the marketing staff and PM), the sales staff convey the demand of clients to the R&D staff, who then decide on a specification. Second, based on the specification, the R&D staff start design, first alone, and afterwards consulting the staff of the production department. Third, pilot runs and mass production are mainly taken over by the production department keeping in contact with the R&D staff. If a firm farms out the entire production process, the production process is transferred to a subcontractor (KI 1). According to another respondent, many different MB models may be developed at the same time. The respondent said that they developed several types of MBs on each Chipset.[15] When new Chipsets or new key parts are put on the market, they start to develop new models of MBs. It usually takes less than two months for products to be ready for mass production (MB 17).

How do extra-firm actors such as parts suppliers influence this process? Key parts suppliers (mainly meaning CPU/Chipset suppliers) may have close contacts with the R&D staff during the design stage. Especially, technical data and instruction on new CPUs and Chipsets offered by suppliers are indispensable in the R&D of MBs (MB 11). But according to our survey, except the case of cooperation between CPU/Chipset suppliers and some selected Taiwanese PC producers, it seems that parts suppliers are not deeply involved in new product design and development process. For example, in

[15] The number of MB models needed to be designed is largely decided by the number of types of CPUs and Chipsets. "The number of MB models = types of CPUs × types of Chipsets × MB design standards × VGA/Audio on-board" (MIC, 1998, *Retrospect and Prospects of the Information Technology Industry 1998-99).* Small-scale MB makers cannot afford to develop all the necessary models, because their technical human resources are limited.

the Monitor sub-sector, a firm interviewed by us adopts proper suppliers as potential partners by using a certain procedure similar to that of Figure 1, and selects a supplier that offers the cheapest and the most compact parts among them each time. A respondent of the firm said: "parts suppliers cannot have a voice in development process. They just conduct their task according to an agreement" (Mo 18).

Close communication with parts suppliers is certainly one of the reasons for short cycles of new model design and development. But other reasons are concerned with in-house effort of individual PC manufacturers. First, according to one respondent (KI 1), the speed of product design and development is due to the hard work of the R&D staff: "Taiwanese engineers work sixteen hours a day... Sixteen hours work by one parson is not equal to eight hours work by two people. Such tasks cannot be split into two." In the capability of design and development, Taiwanese firms are not necessarily superior to major foreign companies such as IBM and Compaq, although they are superior to Korean producers and other second class foreign rivals.[16] Despite this, foreign leading companies offer OEM orders to Taiwanese producers, "because the speed of development is faster, which is the result of the fact that Taiwanese endure hardship." He said: "foreign clients have gradually transferred tasks which they do not like to do to Taiwan. In the early years, they transferred production, now it includes design too, and logistics in the future... Tasks which entail hardship and provide relatively low profit margins are transferred to Taiwan."

Second, the in-house product design and development process

[16] According to the analyst, QC and production engineering technologies of Taiwanese firms are not especially outstanding, although they are beyond the ordinary standard (KI 1).

goes ahead in a parallel and integrated manner, through which they can curtail necessary time, although the whole process is described as if it is conducted one stage by one stage in Figure 3. This is to say that the core staff of all the other related departments such as parts purchasing, QC, sales and finance join in the meeting and submit requests to the R&D department from each of their viewpoints. There are such meetings not only in the R&D stage but also in every stage of product design to mass production, and the staff of the related departments go ahead with their own tasks harmoniously (MB 17). This practice is observed in the Monitor and NB sub-sectors too.

Flexibility : Besides relying on cooperation with subcontractors and suppliers, the intra-firm flexible mobilisation of employees is also crucial. Flexibility is related to social background, namely, that Taiwanese engineers and workers do not mind overtime work (KI 1). According to a manager of the production department from a MB firm (MB 16), the production process, if necessary, can be finished within a few days, although it needs one or two weeks in a normal situation. He stated : "if we have urgent orders, ... we make certain that the necessary parts are carried to the plant in the daytime, and it is possible to start the SMT process in the evening. Of course, all the necessary implements are prepared in advance. After finishing SMT in this evening, the stage of insertion of parts and soldering will be done tomorrow. In the tomorrow evening, we will begin the testing stage by working overtime, then, products will be ready for packing and shipping in the day after tomorrow. The necessary time for the production process can be substantially cut short through such practice."

The organisation of firms is important too. The structure of Taiwanese firms is usually flat, and this is said to contribute to their quick response to market changes. The simplification of the

chain of command has become a trend in the IT industry. This organisational feature of Taiwanese firms is not the result of reengineering, but the result of the fact that Taiwanese firms were originally small and afterwards, when they grew, they tried to keep such a flat structure.

