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Upgrading in the Taiwanese computer cluster: transformation of its production and knowledge systems

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Summary

The relevance of clustering for upgrading continues to be a controversial topic in the industrial development debate. This paper investigates this question for the case of the Taiwanese computer cluster. It is a particularly challenging case because of two features: first, it probably presents the most significant case of industrial upgrading outside the OECD countries; second, a significant and rapidly increasing share of its output is made offshore. What then is left of the much discussed cluster theory and the alleged benefits of clustering for local development and upgrading? This paper argues that, in order to examine such issues, it is important to take two analytical steps: first, distinguish between the production and knowledge systems, and second, complement the local cluster approach with the global value chain approach. On the first, the paper shows that the importance of clustering has diminished in the production system but remained high in the knowledge system. As regards the second analytical step, the paper shows that linkages of the local producers with their global customers have been critical to their upgrading and analyses how local and global linkages have reinforced each other. Particular attention is paid to the qualitative transformation of linkages over time.

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Abbreviations

ACR	arm's-length contractual relation
AI	automatic insertion
BTO	build-to-order
CCL	Computer & Communication Research Laboratories (of ITRI)
CM	contract manufacturer
CPU	central processing unit
CRT	cathode-ray tube
EDI	electronic data interchange
ERP	enterprise resource planning
ERSO	Electronics Research & Service Organization (of ITRI)
FBT	flyback transformer
FDI	foreign direct investment
GVC	global value chain
HDD	hard disk drive
HSIP	Hsinchu Science-based Industrial Park
IC	integrated circuit
IDB	Industrial Development Bureau (of MOEA)
III	Institute for Information Industry
IPO	international purchasing office
ISO	International Organization for Standardization
IT	information technology
ITRI	Industrial Technology Research Institute
LCD	liquid crystal display
MB	motherboard
MIC	Market Intelligence Centre (of III)
MOEA	Ministry of Economic Affairs
NB	Notebook PC
NIEs	newly industrialising economies
OBM	own-brand manufacture
OCR	obligational contractual relation
ODM	own-design and manufacture
OEM	original equipment manufacture
PC	personal computer
PCB	printed circuit board
QC	quality control
R&D	research & development

RAM	random access memory
R.O.C.	Republic of China
SCM	supply chain management
SME	small and medium-sized enterprise
SMT	surface mount technology
SPS	switching power supply
TCA	Taiwan Computer Association
TFT-LCD	thin film transistor-LCD

1 Introduction

In the global economy supported by rapid transportation and high-speed communication technology, the whole or part of the production process can easily be farmed out to distant production sites, and required inputs can be purchased from suppliers all over the world. In such a situation, the importance of geographical concentrations of enterprises which are engaged in closely related activities, so called "industrial clusters", is likely to decrease. Recently, even in Italian industrial districts that were considered the showcases of industrial clustering, the decentralisation of production stages outside the districts was feared to destroy the traditional self-contained business structure (Cossentino *et al.* 1996).

Some authors, however, have argued that intensifying global competition increases the importance of location, rather than diminishing it. According to Porter: 'The enduring competitive advantages in a global economy are often heavily local, arising from concentrations of highly specialized skills and knowledge, institutions, rivals, related businesses, and sophisticated customers' (Porter 1998: 90). He also states that the decentralisation of production stages outside a cluster does not necessarily indicate the decreasing importance of location. The cluster's competitiveness is recovered by moving part or all of production elsewhere to offset local wage rises as far as the cluster succeeds in grasping strategic functions and in enhancing innovative capabilities. He states: 'The essence of a cluster lies in the exchange of insights, knowledge, and technology, and in offering a structure that offers the incentives and flexibility to innovate' (Porter 2001: 145).

The logic of this scenario is easy to grasp. It implies a repositioning of the cluster in the world economy. The cluster upgrades by shedding activities of low value added and concentrating on activities of high value added. We know that this has been central to the growth and prosperity of today's advanced economies. But to what extent can one identify such a strategy in the clusters of late industrialising countries? There is very little evidence. This paper examines to what extent such a dynamic can be observed in the Taiwanese personal computer (PC) cluster.

For this purpose this paper draws on two analytical advances that have been made in the recent cluster literature. The first is the distinction between the cluster as a production and knowledge system, proposed by Bell and Albu (1999).[1] According to them, the previous cluster literature mainly focuses on the analysis of the *production system*; a concept which encompasses inter-firm transactions involving parts, materials, machines and services directly connected with the production of goods at a given level of technology. They suggest that more attention should be paid to the *knowledge system* in order to clarify the connection between clustering and technological dynamism. The concept of the knowledge system is

[1] The challenge posed by Bell and Albu may have a common interest with the literature concerned with region-specific technological development system. It includes several lines of studies that adopt one of the similar conceptual frameworks such as 'regional collective learning' (Keeble and Wilkinson (eds) 1999, 2000), 'the learning region' (Asheim 1996; Morgan 1997), and 'regional innovation systems' (Cooke *et al.* 1997). Collective learning is an indispensable element of a successful 'innovative milieu', as Camagni (1991) states.

concerned with the learning process and technological capabilities accumulated within a cluster which lead to upgrading.[2]

This paper on the Taiwanese PC cluster shows that the two systems have developed in different directions. The main conclusion of the empirical sections is that the role of clustering has decreased in the production system and increased in the knowledge system. That is to say, in the production system, we observe the increasing relocation of manufacturing mature products to neighbouring low wage countries. In contrast, with respect to the knowledge system, the manufacture of the less mature products and innovation activities remain concentrated in the cluster.

The second analytical advance, which this paper builds upon, is the fusion of the local cluster and the global value chain (GVC) approaches proposed by Humphrey and Schmitz (2000). The first approach prioritises local linkages. The second concentrates on global linkages and there is increasing recognition that the two need to be brought together. However, the way in which local and global linkages interact remains a disputed and under researched question. This paper suggests that sustainable growth through global linkages necessitates establishing a local base for continuous innovation and developing a unique product/service mix, which in turn requires the quality of local cluster linkages as a whole to be enhanced.

This paper investigates why Taiwanese PC manufacturers have attained considerable upgrading in the GVC and why their success entails some important limitations, by connecting these two approaches. Much of the empirical analysis is concerned with assessing the quality of inter-firm linkages rather than quantitative examination. This is because the quality of inter-firm linkages is critical for the technological upgrading of the cluster.

The Taiwanese PC industry has been selected as a case study for three reasons. First, it is probably the biggest success story of industrial growth and upgrading in a GVC, based on the clustering of home-grown small and medium-sized enterprises (SMEs). Second, it is also a good example to examine how technological learning by local producers in a rapidly changing industrial sector might be affected by both local and global linkages. Third, the development of the cluster has occurred within the context of a highly internationalised and dynamic industrial sector.

The paper is structured as follows: the next section highlights the main transformations of the Taiwanese PC cluster, mainly based on quantitative data. Sections 3 and 4 provide a detailed examination of the quality of inter-firm linkages of the cluster, focusing on the production and knowledge systems respectively. Section 5 depicts the changing position of this cluster in the global PC chain, and also seeks to show how local cluster linkages interconnect – and are sometimes transformed – by external linkages. The final section draws together the main findings and shows the kinds of upgrading which the cluster has achieved and failed to achieve. The empirical analysis of this paper basically reflects the actual situation during the late 1990s when I conducted fieldwork in Taiwan (see Kishimoto 2002).

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[2] The distinction between the production and knowledge systems, while useful in principle, is often hard to apply in practice because the two overlap and influence each other. In this paper, the cluster relationships concerned with operating an existing mode of production are examined as the production system, while relationships concerned with generating change (i.e. learning and upgrading) are included in the knowledge system. For more detailed discussion of the distinction, see Bell and Albu (1999).

2 The transformation of the Taiwanese PC cluster

This paper uses a simple definition of a cluster as a geographical and sectoral concentration of firms.[3] The main purpose of this section is to provide an overview of the Taiwanese PC cluster and to examine the validity of Porter's thesis quoted above, namely, that simple production tasks can be shed and that more knowledge-intensive tasks benefit from clustering under increasingly global competition. The examination in this section is presented in a summarised manner mainly based on quantitative data, leaving more detailed, qualitative analysis to the following sections.

In the early 1980s 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 and IBM-compatible machines. In 2000, the total output of the Taiwanese information technology (IT) industry reached about US$47 billion (including offshore production) and Taiwan became one of the leading countries in the production value of IT hardware.[4] The Taiwanese IT industry largely consists of PCs and related products, as a result it can be called the "PC industry". The indispensable role of Taiwan in the global PC supply system is reflected in the fact that Taiwan manufactures a wide range of PC-related products (we call these "sub-products"), and that in many sub-products Taiwan accounts for a large portion of the world total output. For example, Table 2.1 shows that in six main sub-products, Taiwan has more than 50 per cent of the world share.

Table 2.1 Basic data of main sub-products in the Taiwanese PC industry (in 2000)

Unit: value (million US$) / volume (thousand)

Ranking	1) Total output (value)	2) Total output (volume)	3) Offshore production (value: %)	4) Offshore production (volume: %)	5) World share (volume: %)	6) OEM rate (%)
1 Notebook PC	13,548	12,707	4	6	53	90
2 Monitor	10,392	62,365	70	88	54	-
3 Desktop PC	7,797	27,660	80	84	25	82
4 Motherboard	5,674	84,372	43	48	70	36
5 CD/DVD/RW	2,605	67,579	74	86	39	48
6 Switching power supply (SPS)	1,879	98,895	91	95	74	-
7 Case	1,580	91,345	77	80	77	-
8 Scanner	1,089	27,135	78	86	93	60
Total	**47,019**		**51**			

Source: The Market Intelligence Centre (MIC) of the Institute for Information Industry 2001, *2000 Yearbook of the Information Technology Industry* (in Chinese).

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3 This is the definition proposed by Schmitz (1995). Porter (1990) in his early cluster work did not use geographical proximity as a defining characteristic of clusters but in his more recent work he did: 'Clusters are geographic concentrations of interconnected companies and institutions in a particular field' (Porter 1998: 78).

4 Taiwan was the third largest country in the production value of IT hardware, next only to the USA and Japan in 1999 (excluding offshore production). Mainland China overtook Taiwan in 2000, but the substantial part of Mainland China's output was produced by Taiwanese firms.

In this paper, the small area from *Taipei* to *Hsinchu* (northern part of Taiwan) is regarded as the "PC cluster".[5] According to an official statistical report from 1996, there were 1,344 units of manufacturing in the computer industry of Taiwan, of which 1,185 units (88 per cent) were concentrated in this area.[6] There are approximately four main groups of actors in this cluster:

(1) Producers of PC systems and peripherals. The PC industry consists of many sub-sectors, in each of which there are dozens of specialised producers.[7] Most of them are SMEs, however, scale is becoming more critical in most sub-sectors.

(2) Specialised suppliers of parts and subcontractors. Critical to the Taiwanese success story is the fact that the production of PCs and peripherals can be dismantled into different production stages, with each stage being undertaken by independent subcontracting units. For example, there were about one hundred subcontractors in 1998. In addition, PCs and peripherals consist of a huge array of electronic parts, every one of which can be obtained from specialised suppliers. Although some key parts/components and high-quality inputs are partly or entirely purchased from foreign suppliers, the broad supply base of electronic parts and the geographical proximity of suppliers and subcontractors has been a major advantage for the Taiwanese PC industry.

(3) Buyers and traders who link local producers to distant markets. As shown in Table 2.1, a substantial portion of the total products of Taiwanese PC firms are sold through original equipment manufacture (OEM – a kind of contract manufacturing which is explained later). Most major world computer companies, as OEM clients, established an international purchasing office (IPO) in Taipei. Hundreds of indigenous traders, most of whom are small-scale firms, played an important role in this especially in the early years.

(4) Other ancillary units including public supporting institutions such as the Industrial Technology Research Institute, trade associations such as the Taipei Computer Association, and suppliers of specialised producer services.

The concentration, in this small area of PC producers and related actors, facilitates an extensive division of labour and cooperation (and competition) among the different units. A pool of experienced engineers and managers has been created. Geographical proximity enables them to keep in frequent contact, and business and technological information quickly diffuses among them. Such conditions enable

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

6 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 computer industry appears in the statistical report under the designation of 'data storage media and processing equipments manufacturing'. It includes not only PCs and peripherals but also other kinds of computers and calculators such as workstations and so on. However, the products other than PCs, peripherals and their components make up a very small portion of the total number, therefore, it does not matter if we neglect it.

7 The number of manufacturing units of sub-products in 1997 were 27 in Desktop PCs, 26 in Notebook PCs, 48 in Monitors, 62 in Motherboards, 14 in CD-ROM drives, 9 in Scanners, 10 in Mouse units, 13 in Keyboards, and 43 in Switching Power Supply units, respectively (MOEA 1998, *1997 Annual Report of Industrial Statistics, Tai-min Districts, the R.O.C.*). The manufacturing units given in the data are those with more than 30 employees among the formally registered firms.

entrepreneurs to enter business with small starting capital. It is obvious that all these conditions are closely connected with the conspicuous success story of industrial growth mainly based on home-grown SMEs.

Beyond the general observation that clustering contributes to the rising status of Taiwan in the world PC hardware production, there is twofold evidence of upgrading. First, Taiwan has gradually shifted its business focus from mature sub-products to new ones. This is an example of product upgrading, namely, a shift to manufacturing more sophisticated products. As shown in Table 2.2, four main sub-products (i.e. Monitors, Desktop PCs, Motherboards and Notebook PCs) have accounted for a substantial portion (about 70–80 per cent) of total PC hardware output. Among them, Notebook PCs – a newly emerging sub-product – has steadily increased its weight. Similarly, among other sub-products, relatively new ones such as Scanners and CD/DVD/RW-drives have taken the place of conventional sub-products such as Keyboards and Mouse units.

Table 2.2 Leading sub-products of the Taiwanese PC industry (every three years)

1986	1989	1992	1995	1998	2000***
Monitor (23.5)*	Desktop PC (25.5)	Monitor (29.3)	Monitor (37.2)	Notebook PC (24.9)	Notebook PC (28.8)
Desktop PC (21.4)	Monitor (24.0)	Desktop PC (15.0)	Notebook PC (17.1)	Monitor (22.3)	Monitor (22.1)
Terminal (14.9)	Motherboard (14.7)	Motherboard (13.4)	Desktop PC (11.8)	Desktop PC (19.1)	Desktop PC (16.6)
… 59.8%	Terminal (8.4)	Portable PC** (10.1)	Motherboard (11.4)	Motherboard (12.8)	Motherboard (12.1)
	… 72.6%	… 67.8%	… 77.5%	… 79.1%	… 79.6%
	Switching Power	SPS	SPS	SPS	CD/DVD/RW
	Supply (SPS)	Graphics card	Graphics card	CD-ROM drive	SPS
	Keyboard	Terminal	Desktop scanner	Case	Case
	Graphics card	Scanner	Keyboard	Scanner	Scanner
	Control card	Network card	CD-ROM drive	Graphics card	DSC (Digital Steel Camera)
	Hard Disk drive	Keyboard	Network card	Keyboard	
	Mouse				

Source: Made by the author based on MIC, *Yearbook of the Information Technology Industry* (each year edition).
*The figures in brackets indicate a percentage of the sub-product in total output (including both domestic and offshore production by Taiwanese producers) of IT hardware.
**Portable PC includes Laptop PC, Notebook PC and so on, but it mainly means Notebook PC.
***The data of 2001 could not be obtained at the time of writing.