Low production costs: Taiwan has established an exceptional low cost production system. Once this system was set up by Taiwan, low profit rates placed an entry barrier to the producers of other countries. This low cost production system is based on not only the inter-firm minute division of labour and specialisation but also intra-firm cost reduction effort. Recently, the establishment of plants in lower-cost countries (especially, Mainland China) has become another major factor.

One respondent told us some examples of cost cutting know-how. First, they improve design in order to display the same functions with fewer parts. Second, material cost is squeezed. It is customary in this industry that most parts suppliers reduce price every quarter. Third, through improvement in production control, they try to reduce the rate of inferior goods. Fourth, costs can be depressed through increasing the turnover rate of the stock (which means decreasing stocks). All the departments of the firm try to find the room to eliminate waste (MB 16). According to another respondent, unlike Japanese firms, Taiwanese producers do not adhere to "perfect quality and design." He said: "Taiwanese producers can supply any level of services following client demand ... very flexibly responding to client demand including design, manufacture process, location of manufacture, ... if you do not need this function, we eliminate it" (Mo 5).

Finally, I introduce the result of our survey on in-house learning effort undertaken by individual firms. In all three sub-sectors, our survey disclosed that Taiwanese producers (except subcontract-

ing units) had normally established specialised departments for R&D and their activities were taken very seriously. Without substantial in-house R&D effort, knowledge flows from other firms and institutions are meaningless. The ceaseless upgrading of technology and the short life span of product models peculiar to the PC industry make it impossible for producers to survive by depending only on price cutting or on imitation and follow-up innovation.

Besides product innovation by the R&D staff, other technical staff who are in charge of engineering, manufacturing and QC may conduct incremental process innovation. According to our observation in the fieldwork, although there seems no deep innovation such as inventing complex equipment and unique production control technique, Taiwanese PC firms make much of improving production skills. This can be understood by the fact that all the sample firms established the specialised production control and QC departments. But there are not major differences in equipment and production lines among the main Taiwanese PC firms. This is because the production process has already been standardised in most sub-sectors and equipment is purchased from a limited number of suppliers. Conventional machines can be obtained from local suppliers, while precise equipment such as SMT is usually bought from foreign companies (especially, Japanese suppliers such as Fuji, Panasonic and Sanyo). There do not seem to be technology transfer and technological cooperation between PC producers and machine vendors beyond standardised after-sales services such as teaching operational use, offering training sessions and repair/adjustment services. These machines are so complicated and include so many functions that user firms cannot (and do not need to) improve them, except for peripheral adjustments.

Despite a substantial learning effort, it is the case that Taiwanese producers still need make much more effort to catch up with the

technological level of world leader firms. On average, the R&D expenditure of Taiwanese information technology and electronics companies accounts for only 3% or less of total sales (*DigiTimes,* 23 December 1999). As far as I heard in the fieldwork, the R&D of the hardware of PCs and peripherals (excluding key parts) was mostly carried out within Taiwan without relying on connections with external advanced regions such as the Silicon Valley in the USA. But the R&D of Taiwanese firms tends to concentrate on the improvement of existing products and technologies directly connected with commercialisation. One respondent said: "in this industry, we often jokingly say that Taiwanese R&D means 'Read and Duplicate' "(NB 14). This is partly because SMEs have been the main driving force of economic development in Taiwan. Recently, however, as large-scale companies have emerged and the importance of scale merits has been emphasised in Taiwan, financial capacity has become less of a bottleneck. Another reason is of cultural nature. One respondent said: "Taiwanese firms are seized with insularism. They pay attention to the prospects for only three years... In contrast, major foreign companies have a company strategy for fifty years. They consider what status their companies will reach after fifty years and invest in R&D from a long-term viewpoint" (Mo 1). According to the same respondent, the negative effect of such a short-term perspective appears in the weakness of Taiwan in specific industries that need a huge and longstanding investment such as the precision machinery industry and the materials and the optical sciences. In the electronics industry, Taiwan has turned in relatively poor performances in products such as Printers and Fax machines, where precision machinery technology plays a crucial role. The respondent also said that it would take 30 years for Taiwan to catch up with Japan and the USA in these industries (Mo 1).

5 : Conclusion

As mentioned above, I selected Motherboard, Monitor and Notebook PC sub-sectors as case study materials in the fieldwork. There are some differences in linkages between PC producers and supporting firms among the three sub-sectors. For example, in the MB and Monitor sub-sectors, the rate of locally purchased parts is relatively high. In contrast, in the NB sector, many key parts such as FDDs, HDDs, CD-ROM Drives, Batteries are supplied largely by foreign companies. In addition, in the MB sub-sector, subcontracting plays an important part in order to cope with seasonal market fluctuation, although the importance of this is decreasing. But in the Monitor and NB sub-sectors, while many of sample firms utilise subcontracting, this seems less important than in MB production.[17] Despite these differences, we can find very similar tendencies in transaction relations with supporting firms among the three sub-sectors. That is to say that linkages with suppliers/subcontractors have many features of OCR.