Second, Taiwan also deserves a mention as a rare example of substantial functional upgrading in GVCs. Functional upgrading means acquiring more complex functions in the chain for example, moving from simple production to design and marketing. Functional upgrading can take place through various ways, and Taiwan has relied mainly on the OEM arrangement. OEM is a specific form of subcontracting under which the supplying firms make a whole product (not just one or several steps of the production process) according to the design specified by the buyer. The product is then sold under the buyer's brand name. By

relying on OEM, local firms can attain product outlets without burdening large investment in marketing and after-sales services, and over time they are also 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. If successful, local firms may advance beyond it to acquire other functions such as logistics and eventually to start own-brand manufacture (OBM). As some scholars point out, this logic is not easily realised (Schmitz and Knorringa 2000). But the Taiwanese PC industry has passed a series of successive development stages from the initial stage (the first-half of the 1980s), the OEM stage (the second-half of the 1980s), the ODM stage (the first-half of the 1990s), and eventually the ODM/Global Logistics stage (the second-half of the 1990s), as will be shown in detail in Section 5.

In tandem with this functional upgrading process, there is an indication that clustering has declined in importance as a simple production site. That is to say, as revealed in Table 2.1, the offshore production rate has reached a considerable level in a number of sub-products. There are two details to be mentioned here. First, the offshore production rate measured by volume is larger than the rate measured by value in all sub-products, although the difference between them is not very large (see columns 3 and 4 of Table 2.1). This implies that the offshore production is more concerned with price-sensitive product segments than high-end products in any given specific sub-sector. Second, in six of the eight products listed in Table 2.1, offshore production (volume) accounted for 80 per cent or more of the total production of the Taiwanese companies. As shown in Table 2.3, detailed observation reveals that the rate started to rise during the earlier stages in conventional, technologically simple (or standardised) sub-products such as Monitors, SPS units, Cases and Keyboards. Yet, the rate has remained low, or started to increase only in the later stages, in relatively new, technologically complex sub-products such as Notebook PCs,[8] Scanners and CD/DVD/RW-drives. The rate has been kept moderately high in the Motherboard sub-sector which is relatively mature but entails rapid model change and technologically complex production control. These facts indicate that offshore production has advanced more in relatively mature sub-products, while the production of less mature sub-products (and the production of high-end product segments of mature sub-products) tends to remain in Taiwan. In addition, as will be examined in detail in the following sections, the original Taiwan cluster has kept, if not increased, its importance in knowledge-intensive or home-base functions such as product design and development, sales and financial management, and coordination activities for offshore production networks.

[8] The low offshore production rate of Notebook PCs can be linked to government's prohibition against moving strategic industries to Mainland China. But many business people that I interviewed stated that it was basically because of technological reasons rather than political consideration during the late 1990s.

Table 2.3 The rate of offshore production of main sub-products (volume: %)

	1993	1994	1995	1996	1997	1998	1999	2000
Notebook PC	0	0	0	0	0	0	3	6
Monitor	24	40	49	50	55	71	73	88
Desktop PC	-	-	-	-	-	89	86	84
Motherboard	26	34	44	40	40	37	41	48
CD/DVD/RW		0	25	32	48	59	81	86
SPS	46	53	77	83	86	91	94	95
Case	-	-	-	57	70	75	78	80
Scanner	0	0	0	0	10	38	58	86
Keyboard	68	69	85	93	90	91	-	-

Source: MIC, *Yearbook of the Information Technology Industry* (in Chinese, each year edition), and other internal reports of the MIC.

This section has introduced some important features of the Taiwanese PC cluster and its upgrading, mainly based on quantitative data. All the facts shown in this section are in line with the above-mentioned suggestion by Porter, namely that clustering does not necessarily decline, instead, clusters can upgrade by shedding activities of low value added and concentrating on activities of high value added even in the era of global economy. But it should be stressed that the transformation entails some important limitations. Central knowledge and coordination functions such as creating new product concepts and brand-marketing are not carried out by Taiwanese firms but remain in the hands of world leading buyers and key parts suppliers which have headquarters in advanced countries such as the USA and Japan. The following sections will detail this. They are largely based on qualitative information obtained from my own fieldwork.

3 The production system

The previous section showed the increasing outsourcing of mature and price-sensitive products. This section investigates what happened in that part of the production system that remained clustered in Taiwan, between *Taipei* and *Hsinchu*. The focus is on the relationships between local computer manufacturers and with suppliers, customers, and institutions. How did they contribute to the success of the cluster? As set out in the literature, clustering may lead to efficiency and flexibility gains derived from *local external economies* and *joint action*; together they are captured in the concept of *collective efficiency* (Schmitz 1995, 1999; Nadvi 1996). Local external economies involve unplanned and circumstantial gains such as the emergence of a pool of sector-specific skilled labour/experts, the easy and rapid availability of local suppliers of specialised machinery and inputs, technological and market knowledge flows and so on. Joint action involves active and consciously pursued inter-firm cooperation that goes beyond anonymous market driven contacts such as sharing equipment, joint technology development, joint marketing and so on. This section examines the significance of collective efficiency in the Taiwanese PC cluster, focusing on the production system.

This task is mainly carried out by analysing the quality of linkages between producers of PCs/peripherals and other related agents. Four main linkage categories are examined: (1) backward linkages with supporting firms such as parts suppliers and subcontractors; (2) horizontal linkages with other local fellow producers;[9] (3) forward linkages with actors who are relevant to marketing, especially OEM clients; and (4) institutional linkages with public and private institutions which are engaged in supporting local firms and promoting cluster development. These categories are analysed in the following sub-sections respectively. In due course, a framework for assessing the quality of linkages is presented and it is shown that cluster linkages in Taiwan generally improved in quality. This seems to support the above-mentioned Porter suggestion.

The analysis of this section is relevant to the actual situation during the late 1990s, when I conducted fieldwork in Taiwan. Among various sub-sectors in the PC industry, three were selected for detailed study – the Monitor, Motherboard (MB), and Notebook PC (NB) sub-sectors. They represent different degrees of maturity, with Monitors being the most mature product and NBs the least. During fieldwork, I conducted a total of 55 interviews. Nineteen interviews were carried out with Monitor firms, 17 interviews were with MB firms, 14 interviews were with NB firms, and five interviews were conducted with key informants.[10]

3.1 Backward linkages

The presence of a critical mass of sophisticated (ideally internationally competitive) supporting firms and close collaboration between them and downstream firms is one of the critical features of dynamic clusters. In developing countries too, relatively successful clusters display an improving quality of linkages with supporting firms (Schmitz and Nadvi 1999). Sako (1992) conceptualises two ideal types of customer-supplier relationships – arm's length contractual relations (ACR) and obligational contractual relations (OCR). In ACR, relations with suppliers are adversarial, characterised by mistrust and poor information flows. In OCR, customers and suppliers are connected through extensive channels of communication, which facilitates open exchange of information and a 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. Table 3.1 summarises the framework for examining the quality of backward linkages, by borrowing and modifying Sako's distinction of ACR and OCR.

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9 Strictly speaking, horizontal linkages consist of two dimensions – bilateral linkages (relationships between individual firms) and multilateral linkages (cooperation through setting up cluster-wide private self-help institutions such as trade associations). However, in this paper, multilateral horizontal linkages are discussed under the category of institutional linkages, because they often play a role as part of a broader support system for local firms which consists of various private self-help institutions and public organisations.

10 The fieldwork was conducted largely in 1998 and some follow-up interviews were carried out in 2000. Most 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), his assistants (Mr Yeh Yong-Zhu and Mr Hsu Wei-Jie), and Mr Su Zhe-Xian who joined this survey as my assistant.

Table 3.1 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 work things 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, quality control personnel and 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: Modified by the author based on Sako (1992) and partly on Helper (1993).

In recent years, global competition is increasingly won or lost on cost-effective quality, flexibility and shorter product development cycles. This is especially the case in the PC industry. Theoretically, OCR is considered more advantageous to deal with these trends. Considering the substantial success of Taiwan in the world PC industry, one may expect that backward linkages in the cluster show the key features of OCR. The main task of this sub-section is to examine this expectation, based on the framework presented in Table 3.1.

Taiwanese PC producers normally buy all the necessary parts from specialised suppliers. It is often said that the existence of a wide-range of supporting firms, especially suppliers of parts and subcontractors, is indispensable for establishing a flexible and low-cost production system. The electronic parts/components sector also has the tendency to cluster, and it overlaps spatially with the PC cluster to a substantial extent. The percentage of business units supplying electronic parts and components located within the area of the PC cluster reached 74 per cent of the total number of business units in this sector in 1981 and gradually increased to 77 per cent in 1996.[11]

A solid supply base of electronic parts/components and geographical proximity to input suppliers have been a major advantage for the Taiwanese PC industry since the early years. However, there are some key parts, such as central processing units (CPUs), hard disk drives (HDDs), cathode-ray tubes (CRTs) and key equipment, that are partly or completely purchased from foreign suppliers (mainly from US, Japanese and Korean firms), as mentioned above. Novelettes, these foreign suppliers normally have

11 Directorate-general of Budget/Executive Yuan, *The Report of Industrial and Commercial Census Taiwan-Fukien Area, the R.O.C. (Volume 3. Manufacturing)* (each year edition).

plants or branch offices/agents within the cluster area, enabling Taiwanese customers to easily keep in contact with them. This is an example of the incidental economies of clustering.

The well-developed subcontracting system is also considered to be one of the sources of Taiwan's competitiveness. The extensive 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 an automatic insertion (AI) machine or by hand and soldering, surface mount technology (SMT) assembly, testing, repair, packaging and so on. These stages 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 stages of production and some can conduct one or two stages. Some are specialised in the processing of MBs 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 in 1998 including not only those in the processing of MBs but also in other kinds of cards/boards, among which relatively large ones counted 30–40. With few exceptions, they were located in the cluster area, especially in Taipei and Taoyuan prefectures. Within the area, it takes approximately one hour for them to visit one another by a car.

Following this overview, we now examine to what extent backward linkages show the feature of OCR (or ACR) during the late 1990s. There are some differences in backward linkages among the three sub-sectors. For example, the rate of locally supplied parts is relatively high in the MB and Monitor sub-sectors, while it is low in the NB sub-sector. In addition, in the MB sub-sector, subcontracting plays an important part in order to cope with seasonal market fluctuation, although this importance is decreasing. In contrast, despite many sample firms utilising subcontracting in the Monitor and NB sub-sectors, it seems much less important than in the MB sub-sector. Despite these differences, the same pattern basically appeared in transaction relations with parts suppliers and subcontractors among the three sub-sectors. As summarised in Table 3.2, the backward linkages have many features of OCR.[12]

Table 3.2 illustrates two supplement comments. First, communication with parts suppliers has recently become much closer. Having a good hold on parts becomes one of the factors to determine business competition. In addition, keeping proper stocks of necessary parts and efficient inventory control are often pointed out as crucial factors for good performance in this rapidly changing industry. 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 electronic supply chain management (SCM) system. Consequently, Taiwanese major PC producers

[12] For details of the three sub-sectors, see Chapters 4, 5 and 6 of Kishimoto (2002).

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).

Table 3.2 Backward linkages of the Taiwanese PC cluster (in the late 1990s)

Attributes of relations	Relations with parts suppliers	Relations with subcontractors
Transact-ional dependence	Producers normally have two or more sources for each kind of part, 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. The number of clients also differs among subcontractors. In many cases, partnership is 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 response time). 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. Contact is maintained even when there is no business dealings.	Length and stability of partnership differs among producers. But there is usually a tacit agreement to avoid a sudden business cancellation.
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.
Communi-cation	They keep multi-channelled, frequent communication involving not only the purchasing/sales staff but also R&D, quality control and top management. There are routine contacts and renegotiations over price, quality and delivery timing, as well as socialising.	There is frequent communication over quality control, 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	To be examined in Section 4.	To be examined in Section 4.

Source: Author's survey.
In the survey on relations with parts suppliers, we focused on several kinds of key parts: CUPs/Chipsets in the MB sub-sector; CRTs, flyback transformers (FBTs), PCBs and Cases in the Monitor sub-sector; CPUs/Chipsets, RAMs, liquid crystal displays (LCDs), CD-ROM Drives, HDDs, Cases, PCBs and Batteries in the NB sub-sector. Relations with subcontractors were mainly investigated for the MB sub-sector, but casual evidence suggests that there are no major differences among the three sub-sectors.

Second, the decreasing importance of subcontracting has become obvious after a peak in the mid-1990s, when offshore production in Mainland China began to grow rapidly. Although I could not obtain detailed data, the information collected shows roughly the same tendency among various sub-sectors. One respondent from a Monitor firm reported: 'In regard to the rise of subcontracting in the mid-1990s, 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'.

In conclusion, a good understanding of the backward linkages is critical to explain the ability of PC firms to compete. As expected, transaction relations with both parts suppliers and subcontractors basically display the key features of OCR. However, under growing pressure of globalisation and ongoing offshore production, the significance of cooperation with suppliers increasingly rises, while that of local subcontracting practice declines. These two actors have a different impact in the sphere of technical interactions. This will be analysed in the next section.

3.2 Horizontal linkages

In analysing the horizontal relationships, I will again contrast the literature with the practice in Taiwan. The cluster literature emphasises two dimensions of horizontal relationships – competition and cooperation. According to Brusco (1992), even in the advanced Italian industrial districts, cooperation tends to take place between firms at different production stages, while strong competition occurs among firms performing a similar work process or producing a similar product.

Porter (1990) stresses the importance of local rivalry in propelling firms forward. According to him, successful industries are much more likely to emerge in nations with strong domestic rivalry than nations in which one or several "national champions" are brought up by protections and subsidies. 'In global competition, successful firms compete vigorously at home and pressure each other to improve and innovate' (Porter 1990: 117). Domestic rivalry need not be restricted to just price competition. Instead, rivalry in other forms such as enhancing technology, quality and efficiency is conducive to more sustainable national or regional advantage. He also argues that geographical concentration of rivals in a small area strengthens these benefits.

The type of competition is as important as its intensity. In the cluster literature, there is a distinction between two kinds of competition – "low road" and "high road". The former 'consists of seeking competitiveness through low labour costs, and a deregulated labour market environment', while the latter means 'constructive competition, based on efficiency enhancement and innovation' (Sengenberger and Pyke 1991: 9–10).

Horizontal relations among local fellow producers in the Taiwanese PC cluster are characterised by strong rivalry, especially price competition. Several respondents said that it was an outcome of Chinese national characteristics. 'Taiwanese do not act in harmony over deciding the bottom price unlike Japanese. Foreign clients take advantage of this in price negotiations. The situation is worse than even in Korea', claimed one respondent from a Monitor firm. This tendency particularly increased after 1997 when the low-price PCs started to be popular. One can readily find a vicious cycle: decreasing profit margin → competition in expanding production capacity to offset it → scrambling for OEM orders from major foreign clients to secure enough outlets (possessing a substantial level of production capacity is a precondition for gaining orders from major clients) → foreign clients take advantage of rivalry between Taiwanese producers to beat down the price → decreasing profit margin further. This is common in

various sub-sectors, but especially the case in mature sub-sectors such as Monitors. Viewing this aspect alone leads us to the conclusion that local rivalry in the Taiwanese PC cluster displays a "low road" nature.

Yet, harsh price competition is not necessarily a bad thing. Price cutting is not realised only by "squeezing labour". Taiwanese producers have also gained more comprehensive cost management capabilities. In the latter half of the 1980s, Taiwan established an exceptional low-cost production system ensured by an extensive division of labour and specialisation, then recently, by the construction of scale-intensive production and offshore production networks. In addition, according to one MB firm, in-house cost reduction efforts are also indispensable. This includes, for example, improving design in order to display the same functions with fewer parts, enhancing production control to reduce the rate of inferior goods, and increasing the turnover rate of the stock (which means decreasing stocks). The establishment of this low-cost/low-profit system raises the entry barrier for producers from other countries.

As well as cost management, innovation and flexibility are other key factors for out-competing rivals. The rapid technological upgrading and the short life span of product models peculiar to the PC industry make it impossible for producers to survive by only depending on price-cutting. Because the speed of product design and development is critical in business competition, firms must make a substantial investment in in-house research and development (R&D) without relying merely on imitation and follow-up innovation. For example, in the MB sector the average lifespan of a model is around (or less than) half a year. By putting a new model on the market one-month later than their rivals results in a sharp reduction of profits for the firm. This issue will be covered in more detail in the next section.

To take advantage of market chances flexibly is also indispensable. Flexibility is often derived from cooperation with subcontractors and suppliers, but the intra-firm flexible mobilisation of employees is also crucial. According to one Taiwanese analyst, such flexibility is related to social background, i.e. Taiwanese engineers and workers do not mind working overtime. The same respondent also pointed out that the structure of Taiwanese firms was usually flat. This was said to contribute to their quick response to market changes. Considering all these conditions, we can conclude that horizontal relationships in this cluster are characterised by a mixture of "high road" and "low road" competition.

Stressing the competitive dimension does not mean that cooperation cannot take place amongst competitors. In dynamic clusters such as the Silicon Valley and Cambridge in the UK, researchers identified the culture of relative openness and cooperative practices (Saxenian 1994; Lawson and Lorenz 1999). Joint action and networking with local firms are more easily established with support from skilled network brokers of public institutions (Pyke 1992).

During my fieldwork in Taiwan, we scarcely heard of joint action in the three sub-sectors. One exception is order transfer (and the transfer of spare parts). Order transfer means farming out the entire production process (sometimes even design too), not only parts of it, to other local producers. It can be regarded as domestic OEM. It is relatively popular in the MB and Monitor sub-sectors but rare in the NB sub-sector, although transfer of spare parts even between competitors is widely observed in the NB sub-sector too. In addition, horizontal cooperation seems relatively popular among small-scale producers. At least in the MB sub-sector, we have heard a number of examples of joint action such as second-hand

subcontracting among subcontractors, the exchange of ideas and information over the issues of R&D, quality control (QC), production process and marketing.

This sub-section has examined horizontal relations in terms of both competitive and cooperative dimensions. Local rivalry in Taiwan is characterised by harsh price competition that leads to the erosion of profit margins (i.e. "low road"). But it has other aspects of "high road" rivalry such as competition based on the speed of product design and development, cost management capability and flexibility. This is a common feature of various sub-sectors, and it is seen as the source of the Taiwanese PC industry competitiveness as a whole. Regarding the cooperative dimension, joint action is rarely observed except for order transfer, although there does seem to be some cooperative interaction among small-scale units.

3.3 Forward linkages

According to Porter (1990), the presence of sophisticated and leading-edge users within the same nation or region creates a valuable opportunity for local producers to anticipate future trends in global markets and discover unexploited market segments before outside competitors do so. However, local producers in developing and late industrialising countries are usually dislocated from leading-edge markets. As a result, forward linkages with external buyers and trade agents who bridge this gap are critical.

In the cluster literature on developing countries, Schmitz (1999) stresses that the substantial size of the market and scale of production are the basis for the deep division of labour and specialisation. A cluster may include specific groups of producers connected with different types of markets and, consequently, their prospects for growth differ depending on the market channel (Knorringa 1999). It is emphasised that establishing trade links with non-local major markets and customer-oriented posture are indispensable in order to embark on a new stage of continuous growth (Humphrey and Schmitz 1996).[13]

These conditions for dynamic growth were fulfilled in the case of the Taiwanese PC cluster. According to the statistical data, in 2000, the domestic market of Taiwan accounted for only 4.4 per cent of the total sales of IT hardware. Mainland China, Japan, Asian-Pacific region, Western Europe, the USA, and others made up 5.1 per cent, 12.8 per cent, 5.8 per cent, 28.1 per cent, 38.8 per cent and 5.0 per cent respectively (MIC 2001, *2000 Yearbook of the Information Technology Industry*). The Taiwanese PC sector consists of producers of various sizes and they focus on different types of markets. For example, in the Monitor sub-sector, most large-scale producers try to gain OEM orders from world leading computer companies. Medium-sized firms aim at European markets and small-scale makers advance into Mainland China, Latin America and the East European markets (Hwang 1997). This is one of the reasons why Taiwanese producers as a whole have succeeded in spreading their products all over the world.

As mentioned in Section 2, OEM has been critical for the development of the Taiwanese PC industry in general, but its importance differs between sub-sectors (see column 6 of Table 2.1). In the MB

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[13] The idea of linkages with distant markets referred to in the cluster literature often means linkages with foreign markets. But there are cases in which domestic markets play an important role. For example, according to Tewari (1999) who studies the Indian woollen knitwear cluster of Ludhiana, linkages with dynamic segments of the domestic market, rather than with the export market of the ex-Soviet Union, were a crucial factor that helped local firms adapt quickly to more demanding markets later.

sub-sector, the rate of OEM has been exceptionally low. This is because Taiwanese MB producers have traditionally developed by focusing mainly on clone markets (i.e. non-brand PC vendors and do-it-yourself assemblers). Taiwanese MB producers provided their products to small-scale assemblers through trading companies and distributors/dealers. However, the situation has changed since 1997, when the low-price PC was popularised all over the world (at that time the low-price PC meant the Desktop PC priced at US$1,000 or less). This has not only compressed the profits of the clone PC business, it has also restricted the development of clone markets because the price difference between brand PCs and non-brand PCs has decreased. In response to this, Taiwanese MB producers have begun to try to gain OEM orders from major brand PC companies, which has led to the gradual rise of the OEM rate in recent years. The trend of continuous (or even increasing) importance of OEM orders from major clients is observed in other sub-sectors too, as shown in Table 3.3.

Table 3.3 The rate of OEM (%) of four main sub-products

	1993	1994	1995	1996	1997	1998	1999	2000
Notebook PC	77	77	79	82	83	84	-	90
Monitor	69	67	66	-	67	65	68	-
Desktop PC	49	40	37	53	65	72	76	82
Motherboard	-	-	-	-	-	27	29	36

Source: MIC, *Yearbook of the Information Technology Industry* (in Chinese, each year edition) and other internal reports of the MIC.

Stressing the importance of OEM does not mean that Taiwanese firms passively depend on foreign clients as their only lifeline to distant markets. As confirmed in the fieldwork, many local producers, including small ones, have already established specialised sales and marketing departments and set up foreign branches in important markets. While establishing foreign subsidiaries needs a lot of investment, there are several advantages, such as easy access to the latest market information, ease of constructing a sales network, efficiently controlling partnerships with distributors, agents and OEM clients, and providing better technical services (*DigiTimes* 1 December 1998).

Although it is still difficult to develop outlets in leading markets such as the USA, many firms have already embarked on own-brand sales as well as conducting OEM in many sub-sectors. The strategy of OEM differs between firms, but it is a delicate task to find a proper balance between OEM and OBM. On the one hand, OBM brings more profits,[14] but firms must invest large sums in advertisements and after-sale service networks. On the other hand, the profit margin of OEM is so small that it can yield a profit only when production exceeds a certain large amount. One interviewee of a small MB maker said: 'If you do not have OBM, OEM is only synonymous with a sacrifice sale' (*DigiTimes* 23 June 1999). In addition,

[14] According to an article of *DigiTimes*, the average gross profit rate of Taiwanese producers in the Monitor sub-sector is less than 6 per cent, but OBM producers record their gross profit rate as 10–12 per cent (*DigiTimes* 27 July 1998).

partnerships with foreign clients are usually unstable in terms of individual firms. Despite this, an increasing number of Taiwanese firms are trying to go into partnership with major world companies because receiving large OEM orders enables them to increase total sales as well as to offset lower profit margins. I will return in Section 5 to the process of upgrading through OEM and the limitations that accompany it.

Own-brand sales are mainly conducted in partnership with distributors/dealers from foreign regions. However, indigenous traders may act as intermediaries between local producers and foreign distributors. The role of indigenous traders was critical especially in the early years. The existence of a host of traders enabled local small-scale producers to expand business without making heavy investments in marketing.15 As confirmed in interviews with several MB producers, while Taiwanese traders are usually small-scale, they specialise in a specific territory and they jointly establish a dense marketing network. The amount of each trader's dealings is small and only involves a small number of footholds, but producers can find markets all over the world by selecting appropriate traders each time. In recent times, their role has diminished as more and more producers have reinforced their own sales/marketing activities. However, producers may still rely on traders with regard to less important markets.

Summing up the main points of this sub-section, the Taiwanese PC cluster was able to connect with huge overseas markets and this was essential for the deep division of labour in the cluster. The main outlets are the USA and Western Europe. Market channels include OEM and own-brand sales. Among these, OEM has been critical and kept (or even slightly increased) its importance recently, although Taiwanese local firms have made substantial efforts to establish footholds in important foreign markets. The role of indigenous traders has rapidly decreased in importance, although some still remains.

3.4 Institutional linkages

The concern here is with linkages to local support institutions, both public and private. In dynamic, advanced European industrial districts, local firms (especially SMEs) are encouraged by a well-developed support system, which comprises various service providers including development banks, universities and other higher educational institutions, trade unions, trade associations, training centres, technical institutes and marketing consortia as well as local/regional governmental agencies. Although it is difficult to offer a framework for systematically analysing the role of a support system, I try to examine it here by focusing on the three following dimensions:

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15 Kawakami (1998) offers an interesting analysis of the symbiotic relationship between trade-oriented firms (which have strength in the purchase of parts and the sale of products) and production-oriented firms (which have strength in manufacturing). According to her, trade-oriented firms entrust all of the production process to production-oriented firms while they take charge of co-ordinating the division of labour among various small-scale producers, the purchase of parts and the marketing of products. Through this practice, the firms can save investing in production lines and maintenance, and they can maintain a flexible manufacturing system. On the other hand, production-oriented firms can avoid the trouble of gathering specialised export market information and know-how for the purchasing of parts where prices ceaselessly fluctuate. Some trade-oriented firms went into the manufacturing field after they had accumulated substantial experience through this process.

(1) *Providing local firms with various services.* A well-developed support system may offer small firms a whole range of services including credit, training and various "real services",[16] many of which are to be sector- and region-specific (for European cases see Schmitz and Musyck 1994; Pyke 1994).

(2) *Promoting inter-firm joint action.* Although joint action and networking are seen as important means of increasing individual capabilities, especially for SMEs, it is unusual that such cooperation, especially in horizontal relations, develops spontaneously. Skilled network brokers from support institutions play a critical role in promoting it (see Pyke 1992; Humphrey and Schmitz 1996). The main purpose of promoting joint action and networking is to find joint solutions to common problems, therefore, it is consistent with encouraging sound competition. As stated by Sengenberger and Pyke: 'Certain kinds of cooperation at certain levels, or in certain contexts, can promote competitive efficiency at other levels or in other contexts' (Sengenberger and Pyke 1991: 2).

(3) *Coordinating activities amongst related institutions in the cluster (a matter of* local governance*).* Besides enhancing abilities of individual agencies and institutions, ensuring the effectiveness of the local support system as a whole is also critical. In some countries, service provision seems to have been introduced on an *ad hoc* basis, without coordinating it with other programmes and activities. In the developed stage, the government may increasingly need to take the initiative in making all related agencies and institutions work together under a common regional development strategy.

In Taiwan, there are various government agencies and public/private institutions that are related to the PC industry. Table 3.4 introduces a profile of the main agencies and institutions.

Table 3.4 Important support institutions related to the PC industry

Supporting institution	Profile
Industrial Development Bureau (IDB)/Ministry of Economic Affairs (MOEA)	The MOEA is charged with national economic administration and economic construction including industry, commerce, trade, energy and mining. The IDB is one of the 13 administrative agencies of the MOEA, and it is concerned with industrial development polices, management of industrial zones and so on.
Industrial Technology Research Institute (ITRI)	The ITRI is the first and largest non-profit autonomous industrial technology research institute. It was established in 1973 under the MOEA. Its core mission is to undertake applied research relevant to national needs and to transfer technologies to the private sector. As of 1997 there were 10 research laboratories/centres under the ITRI.
Electronics Research & Service Organization (ERSO)/ITRI	The ERSO was created in 1974 under the ITRI and has since been involved in every generation of semiconductor development. It also took charge of computer development projects in the 1980s. Recently it has engaged in R&D projects regarding liquid crystal display, sub-micron process and microelectronic technology.

[16] Brusco offers the concept of "real services". 'The idea is to prioritise "real services" as against financial incentives, and to offer companies the services they need rather than the money to purchase those services on the market' (Brusco 1992: 186).