The main findings of the previous sections are shown in Table 5. Relations with parts suppliers were surveyed systematically for the Monitor and NB sub-sectors, while relations with subcontractors

[17] Subcontracting in the Monitor sub-sector seems to be much less important than in the MB sub-sector. There are several reasons. First, the life span of a product model in the Monitor industry is longer and the business environment is more stable than in the MB sub-sector. Second, recently Monitor producers have rapidly enhanced production capacity, with this tending to exceed demand. In the NB sub-sector too, subcontracting plays a limited role. The production of NBs includes a lot of very precise processing and is less standardised. Therefore it is relatively difficult to divide the production process and farm out some stages. Moreover, because the NB design is less standardised and includes more firm-specific technologies, NB makers prefer making it internally. They may farm out only a few routine stages in the assembly of motherboards or the production of small accessory cards.

were mainly investigated for the MB sub-sector. Casual evidence, however, suggests that there are no major differences among the three sub-sectors in the quality of linkages with both suppliers and subcontractors.

Table 5: Relations with Parts Suppliers/Subcontractors in the Taiwanese PC Cluster (in the late 1990 s)

Attributes of relations	Relations with parts suppliers	Relations with subcontractors
Transactional dependence	Producers normally have two or more sources for each kind of parts, although they make one supplier the main source in many cases. On the other hand, suppliers do not serve one client exclusively either. High trust.	Producers usually keep contact with one to several subcontractors. It differs among subcontractors how many clients they have. Partnership is usually not exclusive, namely, subcontractors are allowed to receive orders from other clients.
Ordering procedure	A supplier is chosen as a partner through a fair and strict screening (examining technology, quality and delivery timing). Bidding does not take place. Prices are negotiated after a candidate is adopted as a partner (and renegotiated from time to time).	Basically the same as relations with parts suppliers.
Projected length of trading	Long-term commitment is preferred. Even when there are no dealings, contact is kept.	Length and stability of partnership is different among producers. But generally speaking, there is a tacit agreement about avoiding a sudden cancellation of dealings.
Problem solving	Basically the "Voice strategy," but a supplier is excluded if it cannot meet requested standards within a grace period. In addition, producers routinely investigate suppliers' performance, and change priorities accordingly.	Basically the "Voice strategy," but a subcontractor is cut off if it cannot display sufficient improvement within a grace period.

Communication	They keep multi-channelled, frequent communication involving not only the purchasing/sales staff but also R&D, QC, and top management. There are routine contacts and renegotiations over price, quality and delivery timing, as well as socialising.	There is frequent communication over QC, delivery timing, and so on. The relationship between the bosses (or the heads of related departments) of both parties is generally very close.
Technical interactions	Key parts suppliers are critical as a knowledge source for product design and development. But there seems little substantial technical cooperation and technology transfer with suppliers except that technical data and instructions offered by CPU/Chipset suppliers are indispensable in the design of MBs and NBs.	Producers may provide technical support to subcontractors. But generally speaking, there seems to be no deep technical interaction except regarding QC. Most subcontractors as well as producers possess at least one of the ISO certifications. Subcontractors have no influence as a knowledge source for product design and development.

Source : Author's survey.

Some supplementary comments are to be made, as follows.

First, recently communication with parts suppliers has become more and more close. Having a good hold on parts becomes one of the factors which decide business competition. In addition, keeping proper stocks of necessary parts and efficient inventory control are crucial factors for good performance. Parts' technologies are also rapidly upgrading, and their prices fluctuate according to the suppliers' strategy and the condition of supply and demand. If the stock of parts is too large, it runs the risk of larger inventory control costs and of reducing the value of stocks due to a sudden drop in the price of parts. If the stock is too small, it may result in failure to assimilate orders from OEM clients which exceed the original forecast, thus, causing losses to clients. According to an article in *DigiTimes,* as build-to-order (BTO) has become a business standard, major foreign OEM clients such as IBM and Compaq have recently started to request that their Taiwanese partners establish the elec-

tronic supply chain management (SCM) system. Consequently, Taiwanese major PC producers recommend that their suppliers introduce enterprise resource planning (ERP) and electronic data interchange (EDI) as a precondition for establishing the computerised SCM system (*DigiTimes,* 27 August 1999).

Second, despite close communication with key parts suppliers, it seems that there is little technology transfer and cooperative R& D that have profound influence on the innovation of either party, except partnership between Intel and selected Taiwanese MB/PC producers. The main technological competitiveness of Taiwanese firms is found in the speed of product design and development, flexibility, and low production costs. These advantages can be attributed to intra-firm effort as well as cooperative linkages with supporting firms.