Computer & Communications Research Laboratories (CCL)/ITRI	The CCL was separated from the ERSO in 1990 to handle the R&D of computer and communication technologies. Currently, its main R&D concerns are multimedia computer systems, wireless communication and HDTV.
Market Intelligence Centre (MIC)/Institute for Information Industry (III)	The III was founded in 1979 under the MOEA to serve government in supporting the promotion of the information industry. Its main functions include assisting government in mapping out development plans, studying and introducing advanced software technologies, promoting computer usage, training computer professionals, etc. The MIC is in charge of providing market and technology intelligence through various publications and conferences.
China External Trade Development Council (CETRA)	The CETRA was established in 1970 as a non-profit parastatal agency for export promotion. Its main functions are to provide information, organise participation in trade fairs and carry out market research. By 1998, it had established overseas branch offices or trade centres in 35 cities.
Taipei Computer Association (TCA)	The TCA comprises manufacturers of computer, peripheries, software and their dealers or agents. It was created in 1974 and is now the largest association in the computer industry, with more than 8,000 members in 1998.
Taiwan Electrical and Electronic Manufacturers' Association (TEEMA)	The TEEMA was founded in 1948, and comprises manufacturers of electric and electronics products. In 1998 it had more than 4,500 members. It is the largest association in the electric and electronics industry.

Source: Compiled by the author (drawing from various sources).

Among them, the Ministry of Economic Affairs (MOEA) is especially important. It is charged with national economic administration and economic construction including the industries, commerce, trade, energy and mines. Under MOEA's various administrative branches, there are more than 10 foundations which carry out technology development projects and other service provision. Among these foundations, the Industrial Technology Research Institute (ITRI) and the Institute for Information Industry (III) have close ties with the PC industry. The MOEA also takes charge of public enterprises.

In addition to these government agencies and government-sponsored institutions, trade associations also conduct various support activities for member firms. Among them, the Taipei Computer Association (TCA) provides its member firms with a wide range of services, for example, sponsoring exhibitions,[17] organising sector-specific social gatherings and alliances for specific purposes among member firms, offering trade information, technical services, legal advices, education and training service, developing overseas markets, promoting computer skills, offering suggestions in policy planning by government, assisting the execution of various IT-related governmental projects, issuing certifications and so on. While the TCA was established in 1974, it seems that a number of its functions only became operational during the early 1990s.

[17] For example, Computer Edutainment & Multimedia Show (CEM Show), Taipei Software Exhibition (Softex Taipei), Taipei International Computer Exhibition (Computex Taipei), Taipei Computer Applications Show (TICA Show), and Taipei International Telecommunications Show (Taipei Telecom).

During the fieldwork, we investigated how effective these activities of public and private support institutions were from the viewpoint of business people. The results are offered in terms of three standards – (i) the usefulness of services; (ii) brokerage role; and (iii) local governance. Basically the same tendency is observed in all of the three selected sub-sectors. First, despite a seemingly wide range of services, business people do not seem to have a high opinion of their contribution. One respondent even said: 'No intervention is the largest contribution of government'. Another respondent said that government offered little support and only came out with a general plan. Similarly, it seems that business people are not enthusiastically involved in the activities of associations and their contribution to member firms is not very important. There are several reasons for this:

- State intervention varies across various sectors of the IT industry, and, unlike the semiconductor industry where government and government-sponsored institutions were closely engaged in the construction of integrated circuit (IC) manufacturing plants, the PC sector received only modest state support. The role of the state was basically limited to fixing an institutional and legal infrastructure and adjusting incentive structures (Wang 1995–96).
- Communication with the private sector is not enough. Until recently, the economic policy of the country has been controlled by government with little involvement from the private sector. According to one MB firm, trade associations, which should bridge the gap between them, also have to make more effort to keep close contact with member firms and win their trust.
- Although the Taiwanese government has not sought to favour large firms, it seems that many SMEs feel that they have more difficulties accessing government assistance.

Second, these agencies and institutions do not make a large contribution to joint action promotion. According to one Monitor firm, local firms join together in government-sponsored technical projects, but it hardly facilitates enduring joint action among them. The TCA organises social gatherings and alliances. Since the early 1990s, the TCA has organised approximately 20 such groups. Each of these groups is regarded as a "small trade association", as a high-ranking office of the TCA stated. Nevertheless, private firms are still discontented with the role of the TCA as a network broker. One respondent from Monitor firm said: 'My impression is that we sometimes gather for social contact, but this does not necessarily bring solid fruit. In many cases, this only has a temporal effect, then disappears . . . Especially in marketing, price competition is very strong among Taiwanese firms . . . Associations have never made a contribution to coordinating it'.

Third, industrial promotion policies in Taiwan are controlled by the MOEA. Trade associations that act as multilateral self-help institutions operate like service providers that compete with each other for customers. Therefore, local governance, in the sense of coordinating activities of various related organisations and mediating conflicts among self-help organisations, does not matter very much in Taiwan. Instead, private firms appear to keep government agencies and associations at a distance. This means that

there is no effective mechanism for gauging the opinion of the business world and solving common problems, except through informal connections.

In the context of this paper, it is not possible to undertake a comprehensive and detailed assessment of the role of government and support institutions. The support system played a limited part in my assessment which was mainly based on the responses of business people during the late 1990s. Other authors that have focused on the support system have come to different conclusions (e.g. Mathews and Poon 1995; Kim and Tunzelmann 1998). These differences may have arisen because studies that focus on the activities of state and support institutions tend to accord them a much greater significance. In addition, the impression of their significance may differ depending on the issue area, firm size and firm development stage.

3.5 Summary

This section has examined the production system of the Taiwanese PC cluster in terms of four kinds of cluster linkages respectively. Each sub-section offered theoretical expectations about the quality of cluster linkages that should be observed in dynamic (and static) clusters. These references are drawn together in the left-hand column of Table 3.5. This can be seen as a framework for assessing the quality of cluster linkages.

Table 3.5 Framework for assessing inter-firm linkages of clusters and the production system of the Taiwanese PC cluster during the late 1990s

Linkages of clusters	**How does the quality of inter-firm linkages vary between static and dynamic clusters?**		**The Taiwanese PC cluster during the late 1990s**
	Static clusters	**Dynamic clusters**	
→ 1) Backward linkages with parts suppliers/ subcontractors	Arm's-length contractual relation (ACR)	Obligational contractual relation (OCR)	Linkages with parts suppliers: basically OCR; increasing importance of partnerships with key parts suppliers. Linkages with subcontractors: basically OCR; decreasing importance of the subcontracting system after the peak of the mid-1990s.
→ 2) Horizontal linkages with fellow firms	Local rivalry based on low labour cost and price-cutting ("low road")	Local rivalry based on efficiency enhancement and innovation ("high road")	A mixed nature of both "low road" rivalry (i.e. harsh price competition; a vicious circle between expanding production and decreasing profit rates) and "high road" rivalry (i.e. competing in the speed of product design and development, flexibility and cost management capabilities).

→ 3) Forward linkages with external buyers	No connection with non-local major markets	Solid connection with distant large markets; customer orientation	Connection with huge overseas markets, especially the USA and Western Europe as the main market; continuous (or even increasing) importance of OEM, with substantial effort for own-brand sales (mainly through traders and distributors/ dealers); decreasing role of indigenous traders.
→ 4) Institutional linkages	Undeveloped support system (non-existent or limited range of activities)	Well-developed support system (playing brokerage role, providing wide-range of services and ensuring local governance)	A half-developed support system (i.e. insufficient brokerage role; a wide-range of services, but not highly rated by business people; assured local governance, but few effective mechanisms for summing up opinions from the private sector and for solving common problems).
→ Sources of competitiveness	Mainly local external economies	Increasing joint action	

Source: Author.

This framework illustrates how the quality of cluster linkages varies between static and dynamic clusters, which can be regarded as the extremes of the broad spectrum of development level. The table implies that clustered relationships strengthen collective efficiency based increasingly on joint action as well as local external economies. This is evident as one moves from the left-hand to the right-hand of the spectrum. One can assess the degree of a certain cluster's development by viewing where it is located on the spectrum. However, this framework does not offer a precise measure for grading various clusters. Instead, it should be seen as an experimental tool for roughly indicating the direction of cluster development trajectory and for discovering opportunities and bottlenecks for upgrading.

Based on this framework, the empirical analysis results from this section are summarised in the right-hand column of Table 3.5. Several important implications can be drawn from this. First, the Taiwanese PC cluster has obtained many features of dynamic clusters during the late 1990s, which substantiates that the rising status of Taiwan in the world PC industry is accompanied by an enhanced quality of cluster linkages. This is in line with the above-mentioned Porter's thesis. Second, despite considerable success, we can identify some important qualifications, for example, lack of local supply bases for some key parts, harsh price competition among local firms, continuous (or increasing) importance of OEM with its profit margin squeezed and a limited role of support system. These achievements and limitations will be examined in terms of the knowledge system in the next section.

4 The knowledge system

Collective efficiency derived from clustering is relevant not only to efficiency in the production sphere, but also to technological learning and innovation, the latter of which is the focus of this section. Like Section 3, the analysis is based on information gained from my survey of three selected sub-sectors (i.e. Monitors, MBs and NBs) during the late 1990s, by examining four categories of cluster linkages (i.e. backward, horizontal, forward and institutional) respectively in the following sub-sections. In the same vein as the analysis of the production system, this section reveals that the knowledge system of this cluster shows a high-quality nature with some important limitations.

4.1 Flows of knowledge

Before analysing in detail each category of cluster linkage, based on results from the questionnaire survey conducted in 1998, the importance of various extra-firm knowledge sources for new product design and development (here this refers to model changes, rather than developing totally novel products) is examined in this sub-section. The survey results are provided in Table 4.1. What I should stress here is that currently all the firms (except subcontracting units) in the three sub-sectors that I interviewed have specialised R&D departments, and knowledge flows from extra-firm sources are meaningful only when they are connected with in-house learning efforts.

Table 4.1 Importance of various knowledge sources for new product design and development (except in-house R&D) (sample: 41* from the MB, Monitor and NB sub-sectors)

Knowledge sources	Very important	Important	Moderately important	Not important	Assessment **	
a) Local informal social gatherings	4	21	11	2	65	B
b) Key parts suppliers	25	11	2	1	99	A
c) Foreign clients	19	15	4	2	91	A
d) Domestic clients	3	11	19	5	50	C
e) Taiwanese rival firms	8	19	12	2	74	B
f) Foreign rival firms	7	23	8	1	75	B
g) Traders/dealers	1	7	20	9	37	C
h) Exhibitions	8	19	10	0	72	B
i) Foreign subsidiaries	2	20	9	9	55	C
j) Specialised publications	10	14	16	0	74	B
k) Trade associations	0	1	21	16	23	D
l) Public support institutions such as the MIC***	0	3	20	14	26	D
m) Public research institutes such as the ITRI***	0	2	22	14	26	D
n) Workers from other firms	1	9	19	8	40	C

Source: Author's survey.
*Total of each row may be less than 41 because some respondents gave no answer.
**'Assessment' shows the total score of each row, allotting 3 points to 'very important', 2 points to 'important', 1 point to 'moderately important' and 0 point to 'not important'.
***Regarding the MIC and the ITRI, see Table 3.4.

Although the breakdown of each sub-sector is not provided here, the same tendency is roughly observed among the three sub-sectors (for details, see Kishimoto 2002). Each knowledge source can now be classified into one of four categories as follows:

- Group A (score 91 or more): key parts suppliers and foreign clients.
- Group B (score 61 to 90): local informal social gatherings, Taiwanese rival firms, foreign rival firms, exhibitions and specialised publications.
- Group C (score 31 to 60): domestic clients, traders/dealers, foreign subsidiaries and workers from other firms.
- Group D (score 30 or less): trade associations, public support institutions such as the MIC and public research institutes such as the ITRI.

Three conspicuous features can be pointed out. First, considering that many key parts are purchased from foreign suppliers, foreign actors are a critical knowledge source. Second, contrary to the popular image of high-technology industries, support institutions and research institutes seem to play only a small role in the Taiwanese PC industry. Third, the knowledge sources that are classified as group B concern learning mainly from fellow firms. This implies that horizontal linkages have a relatively important impact in this field. These findings are confirmed in the case study material detailed in the following sub-sections.

4.2 Backward linkages

Clustering facilitates the vertical disintegration of production processes based on process and product specialisation, 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 the deepening of technological capabilities for each firm.

Learning is helped 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 new Silicon Valley computer firms specialise in a limited number of core capabilities and establish close partnerships with key input suppliers and contract manufacturers. In this way, 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 clustering in itself does not guarantee that interactions will take place, nor that they enhance efficiency and innovation. In general, it is

expected that in dynamic clusters, partnerships between the main producers and supporting firms display innovative interactions that go beyond unconscious circumstantial interactions, such as maintaining close communication and cooperation on quality, efficiency and R&D as well as price. Key partners may be involved in new product design and development processes, and their relations should be reciprocal and based on each speciality.

In the context of the Taiwanese PC cluster, key parts suppliers are a critical knowledge source for new product design and development (see Table 4.1). This is most prominent in the overwhelming influence of CPU and Chipset suppliers in the MB sub-sectors.[18] As the design and production technology of PC hardware has matured, technological trends come to be largely initiated by the upgrading of key parts. Intel has a predominant position in the supply of CPU/Chipsets.[19] Getting technological information about new CPUs/Chipsets from Intel as early as possible is crucial in the process of new model development. For several years Intel has maintained a cooperative relationship with several top Taiwanese MB and PC producers. These selected partners not only receive detailed technological information but they can also obtain more samples of new trial products. Such partnership is indispensable for Intel as well in order to test its trial products and extend its sales.

Yet, such a symbiotic relationship is rather exceptional. Relationships with suppliers of other key parts are less significant. In the questionnaire survey, we asked whether there was explicit technological cooperation, for example with CRT suppliers in the Monitor sub-sector or with liquid crystal display (LCD) suppliers in the NB sub-sector. Unexpectedly, few respondents have such cooperation. Where cooperation was reported, it was not substantial in nature. 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'. This seems to be the case in relationships with suppliers of other key parts too.

Technological interactions between PC manufacturers and subcontractors were investigated in detail during the MB sub-sector survey. 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 there is no extensive technical interaction except QC. Subcontracting units must meet a certain quality standard to survive. For example, one respondent pointed out that passing ISO 9002 was the minimum condition. Furthermore, technical assistance is not necessarily provided by contracting units for subcontractors. It is not rare in Taiwan for a contracting unit that undertakes only R&D and sales to receive technical assistance from its subcontractors or purchase their plants when the contracting unit advances into the production sphere. But, as our fieldwork confirmed, interaction with subcontractors has no importance as a knowledge source for product design and development.

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18 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.

19 The share of Intel in the world total supply was about 77 per cent in CPUs and 75–80 per cent in Chipsets in 1998 (*DigiTimes* 7 October 1999, 11–13 March 2000).

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. One exception is the technical data and instruction offered by CPU/Chipset suppliers (especially Intel) which is crucial for the design of MBs and NBs. 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. However, it seems that technical interactions with suppliers are more concerned with routine model change than with fundamental innovation. In regard to local subcontracting practice, this is critical for specialisation to develop. However, in itself this practice is not a source of new knowledge for product innovation.

4.3 Horizontal linkages

Clustering may lower entry barriers and a resulting large number of fellow firms may bring about the coexistence of many different technical approaches and greater ease in forming new combinations. According to Schmitz: 'Indeed, a typical feature of clusters is the speed with which information travels and successful innovations spread' (Schmitz 1999: 474). There are a variety of conduits for knowledge flow such as the local grapevine, labour mobility, trade papers, exhibitions, spin-offs and imitation of rivals' products. The exclusive utilisation of created technologies for individual firms is not secured, but participating in clustering provides advantages over firms outside it, because it offers a valuable opportunity for monitoring and evaluating advanced R&D performed by other local firms.[20] Such a situation is more likely to take place in industrial sectors with fast technical change, or in high-end product segments in which technological opportunity is sufficiently plentiful.

In Taiwan, despite harsh rivalry, as revealed in Section 4.1, local fellow firms are seen as an important knowledge source for product design and development. Studying each other's product, equipment and process skills usually takes place through informal and indirect routes such as reverse engineering, snatching technical staff and personal connections. High turnover rate of R&D staff accelerates this. It is an example of local external economies. The rapid diffusion of technical knowledge is of great value for local firm upgrading in the rapidly changing and uncertain business environment. For example, according to one respondent from a NB firm, there are many different types of new Chipsets and technology displays rapid change. Thus, the smaller the risk of adopting a certain Chipset becomes, the more NB producers have a trail of it and the more widely the information spreads. 'The largest difficulty of NB design is that more and more functions must be crowded into a limited space. Unlike Desktop PCs, NBs are small. So, you can have inspirations through studying each other, and the ideas can be utilised in the

[20] Such a situation is called "forced risk-taking" by Gemser and Wijnberg. They state: 'The element of forced risk-taking is present as long as technological opportunity is sufficiently plentiful, barriers to entry are low enough to make potential competition a real threat to established firms and, in particular, appropriability of technological knowledge is not too secure to prevent follow-up innovation or imitation efforts by competitors' (Gemser and Wijnberg 1995: 133). They state that in a situation of fast technological change, firms can enjoy a quick diffusion of state-of-art technology through participating in the network and defeat firms outside it, although they cannot secure exclusive utilisation of technologies created by themselves.

next model. It is not necessarily an imitation. Some improvements are added. Such a practice is advantageous for everyone'. Even in the Monitor sub-sector which is relatively mature, one respondent noted that an effective new solution would become widely known after only one month and this practice had contributed to the strengthening of the whole Taiwanese Monitor sub-sector. Although product designs and functions have become similar between Taiwanese producers as a result of mutual learning, Taiwan as a whole has attained solid capabilities for conducting ceaseless model change and supplying a wide-range of products.

Besides such technical external economies, more conscious cooperation (i.e. joint action) can theoretically take place even between rival firms. According to Schrader (1990), technology exchange between competitors can take place if the economic cost for the transferring firm is small. Technology exchange is more likely to occur, for example, if receiving firms have easy access to alternative sources and if the transferred technology does not relate to the dimension in which they compete with each other. But in Taiwan, joint action in the technology sphere, such as cooperative R&D and technology transfer, is rarely observed.

The main findings of this sub-section are summarised as follows: mutual learning among local fellow firms is an important knowledge source for product design and development and other innovation. This is a form of local external economies, which is of great value for the upgrading of all local firms in the rapidly changing PC industry. While the gains are often difficult to appropriate for individual firms in such an environment, operating inside the cluster offers an advantage over outside firms.

4.4 Forward linkages

The review of several recent cluster studies in developing countries presented by Schmitz and Nadvi (1999) highlights the importance of knowledge flows from outside. While poorer, stagnant clusters had a closed inward-looking structure, relatively advanced clusters 'relied heavily on knowledge from the outside and its rapid diffusion inside' (Schmitz and Nadvi 1999: 1511). Although there are various kinds of outside knowledge sources, the role of external buyers and trade agents is critical.

One of the advantages of clustering is to attract external buyers and traders who sell the output to outside dynamic markets. In developing and newly industrialising countries, forward linkages with these external actors are indispensable for the development of clusters not only as an outlet for products but also as a conduit for advanced knowledge. Through contact with them, local producers can understand the level of technology, quality and response time needed to attract users who are very demanding. Buyers and trade agents sometimes provide a variety of specialised producer services including model shops, technical assistance, training of staff, information on production and process innovation, and inspection of product quality (Schmitz and Knorringa 2000).

In the development of the Taiwanese PC industry, learning from external buyers has largely taken place through the OEM system. In the field of design (as seen in Section 4.1), interaction with foreign clients is one of the most important knowledge sources for product design and development even in the late 1990s. OEM clients include not only major foreign computer companies such as IBM and NEC, but

also non-major vendors and distributors. Partnerships with major OEM clients may provide a good opportunity to learn technical and other management know-how, because major clients make stricter requests. Major clients may provide various kinds of technical assistance. According to our questionnaire survey, at least in the Monitor and NB sub-sectors, a substantial number of sample firms received various kinds of technological assistance from OEM clients, such as 'technical assistance for QC', 'technical assistance for the improvement of production process', 'cooperative R&D/technology transfer for new product development', and 'technical assistance for product improvement'.

However, a closer examination of these results reveals that regardless of differences in industrial maturity among sub-sectors, Taiwanese producers in general have already reached the ODM stage. They have already accumulated substantial capabilities in product design and development as well as in production. Furthermore, Taiwanese producers basically undertake the whole process from new model design and development to mass production. Therefore, most buyers' assistance is not very substantial in nature. In many cases, it seems to mean that Taiwanese producers receive only "demands" for improvement or have minor technical interactions. For example, according to one respondent from a Monitor firm, as the Monitor industry has matured, there are few profound technology transfers now. And possessing enough technology is a necessary condition for getting orders. Similarly, in the relatively new NB sub-sector, one Taiwanese analyst stated that ODM had become the mainstream in the last two years and there was rarely OEM (i.e. just undertaking production) in 1998. In the ODM stage, the design of a new product model is carried out by Taiwanese firms without relying on buyers' assistance.

Despite this, a closer examination also reveals that strict requests from major buyers are conducive to the upgrading of QC and production control, and many of the latest technologies are still obtained from foreign buyers. According to one respondent, for example in the Monitor sub-sector, the degree of dependence on foreign technological sources is low. Yet, complete ODM is not very high. Many new technologies are obtained from foreign sources. Another respondent also claimed that major PC companies such as Dell provided a new concept for future business and that Taiwanese firms carried out design and development based on this. Even in the MB sub-sector with a low OEM rate, it is said that major computer companies may take the initiative in deciding specifications and that the level of quality and performance required is higher than that of non-brand markets. Besides this, partnerships with world leading companies may enable Taiwanese MB firms to learn other aspects of business management such as personnel control, company culture and management policy (Zhou 1999).

This sub-section has revealed some important features of forward linkages with foreign clients. As Taiwanese producers have already accumulated substantial production and design capabilities, technical support from external buyers is no longer critical, and design and production processes are basically undertaken by Taiwanese firms. However, foreign clients are one of the most important knowledge sources for new product design and development, and strict requests from major OEM clients facilitate the improvement of QC and production control. The latest technological trends and new product concepts are also obtained from foreign sources.

4.5 Institutional linkages

In the advanced clusters it is often observed that knowledge institutions such as research institutes and universities make an important contribution to the evolution of local learning/innovation networks through various ways. They include creating the cultural and psychological identity of localities which is a precondition for collective learning, providing highly skilled human resources, conducting forefront R&D and generating technology-based spin-offs (Smith and De Bernardy 2000).

In Taiwan, among knowledge institutions, the ITRI is the most important. In the 1980s, the Electronics Research & Service Organization (ERSO) of the ITRI executed three successive computer-related R&D projects. Among the fruits of these projects was the development of the IBM-PC/XT in 1983, which was the first IBM compatible PC in Taiwan.[21] In the 1990s, R&D projects on computer and communication technologies were transferred to the Computer & Communications Research Laboratories (CCL), which had separated from the ERSO in 1990. Among the contributions by the CCL, the most impressive one was the Notebook PC Strategic Alliance which was launched in 1990. The alliance succeeded in developing the mass production design sample of 386 SX Notebook PCs within just seven months.[22] According to a recent document, the ITRI is engaged not only in advanced, forward-looking research but also in providing industrial services such as technical consultations, testing, information, training, entrusted R&D, holding conferences and workshops, helping entrepreneurs start up their new technology-based business (called 'Incubator Center') and on-site joint research and product development projects with private firms (called 'Open Lab').[23]

It is difficult to systematically assess the contribution of the ITRI to the development of the PC industry. In contrast to the semiconductor industry, the influence of the ITRI has been much smaller.[24] For example, the development of IBM compatible machines by the ERSO speeded up the technological development of private firms and reduced their R&D expenses, but it remained possible for private firms to develop these by themselves. Moreover, technology transfer from the ERSO was not necessarily suitable for commercialisation.[25] Its role as a coordinator of the Notebook PC Strategic Alliance was often considered a failure, because after attaining the first common goal, the incompatibility of interests among members made it difficult to maintain and manage the alliance. Recently, the chief aim of the ITRI has shifted to R&D in specific forefront technologies and key parts, transferring conventional R&D into the hands of private firms (*DigiTimes* 2 September 1999).

Finally, based on our survey, an overall assessment of the role of knowledge institutions including the ITRI and others during the late 1990s is shown here. Despite various services, their role is not critical for private companies except for a plentiful supply of human resources from a number of local

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21 ITRI (1991) offers detailed information about the contribution of the ERSO in the 1980s.

22 As regards a detailed explanation of the Notebook PC Strategic Alliance, see Chapter 7 of San (1995).

23 Recent information on the activities of the ITRI is obtained from Internet homepage (www.itri.org.tw).

24 In regard to the semiconductor industry, see Hong (1995).

25 According to the ITRI (1991), there were 77 cases of technology transfer involving 47 firms during the term of three successive Computer Projects (1979-1991), and only 15 of these cases (19 per cent) succeeded in commercialisation.

universities/colleges. Spin-offs from universities and research institutions appear to be far less important as a source of start-ups than in the semiconductor industry. Our survey reveals that the majority of sample firms have little or at most occasional contact with the ERSO, the CCL and universities/colleges. As mentioned in Section 4.1, such research institutes and trade associations are considered low importance as a knowledge source for new product design and development. There are several reasons for this. The speed of their R&D is slow. Technologies developed by them cannot be commercialised immediately. Entrusting them with R&D requires a lot of money which one company cannot shoulder. In addition, because the design and production technologies of PC hardware (excluding key parts and materials) have typically already matured, private firms do not need very much assistance from research institutes.

4.6 Summary

This section has analysed the knowledge system of the Taiwanese PC cluster during the late 1990s. Sections 4.2 to 4.5 began by theoretically considering how clustering can promote learning/innovation. The section then turned to the empirical analysis of Taiwan's case in terms of four linkage categories respectively. The main findings are shown in Table 4.2.

Table 4.2 The knowledge system of the Taiwanese PC cluster during the late 1990s

	How clustering may facilitate learning/innovation	**The Taiwanese PC cluster during the late 1990s**
1) Backward linkages with parts suppliers/subcontractors	Cooperation and joint problem solving over quality, efficiency and design.	Key parts suppliers are the most important knowledge source for new product design and development. Despite close communication, there is little substantial technology transfer and cooperative R&D (except CPU/ Chipset suppliers). Subcontractors have no importance as a knowledge source for product design and development, and there is no extensive technical interaction except QC.
2) Horizontal linkages with fellow firms	Rapid knowledge diffusion and mutual learning which are conducive to continuous innovation of a cluster as a whole, through both informal conduits (local external economies) and conscious technical cooperation (joint action).	Mutual learning and rapid knowledge diffusion mainly through informal and indirect routes is of great value for the upgrading of all the local firms in the rapidly changing environment; but product design and production line have become similar between Taiwanese producers. Normally no technical cooperation as joint action.
3) Forward linkages with external buyers	Understanding the level of technology, quality and response time needed in advanced markets through buyers. Buyers offer a variety of producer services such as technical assistance, training of staff and inspection of product quality.	Technical support from external buyers is not critical, and design and production are basically undertaken by local firms; but clients are one of the most important knowledge sources for new product design and development, and strict requests from major clients facilitate the improvement of QC and production control. Plus, latest technological trends and concepts are obtained from foreign sources.
4) Institutional linkages	Local knowledge institutions play an important role as a node of local learning/innovation network, supplying industrial services, advanced technology and human resources.	Despite offering various services, their impact is limited. Knowledge institutions also have small importance as a knowledge source for new product design and development. Their main concern turns toward specific forefront technologies and key inputs.

Source: Author.

The theoretical part of this section, summarised in the left-hand column, can be seen as fleshing out Porter's suggestion that the essence of clustering lies in offering incentives to innovate rather than bringing about production efficiency. The comparison between this and the empirical analysis summarised in the right-hand column shows that this possibility is realised in the Taiwanese PC cluster to a substantial extent. However, it is accompanied with some important qualifications, for example, lack of profound innovation and forefront technological trends still being led by foreign key parts suppliers and major clients, an absence of technical joint action, and a limited role of knowledge institutions. In terms of the technological dimension, this confirms the achievements and limitations mentioned in the previous section.

5 Upgrading trajectory in the PC value chain

Based on largely quantitative analysis, Section 2 illustrated that the trajectory of the Taiwanese PC industry confirmed Porter's suggestion that clusters can upgrade by shedding activities of low value added and concentrating on activities of high value added even in the era of globalisation. Sections 3 and 4 confirmed this logic through the examination of the quality of cluster linkages during the late 1990s, in terms of the production and knowledge systems respectively. This section is concerned with how this transformation of the cluster was achieved by examining the history of the Taiwanese PC industry from the early 1980s to the late 1990s.

As stressed in Section 1, such analysis should consider not only the linkages within the cluster, but also the external linkages. Bell and Albu (1999) point out that external knowledge flows are a key factor when explaining differences in long-term development dynamism. Similarly, Humphrey and Schmitz (2000) propose the fusion of the local cluster and value chain analyses. These external linkages, especially forward linkages with external buyers/lead firms, have been the focus of the GVC literature. In this section, I will draw on this literature to investigate the case of Taiwan.