As mentioned, Taiwanese PC producers have normally purchased all the necessary parts from specialised suppliers, and some key parts have been entirely or largely supplied by foreign companies. I asked a Taiwanese analyst of the PC industry whether or not this become potential weakness in technological and other fields in comparison with Japanese PC/electronic companies which produce key parts internally.[18] According to the respondent (KI 1), it depends on the situation. The Taiwanese manner is more flexible, although trouble may occur when the shortage of parts supply develops. Although purchasing key parts from extra-firm sources leads to a rise in production costs, this can be compensated by offshore production in lower-cost countries. But the respondent also said that Japanese companies were advantageous in the develop-

[18] For example, Toshiba can produce many (but not all) of the key parts for NBs such as HDDs, CD-ROM Drives, Memories, LCDs and so on. But recently Toshiba has started to make several sections independent companies and to introduce the self-supporting system (*DigiTimes,* 28 May 1999).

ment of novel products : "One of the reason why the product of Toshiba is such advanced is that the company can use many new parts specially developed internally" before these parts are mass-produced and sold to other PC companies.

Third, the decreasing importance of subcontracting has become obvious after the peak in the mid-1990 s, when offshore production in Mainland China started to grow rapidly. Around 1992~1993, OEM orders from major foreign clients began to surge into Taiwan and their stricter requirements on QC accelerated the decline of subcontracting. But subcontracting has not simply decreased its importance since that time. Subcontracting expanded rapidly in the first half of the 1990 s and went into decline after its peak of the mid-1990 s. Although I could not obtain data for each sub-sector on this matter, the information collected shows roughly the same tendency. One respondent from a Monitor firm reported : "in regard to the rise of subcontracting in the mid-1990 s, this occurred because the majority of producers had not yet moved production to Mainland China in earnest and market demand increased rapidly at that time. But in 1996~1997, offshore production gradually rose, and so subcontracting declined" (Mo 19).

Finally, I should mention several issues to be explored from now on. First, future research needs more comparative work, because most existing empirical research focuses on case studies of individual clusters. There are three promising types of comparison : (a) between clusters and other types of production organisations, (b) between successful and non-successful clusters in the same industrial sector, and (c) between clusters belonging to different industrial sectors.[19] Second, future research should examine how inter-

[19] Regarding the last type of comparison, Luo and Yeh (1999) provide an initial research. According to them, there are some conspicuous differences in linkages

firm linkages with supporting firms change their features from ACR to OCR. This is needed because, in most cases, firms are faced with the task of transforming existing relationships rather than committing themselves to a new model of relationships. Under the pressure from the global economy, many regions cannot avoid some kinds of transformations regardless of developed or developing countries.

List of Abbreviations:

ACR	arm's-length contractual relation
AI	automatic insertion
BTO	build-to-order
CPU	central processing unit
CRT	cathode-ray tube
EDI	electronic data interchange
ERP	enterprise resource planning

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with suppliers and subcontractors between high-technology industries such as the PC industry and traditional industries such as tbe garment industry. For example, in the PC industry, the process of starting a partnership is primarily managed on an institutionalised procedure of examining a candidate by objective standards such as quality, lead-time as well as price. The partnership is based on the trust generated by rational calculation and repeated transactions. In the garment industry, personal connections play a more important role. The partnership is based on the trust generated by social and geographical ties. In addition, in the PC industry, the amount of orders to suppliers normally changes according to their performance, which is periodically evaluated. But once a supplier is adopted as a partner, the relationship is usually maintained for the long term. Even when dealings are suspended due to the unsatisfactory performance of a supplier, the partnership is maintained until a new opportunity arises. In contrast, in the garment industry, a partnership is usually very close and managed on a long-term basis. But once dealings are discontinued, the partnership also terminates.

FBT	flyback transformer
FDD	floppy disk drive
HDD	hard disk drive
IC	integrated circuit
III	Institute for Information Industry
ISO	International Organization for Standardization
IT	information technology
ITRI	Industrial Technology Research Institute
KI	key informant
LCD	liquid crystal display
MB	motherboard
MIC	Market Intelligence Centre (of III)
Mo	Monitor
NB	Notebook PC
NIEs	newly industrialising economies
OCR	obligational contractual relation
ODM	own-design and manufacture
OEM	original equipment manufacture
PC	personal computer
PCB	printed circuit board
PM	product manager
QC	quality control
R&D	research & development
RAM	random access memory
R.O.C.	Republic of China
SCM	supply chain management
SMEs	small and medium-sized enterprises
SMT	surface mount technology
TFT-LCD	thin film transistor-LCD

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