As mentioned in previous sections, upgrading in the value chain of the Taiwanese PC cluster took place mainly through the OEM mechanism. The OEM strategy has been analysed by several scholars. Within this literature opinions differ as to whether OEM upgrading is smooth or not. Gereffi (1996, 1999) examines how East Asian newly industrialising economies (NIEs) have successfully enhanced their capabilities and eventually reached OBM status through integration into GVCs by becoming an OEM producer. Hobday (1995ab, 1997) analyses the export-led learning process of NIE firms in the electronics industry. Although he does not adopt an explicit value chain framework, he confirms the analysis offered by Gereffi. Some scholars, however, have questioned this optimistic view that OEM leads progressively to ODM and OBM (see Schmitz and Knorringa 2000; Humphrey and Schmitz 2000; Sturgeon and Lester 2002). The case of Taiwan appears to confirm the view by Hobday. Yet, as this section will now show, detailed observation reveals important qualifications.

Humphrey and Schmitz (2000) suggest that both internal and external linkages need to be studied in order to show how this upgrading has evolved. But there is very little understanding on how the two

interact. Therefore, this section will attempt to analyse this. The previous two sections disaggregated the cluster linkages into four categories. Therefore, this section considers how the transformation of forward linkages with external buyers, especially OEM clients, is connected to the transformation of local cluster linkages (i.e. backward, horizontal and institutional linkages). The upgrading trajectory of the last two decades is examined by dividing the history into two periods, namely, the 1980s (the initial and OEM stages) and the 1990s (the ODM and ODM/ Global Logistics stages).

5.1 The 1980s: from the initial to OEM stages

Around the early 1980s, American computer and electronics companies set up subsidiaries in Taiwan and started to produce Terminals and Monitors. Taiwan was selected as a production site because it had the advantage of a relatively well-developed supply base of electronic parts and an ample supply of low-cost but good-quality engineers, which had coincided with the development of the consumer electronics industry since the 1960s. In the 1980s, several indigenous electronics product makers such as Tatung and TECO began to produce Terminals and Monitors based on their experience in manufacturing TVs. Before long these indigenous producers came to receive OEM orders of Monitors, Terminals and so on from foreign companies. In the first half of the 1980s, OEM and foreign direct investment (FDI) companies were the main driving force of export expansion from Taiwan in the PC industry, accounting for 40 per cent and 57 per cent of total export value in 1984 respectively (MIC 1989, *1988 Yearbook of the Information Technology Industry*). I regard the first half of the 1980s as *the initial stage*.

It is important to point out that the major Taiwanese producers already possessed basic production skills and some design capabilities at that time. For example, according to one respondent from the Monitor sub-sector, when Tatung, which was one of the most reputable makers of electronics products, started to produce Monitors, 'they set up design as well as production technology through their own efforts. In addition, they also developed some equipment and measuring instruments on their own'.

As well as these major local producers, there were many other indigenous forerunners for the PC industry. In the latter half of the 1970s, many local producers embarked on the production of pocket calculators, electronic clocks and video game machines. These producers were mostly SMEs, because the production of these electronic items did not require large funds. Among them, many firms advanced into PC production in the 1980s. For example, Acer, which has been a representative company of the Taiwanese PC industry, developed PCs of their own architecture in 1981, and this was mainly based on the experience of producing pocket calculators (Mizuhashi 1997). In addition, around the same time, many local small producers became engaged in the production of fake Apple II computers (i.e. illegal clones of Apple II). They had produced video game machines, but moved to fake Apple II after the government banned video games because of their alleged damaging influence on youth in 1982. Although the fake Apple II boom declined before long once Apple charged several Taiwanese manufacturers with counterfeiting, manufacturing fake Apple II provided a valuable opportunity to accumulate technological capabilities including design, production engineering and organising subcontractors. Through these

experiences, Taiwanese manufacturers established a solid initial technological basis from the very beginning of the history of the PC industry.[26]

In the latter half of the 1980s, when the Taiwanese PC industry experienced its rapid growth phase, the inflow of many new entrants, especially SMEs, contributed to the formation of the flexible network system of production, which was based on an extensive division of labour and specialisation. But OEM and FDI companies still made up a large portion of total export. These accounted for 43 per cent and 35 per cent of total export value in 1989 respectively (MIC 1990, *1989 Yearbook of the Information Technology Industry*). On the basis of a good initial technical foundation, Taiwanese local producers actively enhanced their production skills and learned product design capability, largely relying on interaction with OEM clients and assistance from them. Therefore, the second half of the 1980s is seen as *the OEM stage*.

Through partnership with foreign companies, local producers continued to improve capabilities in both product design and production control. Foreign companies, including OEM clients and FDI firms, provided various forms of technological and managerial assistance to local partners. The company IBM exemplifies this development. 'IBM's demanding procedures for product development, product ramp-up and quality control as well as its gruelling requirements for vendor qualification forced Taiwanese firms to radically upgrade their product quality. It also forced them to develop a broad spectrum of capabilities required for manufacturing as well as product design. In the process of qualifying as an IBM supplier, countless Taiwanese firms learned how to improve their input procurement and production control methods in order to cut costs, improve quality and to speed-up product development cycles and delivery. IBM engineers regularly visited Taiwanese suppliers, screened their production facilities and logistics and assisted them to improve their overall efficiency' (Ernst 1998: 40–1).

Besides expanding export through OEM, however, in the latter half of the 1980s, Taiwanese local companies began an initial attempt at own-brand overseas sales. The percentage of OBM of local firms in total export rapidly increased from 5 per cent in 1985 to 17 per cent in 1986, and was maintained at around 20 per cent until the end of the 1980s (MIC 1989, *1988 Yearbook of the Information Technology Industry*). At that time, there were hundreds of indigenous (mainly small-sized) traders. The existence of traders as well as subcontractors provided channels for the rapid expansion of new entrants, even in the absence of heavy investment in production equipment and marketing. For example, in 1989, the number of exporters of all PC-related products reached more than 3,700, but out of these no more than 650 (17.6 per cent of total exporters) were engaged in manufacturing products (MIC 1990, *1989 Yearbook of the Information Technology Industry*).

As mentioned above, one of the main objects of this section is to examine the connection between the transformation of external linkages and that of local linkages. External linkages with large distant markets may stimulate the development of local cluster linkages, and this is observed in the early years of the Taiwanese PC industry. In tandem with export growth, mainly based on FDI and OEM, local linkages

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[26] For more detailed information on the situation of the Taiwanese PC industry in the early 1980s, see Kawakami (1996). My explanation here is largely based on this.

also evolved. They included the formation of a solid base of supporting firms such as suppliers and subcontractors in backward linkages, an increasing new entrance of local firms and dynamic processes of competition and cooperation in horizontal relations, and encouragement of the PC sector as a leading export industry by government and support institutions. The remaining part of this sub-section provides a detailed depiction of this local evolution in terms of backward, horizontal and institutional linkages respectively.

Backward linkages. Taiwan had had solid experience in manufacturing consumer electronic products such as radios, TVs and pocket calculators in the 1960s and 1970s, and this was a major advantage for the PC industry. Accompanying the development of the electronics industry, the electronic parts and components sector had also developed. After the late 1970s 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. The rate of local supply of necessary parts was relatively high from the start of the PC industry.

Besides the solid supply base of electronic parts, the well-developed subcontracting mechanism is another crucial factor supporting the competitiveness of the Taiwanese PC industry. The subcontracting system in the PC industry developed rapidly in the second half of the 1980s, 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 in the process. Unlike the 1990s, when production automation was advancing, the assembly of electronic circuit boards depended largely on manual work in the 1980s, as a result the necessity for subcontracting remained high in order to utilise lower labour costs. In this way, the system of a deep division of labour developed (Kawakami 1998).

In the second half of the 1980s, the primary competitive edge of the Taiwanese PC industry was the low cost and flexible manufacturing system compounded by the well-developed input supply base and the subcontracting network, upon which Taiwan could attract foreign buyers.

Horizontal linkages. Analysts agree that horizontal relations between fellow producers in many industrial sectors in Taiwan are characterised by strong rivalry, especially price competition. According to Shieh (1993), it is often observed that a lot of firms flood into a promising market by imitating (or slightly changing) products and technologies pioneered by other firms, a practice which leads to the oversupply of similar goods and results in harsh price competition. The rush into a niche market is often figuratively described as a "swarm of bees".

The same phenomenon was observed in the PC industry in the latter half of the 1980s. In the first half of the 1980s, the PC business was mainly in the hands of a small number of FDI companies and large indigenous firms that received OEM orders from foreign clients. The share of the top 20 firms (including FDI companies) made up 82.4 per cent of total exports in 1984. This business scene changed due to the inflow of a large number of new entrants, especially SMEs, in the latter half of 1980s. Although the role of FDI and indigenous large firms was still important, SMEs became the leading contributors to the rapid expansion in exports. The share of the top 20 firms in total exports reduced to 57.4 per cent in 1986 (MIC

1987, *1986 Yearbook of the Information Technology Industry*). The *Yearbook* reports: 'This phenomenon is desirable in one aspect, but undesirable in another aspect. It is desirable because the sharp drop in the share of the top 20 firms reflects the rising vitality of SMEs and the expanding base of industrial development. It is undesirable because most firms concentrate on the narrow range of similar products and compete against each other, which leads to low profit rates' (MIC: 137).

This does not mean that horizontal relations in Taiwan were restricted to "low road" rivalry. Levy and Kuo (1991) describe the basic attitude of Taiwanese PC producers towards innovation in the late 1980s. According to them, Taiwanese PC producers took the "bootstrap strategy", whereby a firm enters into trade often with limited funds and readily takes risky initiatives while seeking lucrative lines of business.[27] The low cost of failure ensured by the network of subcontractors and traders made it easier. Although the mastery of complex technology was not necessarily a part of the "bootstrap strategy", firms could get the opportunity to achieve technological learning 'via an incremental process of graduating from simpler to more complex tasks, and from tasks that involved relatively little research and development (R&D) expenditures, to those for which the R&D requirements were more substantial' (Levy and Kuo 1991: 368). All these conditions implied that a large number of new entrants tried out many alternative technical approaches simultaneously as a result of the low entry barrier, which was one of the advantages of clustering. Consequently, this led to rapid trial-and-error learning within the cluster as a whole. In this environment, where the capacity to respond quickly and flexibly to emerging market opportunities was critical, this strategy seemed to work very well.

OEM clients and FDI companies also made a significant contribution to the proliferation of indigenous new entrants in the sphere of training and nurturing human resources. According to Kawakami, ex-employees of foreign companies 'eventually left FMs [foreign manufacturers] 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' (Kawakami 1996: 15). Kawakami also reports that the required experts for local manufacturers were supplied from foreign firms in the early to mid-1980s. Moreover, around 1990 when many FDI companies withdrew from Taiwan because of rising production costs, a lot of experienced engineers that were released from the foreign firms flowed into local manufacturing, and this solved the shortage of human resources for local firms.

As well as foreign companies, local first generation manufacturers also played a role as the cradle of human resources. Among them, the contribution of Acer is often mentioned. High-calibre people who came from Acer moved to occupy positions among the high-ranking executive-officers of many local firms in various sub-sectors including PCs, peripherals, PC-related parts, and even communication equipment (Zhou 1999). In the Monitor sub-sector, Tatung played a similar role. According to one

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[27] In the work of Levy and Kuo which studies PC and Keyboard sectors comparing Taiwanese and Korean manufacturers, the "bootstrap strategy" followed by Taiwanese firms is contrasted with the "assembly strategy" adopted by Korean large firms. In the "assembly strategy", a firm enters into business with a large starting capital and aims at moving rapidly down the learning curve, increasing productivity and thereby reducing unit costs as experience accumulates.

respondent, in the early 1980s, Tatung possessed a R&D department with 200–300 engineers. Many of them have joined newly emerging Monitor firms. The respondent stated: 'Now you can find ex-Tatung employees in the R&D departments of all the Monitor manufacturers in Taiwan'. The outflow of these human resources from foreign and major domestic firms alike was an indispensable factor in encouraging the rapid expansion of the number of local manufacturers in the latter half of the 1980s.

Institutional linkages. The commitment of government to the IT industry became obvious in the 1970s. The Electronics Research & Service Organization (ERSO) was established in the Industrial Technology Research Institute (ITRI) in 1974 and an integrated circuit (IC) model plant was set up by the ERSO in 1977. In the 1980s, the promotion of the IC and data processing equipment sectors was viewed by the government as an important focus. In 1980, the Hsinchu Science-based Industrial Park (HSIP) was established to facilitate investment in high-technology industries for both foreign and domestic companies. Around the same time, two national plans for the industrial development of the electronics and IT industry were published. The Ten-Year Plan for the Development of the IT Industry (1980–89) is especially relevant.

This plan had two main goals: (1) developing the new IT industry as a strategic industry, and (2) promoting it for exports. State intervention varied across the various sectors of the IT industry. The degree of state intervention was particularly high in the semiconductor sector. Government intended to construct a full-scale production system of ICs. In the 1980s, several IC manufacturers were established under the government initiative. In terms of PCs and peripherals, state support was modest. Although several computer projects were carried out by the ERSO and developed technologies were transferred to private companies, it seems that these contributions were not indispensable for starting up the PC industry. Government efforts were largely limited to offering a good institutional and legal infrastructure and providing fiscal and financial incentives.[28]

5.2 The 1990s: from the ODM to ODM/global logistics stages

After the easy growth phase of the 1980s, the Taiwanese PC industry encountered a setback from 1989 to late 1992. The growth rate sharply decreased from 38.7 per cent in 1988 to 3.0 per cent in 1989 (MIC 1996, *1995 Yearbook of the Information Technology Industry*). This setback was caused by a worldwide recession in the USA, Europe and Japan. It was accelerated by the appreciation of the New Taiwan Dollar (NT$) and an increase in land and labour costs, which resulted in Taiwan losing its comparative advantages as a low-cost production site. At the same time, Taiwan faced serious competitive pressure both from below and above. New lower-cost competitors entered the battle in Southeast Asia and China, while South Korea strengthened its position as a supplier of Monitors. Furthermore, Japanese firms started to develop much more aggressive global market penetration strategies (Ernst 1998). Original brand sales of Taiwanese PC firms came under fierce attack, and major foreign firms with investments in Taiwan

[28] This explanation of the Ten-Year Plan for the Development of the IT Industry (1980–89) is largely based on Wang (1995–6).

removed production sites to less developed countries. In addition, many local firms, including not only small firms but also larger ones, went out of business. For example, during the second half of 1991, between 50 and 60 Taiwanese computer companies disappeared from the sector each month (this data is cited from Ernst 1998: 44).

Behind this major setback, there was another movement that shook the previous business custom of marketing PCs. In 1988, America's Packard Bell and Dell Computers revolutionarily altered the rule of business for distributing and marketing PCs. Packard Bell and Dell embarked on lower price and zero-tier marketing. That is to say, they altered the traditional multiple tiers sales conduit which relayed from manufacturers to dealers/distributors to retailers and so on, and they established the route of direct sales and sales through department and discount stores. Once middlemen were eliminated from the chain, the price decreased. Their PC price was 20–30 per cent cheaper than that of other PC firms. By 1989, the impact of Packard Bell and Dell was beginning to be felt by all major PC companies. The growth rate was failing sharply and profit was squeezed. This hit Taiwanese manufacturers especially hard, since their profit margin was originally smaller than that of the world's leading companies (Chen 1997).

In June 1992, there was another crucial blow to the industry. Compaq Computer started harsh price-cutting and the price of its PCs was reduced by 30–40 per cent. It made further attacks on the PC industry, which had already become depressed. However, Taiwanese firms were offered a good opportunity for recovery, as many PC firms from advanced countries started to send out larger amounts of OEM orders to Taiwan in order to reduce costs. In the 1980s, Taiwanese OEM clients mainly consisted of middle-level PC vendors from the USA (Mizuhashi 1997), but in the 1990s, these clients included most international leading computer companies. Since the early 1990s, even Japanese computer companies, which had formerly had an antipathy to "low quality" parts and products supplied by other Asian countries, have begun purchasing from Taiwan in order to survive harsh price competition (Fujita and Imai 1995).

After 1992, the Taiwanese PC industry established a different kind of international competitiveness. The primary competitive edge shifted from the low-cost and flexible manufacturing system facilitated by subcontracting to strong capabilities in product design and production control including the introduction of scale-intensive production lines. The majority of OEM was upgraded to ODM. So, I regard the first half of the 1990s as the ODM stage. More and more firms had concerns with QC. One respondent from a NB firm said that it was around 1994 that applying for ISO certifications began to become popular. Now Taiwan has become one of the most important international purchasing office (IPO) centres in the world. Many of the major leading computer and electronics companies put their IPOs in Taiwan, for example, AMP, AOC, Apple, AST, AT&T, Bull, Compaq, Dell, Fujitsu, GE, HP, IBM, Motorola, NEC, Philips, Seiko-Epson, Siemens, Toshiba, Unisys, Xerox, and so on.[29]

In the sphere of marketing, Taiwanese firms experienced a reversal in own-brand sales when the world PC industry encountered a severe recession from 1989 to 1992. Although they did not give up on

[29] For detailed information of IPOs, see 'International purchasing centre: Taiwan' (*Components Times* 1996, July, pp 81–96) (in Chinese).

efforts for OBM, the share of OBM in total sales has not grown smoothly since then. In regard to the role of indigenous traders, the importance of these actors seemed to decrease rapidly. There were several reasons for this. First, as manufacturing firms grew, it became normal for them to establish specialised sales and marketing departments internally, which reduced the necessity for relying on traders. Second, establishing direct contact with main clients and key parts suppliers was also needed in order to conduct the cooperative development of new products in a more and more rapidly changing business environment. Third, profit margins had become too small to pay traders a brokerage fee.[30]

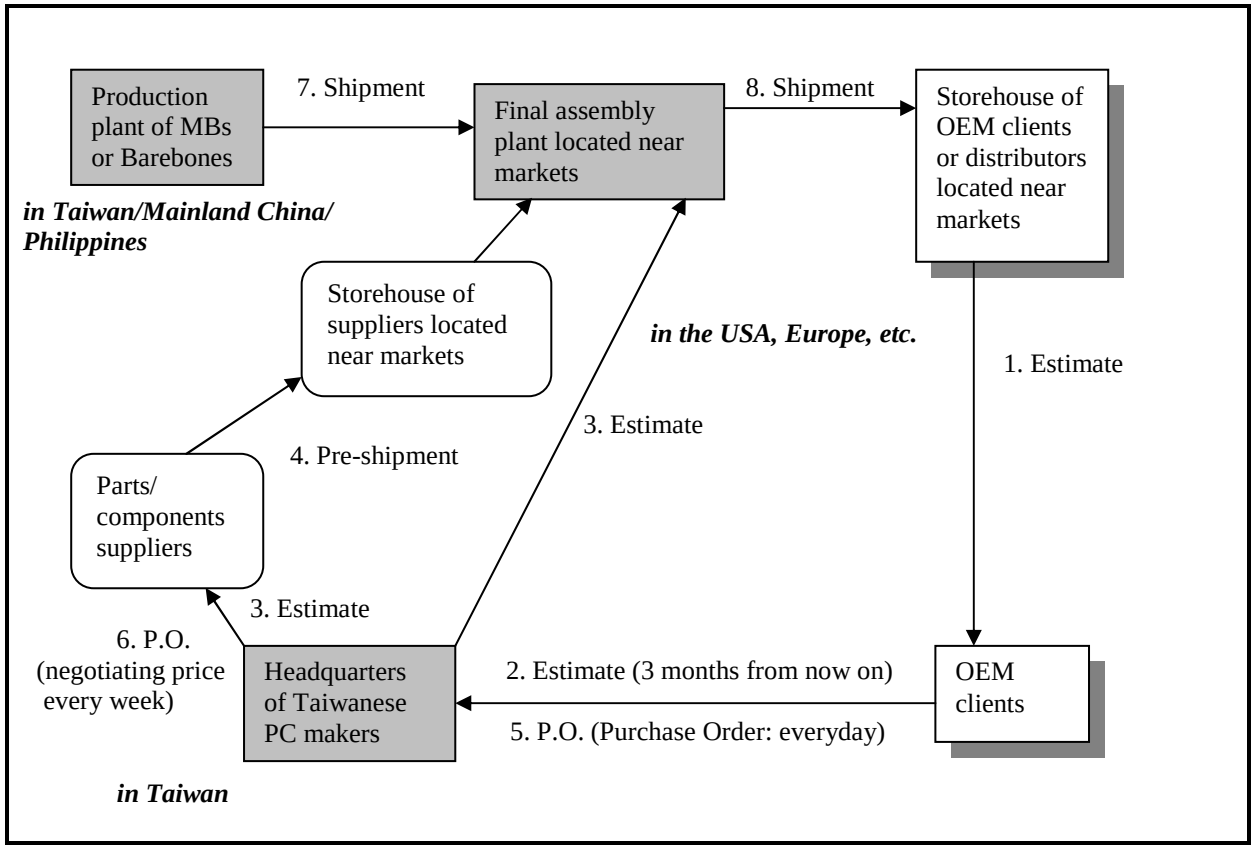
The second half of the 1990s can be regarded as the ODM/Global Logistics stage. Through OEM partnerships with major foreign clients, Taiwanese manufacturers have further enhanced their technical capabilities in both production skills, including QC, and product design and development since the first half of the 1990s. In recent times, Taiwanese manufacturers have gradually been forced to enhance production management capability in order to respond to decreasing profit margins and fast technical upgrading. These include production control, cost management, materials management and QC, as well as increasing production capacity. The offshore production of low-end products in Mainland China was accelerated after the mid-1990s in order to expand production capacity as well as to reduce production costs.

Since the mid-1990s, partnerships with major world clients have evolved further. In order to reduce costs and enhance time-to-market efficiency, Compaq made the Global Logistics production and supply model agreement with Taiwan's MiTAC, whereby Compaq farmed out all stages of the value chain for some of its Desktop PCs, with the exception of basic product planning and marketing. In the Global Logistics model, the production process of Desktop PCs is divided into several stages, and each stage is conducted in a location in which the best cost efficiency for that stage can be realised. For example, the production of MBs is to be carried out in Taiwan or lower-cost countries such as Mainland China and Philippines, because the design of MBs is increasingly standardised and scale merits have become more and more important in the MB production. In addition, other parts/components such as Cases and switching power supply (SPS) units, of which content is large but of which price is relatively stable, are also assembled with MBs into half-finished goods (called "Barebones") in plants located in the same region. Half-finished goods are shipped to final assembly plants afterwards. Meanwhile, for some parts/components, such as CPUs, random access memories (RAMs), HDDs of which price is high and of which technology is changing rapidly, it is better for them to be purchased and assembled into final products after receiving orders. Therefore, final assembly plants are required to be located near important markets such as the USA and Europe. Parts/components suppliers such as Monitor makers are also required to establish storehouses near important markets (see Figure 5.1). In this way, PC producers can reduce the inventory pressure of final products and avoid a loss caused by sudden drop in parts prices. At

[30] This explanation is based on my interviews with Taiwanese business people and Lin (1996).

the same time, they can quickly respond to market changes and realise customisation to a certain extent according to user demand.[31]

Figure 5.1 Global logistics production and supply model (the case of Desktop PCs)



Source: MIC (1999: 90).

This evolution has meant that Taiwan has declined as a production site. According to statistical data, Taiwan accounted for only 49.1 per cent of total production of hardware of all IT products in 2000. Mainland China, Malaysia, Thailand, and others made up 31.3 per cent, 4.2 per cent, 1.5 per cent and 13.9 per cent respectively (MIC 2001, *2000 Yearbook of the Information Technology Industry*). Despite decreasing importance in the production sphere, the original industrial base in Taiwan remains important because the headquarters function for the offshore production system is still located there. This includes supplying important inputs, equipment and technologies, handling core activities for foreign subsidiaries, such as product planning, R&D, communication with suppliers and clients, logistics, and financial management.

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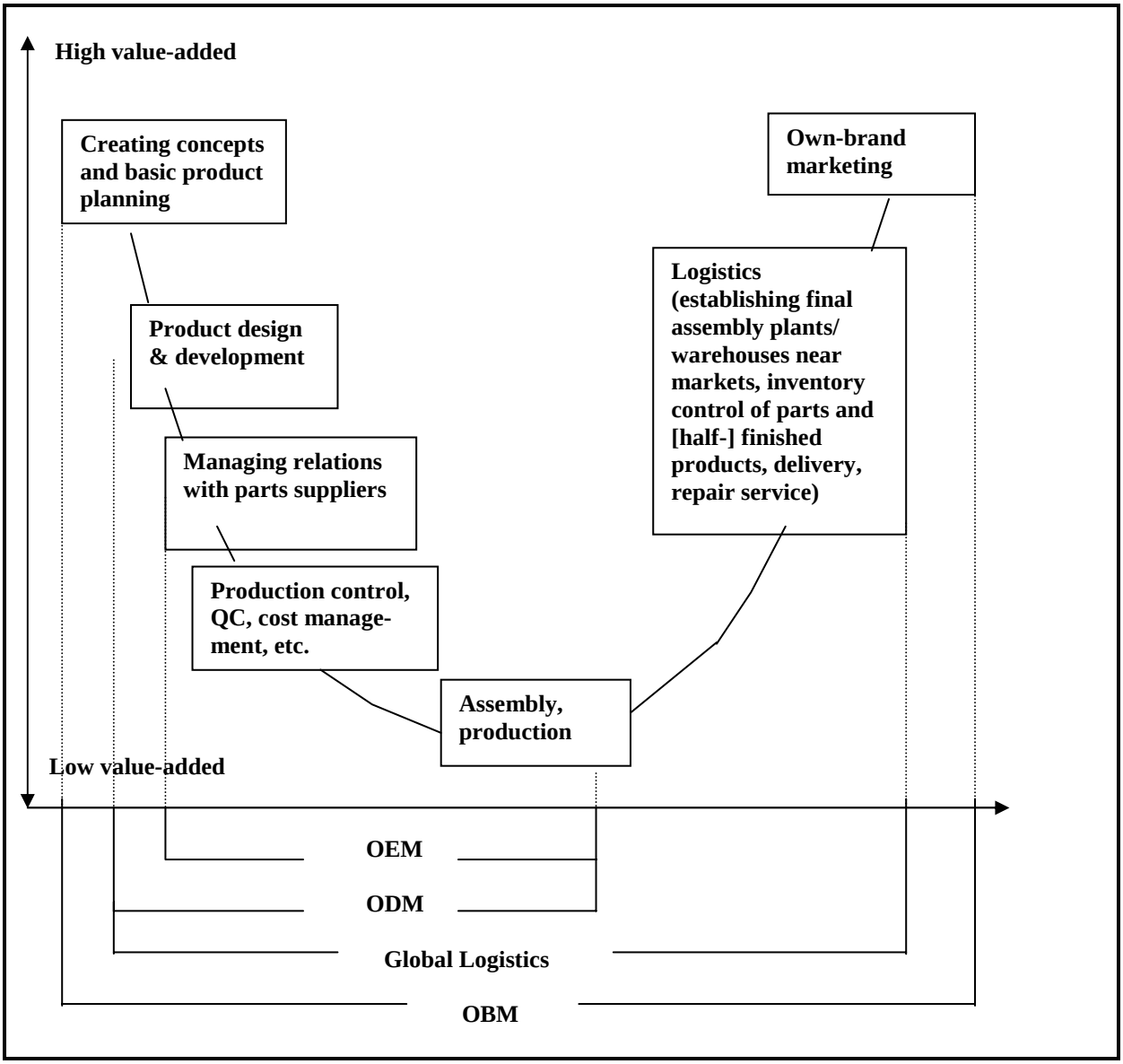
[31] This explanation of Global Logistics is mainly based on MIC (1999). According to an article in *DigiTimes*, the Global Logistics model only works well in the production and supply of high-end products which are expensive and have room for customisation. Regarding low-end standardised products, it is economical to assemble final goods in low-cost countries such as Mainland China and then ship them to markets. This is why there was a reversal in the spread of the Global Logistics model at the end of the 1990s (*DigiTimes* 17 August 1999). It is also expected that IT products will become more and more compact in the future. Thus, they will be easily and quickly transferred from production sites to markets. If so, it is questionable whether the Global Logistics model should be followed with so little thought (*DigiTimes* 19 November 1999).

In the Global Logistics model, Taiwanese PC makers have to perform many more functions in the value chain. They are responsible not only for the design and production of goods, but also for other functions such as the physical delivery and inventory control of parts/components and of (half-finished) products. In addition, they are required to establish final assembly plants (where assembling finished products takes place by combining half-finished products with several key components), warehouses, and repair centres near important markets. Through shifting OEM to ODM to Global Logistics, they are climbing a ladder up in the value chain (see Figure 5.2). In the GVC literature, it is recognised that chain structures which facilitate the fast learning of production skills may result in barriers for the acquisition of more complicated functions such as design (Schmitz and Knorringa 2000). Taiwan is a rare case in this regard.

Figure 5.2 Functional upgrading in the PC value chain



Source: Author's survey.

But this successful functional upgrading is accompanied by an important qualification, which is clearly observed in the fact that it does not necessarily guarantee large profit margins and strong bargaining power against foreign major clients. As mentioned in Section 3.3, profit margins drawn from OEM are squeezed and advance into OBM is still not an easy task. One Taiwanese analyst 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'.

In terms of the difficulties in advancing into OBM, Lee and Chen (2000) provide an insightful analysis. They specify several different types of ODM and OEM, and then point out different possibilities for learning and raising profits in various practices. In their model, the development trajectory is not linear (i.e. from OEM to ODM to OBM). OBM in one market segment can be combined with being a subcontractor in other market segments. Lee and Chen suggest, mainly based on theoretical considerations, that for a company with a relatively constrained space for resource development, such as OEM suppliers, it is vital to pursue a growth strategy based on the synergies between multiple business strategies.

According to the recent GVC literature, it is often recognised that prices for producers are falling and that the upgrading of products and processes does not necessarily result in increased profits and bargaining power. In connection with this, as one of the current trends in GVCs, it is reported that many world-class lead firms have focused on product development and marketing while outsourcing production-related functions to suppliers in many industrial sectors. This is a result of the fact that the cost and importance of intangible assets such as brand identities and marketing capabilities have increased over these of tangible (production-related) activities (Gereffi *et al.* 2001). This is the case in the PC industry too. World leading computer companies have recently focused on core and profitable functions such as basic product planning, production of some key parts, limited involvement in the final assembly of higher value-added products, brand marketing and IT-related service providing.

Despite such limitations, Taiwan can be seen as one of the most successful cases of functional upgrading in GVCs. However, in the late 1990s, probably the biggest challenge was recognised by the emergence of a handful of sophisticated contract manufacturers (called CMs, hereafter), who were largely North American-based and capable of supporting the manufacturing needs of US and European lead firms all over the world. By comparison, Taiwanese OEM firms have both advantages and disadvantages. On the one hand, Taiwanese producers have a wider range of capabilities in the area of post-architectural product design and development as well as production, while CMs concentrate on the base manufacturing processes and have been much slower to develop design services. On the other hand, North American CMs are able to deal with a wider range of product categories including various kinds of electronics products, without restricting themselves to computers. In addition, CMs have an advantage in logistics and supply-chain management based on globally-established footholds, while the manufacturing sites of Taiwanese OEM firms are largely located in Taiwan and Mainland China (Sturgeon and Lester 2002).

Challenge from North American CMs is pressuring Taiwanese producers to establish different kinds of capabilities to respond to emerging new organizational structures of GVCs.[32]

As examined in the previous sub-section, export growth through OEM was accompanied with the corresponding evolution of local cluster linkages in the 1980s. In the 1990s, partnership with OEM clients has increased its inter-dependent nature as Taiwanese producers have enhanced their capabilities and succeeded in functional upgrading. In response to this external transformation, local linkages have also changed in nature. This can be seen through the enhancement of cooperative relationships with suppliers and of local supply bases of key parts in backward linkages, the increasing importance of scale merits and in-house technical efforts of individual firms in horizontal competition, and the continuous support of government and related institutions to strengthen the IT sector as a strategic industry and to upgrade the status of Taiwan as a regional operation centre. I will now focus on the three local linkage categories.

Backward linkages. In the framework for assessing inter-firm linkages of clusters, which was outlined in Section 3.5, it is suggested that backward linkages with parts suppliers and subcontractors change in nature from ACR to OCR over time (see Row 1 of Table 3.5). My examination in Section 3.1 revealed that backward linkages were basically classified as OCR in the late 1990s. This leads to the question: when and how did the shift from ACR to OCR occur? Answering this question based on a rigid empirical proof is a difficult task because of a lack of data. But it is relatively easy to offer a plausible inference. I suggest that the shift from ACR to OCR occurred (or was accelerated) in the early 1990s when many major foreign computer companies started to provide large-scale OEM orders to Taiwan in order to deal with increased downward pressure on prices. Before then, OEM orders came mainly from North American small and middle-level computer vendors. Major foreign clients normally make stricter demands on quality, functions and lead-time, therefore, in order to respond to these, Taiwanese producers could not help strengthening partnerships with their suppliers.

With enhancing global competition, communication with parts suppliers has become increasingly close of late, although the significance of subcontracting has decreased. Having a good hold on parts sources becomes one of the factors which decides business competition. In the late 1990s, the major Taiwanese producers started to introduce IT-based management systems such as ERP, EDI and SCM, thus involving their suppliers. This is also a precondition for constructing Global Logistics.

Besides strengthening cooperation in backward linkages, the Taiwanese cluster has expanded the local supply base for key parts. The rate of local supply of necessary parts was relatively high from the start of the PC industry in Taiwan. However, many high quality electronic parts have been supplied by Taiwan subsidiaries of Japanese manufacturers, and some key components such as HDDs and LCDs have been imported from foreign suppliers. One respondent from a Taiwan affiliate of a major Japanese supplier of electronic parts and materials said: 'In Taiwan you can easily get parts of middle-to-low-quality level because supporting firms have developed well. Although Taiwan is weak in manufacturing parts of

[32] In regard to the new business model constructed by globally-operating partnership between US-based major electronics firms and large-scale CMs, see Sturgeon (2002) and Sturgeon and Lester (2002).

high-quality level, it reaches a quite high-standard in comparison with other countries'. However, indigenous firms have gradually begun to produce high-quality parts and key components. For example, government has tried to establish a solid supply base of TFT (Thin Film Transistor)-LCDs (*DigiTimes* 31 August 1999). TFT-LCDs account for the largest portion in total material costs of Notebook PCs, which had been entirely imported from Japanese and Korean suppliers. In 1999, there had been seven established TFT-LCD producers in Taiwan, most of which were based on technology transfers from Japanese producers. This appears to be one example of Japanese firms advancing into more profitable and technologically higher products, while transferring old-generation technology to their Taiwanese partners (*DigiTimes* 8 October 1999). Yet, expanding the local supply basis of key parts contributes to shifting cluster activities to more profitable spheres in the value chain.

Horizontal linkages. From the late 1980s when the hyper-growth phase terminated, there were signs that the business environment was changing and the importance of scale-intensive manufacturing systems increased once again. OEM orders from major foreign clients tend to concentrate on several top manufacturers from each sub-sector in Taiwan, which leads to these top manufacturers increasing their share in the total output of Taiwan. In the mid-1990s, one Taiwanese senior industrial analyst reported: 'The Taiwanese PC industry has already reached the matured stage and new entry is becoming more and more difficult. It is a very hard task for new entrants to attain large-scale production capacity, to develop new products ceaselessly, to purchase parts at reasonable prices, and to sell products to the world market through establishing partnerships with respectable buyers' (Hwang 1996: 77).

This tendency has recently accelerated, especially since the low-price PC started to become popular in 1997. Harsh price competition is still often found in many sub-sectors. Producers now compete with one another in expanding production capacity, and scramble for large-scale OEM orders from major foreign computer companies; this practice depresses profit margins further, as mentioned above.

As stated above, in the sphere of the knowledge system, it had already been observed in the late 1980s that risk-taking initiatives of a number of firms and their incremental technological mastery under the "bootstrap strategy" had contributed to technological upgrading of the cluster as a whole. As examined in Section 4, in the late 1990s, the same mechanism also played an important role, and mutual learning among local producers, mainly through indirect routes, was an important knowledge source for technological upgrading. It should be also emphasised that openness of knowledge systems to external knowledge sources, besides mutual learning among local firms, is indispensable to sustaining competitiveness in the long term. According to Bell and Albu (1999), replicating and re-circulating knowledge that is already established within the cluster may create the impression of dynamism at the individual firm level, but this leads to technological stagnation of the cluster as a whole. In this regard, learning from external buyers and mutual learning among local producers are seen as reinforcing each other.

Recently in-house learning efforts by individual firms seem to have increased in relative importance. As stated in Section 3, nowadays manufacturers cannot survive by depending only on imitation and follow-up innovation without a substantial in-house investment in R&D. At the same time, the recent

design and performance of products is becoming similar among local producers because the industry has become mature and now they all use common key parts. Therefore, the outcome of business competition is increasingly decided by scale economies and financial power. This is the case even in relatively new sub-sectors such as Notebook PCs, as reported by several respondents from NB firms. In many sub-sectors, conducting business has recently become more difficult for small-scale firms because it requires more and more additional resources for large-scale production, ceaseless innovation and global operation.

Institutional linkages. Following on from the first Ten-Year Plan of the 1980s, the Ten-Year Plan for the Development of the IT Industry (1990–2000) was set out and followed.[33] This second Ten-Year Plan aimed at facilitating the application of IT technology for the improvement of the quality of life of citizens, upgrading technology and product level, and expanding supply of IT-related human resources. In addition, the plan viewed the software industry as the future leading force and put forward the plan of constructing a Software Industrial Park. In connection with this, several new assistance programmes were launched in the early 1990s, for example, the Programme for Encouragement of the Development of New Leading Products, the Programme for the Development of Key Parts and Products, and the Programme for Developing and Training Industrial Technology Specialists. These are not necessarily devoted to the PC industry, but the IT (including PC) industry has been the main beneficiary in many cases.

From the late 1990s, several new tendencies in the promotion policies for the IT industry and S&T activities in general have emerged. First, reflecting increasing democratisation, the science and technology policy which has been under the control of government has started to change in nature and now accepts more initiative from the private sector (Satou 1997). Second, in order to upgrade the industrial base of Taiwan, government aims at encouraging major foreign companies to set up R&D centres in Taiwan (*DigiTimes* 23 February 2000). Third, the IT industry includes several different sectors such as PC hardware, software, internet and communication equipment, which until now have developed without complementing each other. Therefore, it will be an important task for government to link them together (*DigiTimes* 23 December 1998).

Viewed in a broader context, government and government-sponsored institutions in the 1990s have advanced various polices to upgrade the high-technology industries of which the IT industry is the core, as well as to secure sufficient supply of human resources, promote R&D by private firms and interaction between them and public research institutes, and improve the general business environment such as planning to construct intelligence-intensive industrial parks across the country and make Taiwan the "Science and Technology Island" by constructing the national information infrastructure, and so on.

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[33] The following explanation of the Ten-Year Plan for the Development of the IT Industry (1990–2000) is largely based on Wang (1995–96); MIC (1989), *1988 Yearbook of the Information Technology Industry*; and, MIC (1991), *1990 Yearbook of the Information Technology Industry*.

Recently, faced with the rising importance of Mainland China as a production site, government has accelerated policies to strengthen Taiwan's status as a regional high-technology and operation centre.[34]

5.3 Summary

This section has examined the upgrading trajectory of the Taiwanese PC cluster in the PC value chain from the early 1980s to the late 1990s. The transformation of local cluster linkages (i.e. backward, horizontal and institutional linkages) has also been analysed in terms of how it is connected to the transformation of external (forward) linkages. The main findings are summarised in Table 5.1.

As confirmed in the previous two sections, linkages in the Taiwanese PC cluster show a high-quality nature in the late 1990s. This section examined how the transformation has taken place since the early 1980s. The table is not conclusive due to a lack of data. However, it does reveal that forward linkages and local cluster linkages have reinforced each other and enhanced the quality of linkages in all the categories. It can be said that Porter's scenario mentioned in Section 1 is clearly realised in the case of Taiwan.

One of the advantages of my analysis is that it focuses on cluster dynamism in terms of the different types of linkage categories respectively. Each linkage category has its own specific kind of importance. Examining the Taiwanese case reveals that forward linkages with foreign buyers are critical; through these linkages both opportunities and pressures for upgrading are created. However, in the Taiwanese computer cluster, the existence of well-developed supporting industries such as input suppliers and subcontractors, and cooperation in backward linkages are also a fundamental factor. It is the main source of flexibility, speed and excellent cost performance; without this, Taiwan could not have attracted foreign buyers. Horizontal linkages between local fellow firms contribute to enhancing the competitiveness of the cluster as a whole through both the effect of severe competition and that of unconscious cooperation. A combination of harsh rivalry and cooperation mainly through informal routes seems one of the key factors in Taiwan's success. In knowledge flows, vertical (backward and forward) linkages and horizontal linkages may play complementary roles. In many cases, new knowledge enters the cluster through interactions with agents in vertical linkages such as external buyers and foreign key parts suppliers; this knowledge is diffused and improved through horizontal interactions. In terms of institutional linkages, as stated in Sections 3 and 4, this linkage category does not seem to have played a very active role, with the exception of regional universities/colleges which have supplied high-quality human resources. However, advancing into more promising related businesses and key technology development will necessitate constructing a sophisticated support system and local learning/innovation network in the future in which knowledge institutions will become nodes and catalysts. In recent years, it seems that government have accelerated policies for this purpose.

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[34] The IDB/MOEA publishes *Yearbook of Industrial Development* (in Chinese) and an overview of various programmes for industrial development administered by the IDB can be found here. *Yearbook of the Information Technology Industry* published by the MIC also introduces important government policies concerning the IT industry.

Table 5.1 Upgrading of the Taiwanese PC cluster (from the early 1980s to the late 1990s)

<table>
<tr><th>Stages</th><th>Forward linkages with external buyers</th><th>Local cluster linkages</th></tr>
<tr><td>The first half of the 1980s

The initial stage</td><td>FDI firms/OEM clients were the main driving force of export expansion.

Some local firms had already possessed basic production skills and some product design capabilities (the heritage of the electronics industry since the 1960s).</td><td rowspan="2">Backward linkages. The solid supply base of electronics parts and the geographical proximity of suppliers were a major advantage from the beginning. The subcontracting system developed in the latter half of the 1980s.

Horizontal linkages. The inflow of many SMEs led to harsh price competition in the latter half of the 1980s. It was also observed in the late 1980s that risk-taking initiatives by many firms and incremental technological mastery under the “bootstrap strategy” were conducive to technical upgrading of the cluster as a whole.

Institutional linkages. Government promoted the IT sector as a strategic industry and a leading exporter since the early 1980s, although the PC industry received only modest state support. Several computer projects were carried out by the ERSO/ITRI.</td></tr>
<tr><td>The second half of the 1980s

The OEM stage</td><td>FDI firms/OEM clients provided various forms of technical and managerial assistance to local producers, besides shouldering marketing.

The low-cost and flexible manufacturing system ensured by the subcontracting network was established.

Local firms began the initial effort of own-brand offshore sales (indigenous traders played an important role).</td></tr>
<tr><td>The first half of the 1990s

The ODM stage</td><td>Around 1990, many FDI firms withdrew due to rising production costs. But many world leading companies started to give large amounts of OEM orders after 1992.

The primary competitive edge shifted to strong capabilities in product design and production control including operational skills for the automated equipment and scale-intensive manufacturing system. The QC procedure also started to be established.

Local firms experienced a reversal in OBM due to the world recession of the late 1980s and the early 1990s (the importance of indigenous traders decreased rapidly).</td><td rowspan="2">Backward linkages. The shift from ACR to OCR seemed to occur (or be accelerated) in the early 1990s in order to respond to stricter demands from major clients.
In the late 1990s, cooperation with parts suppliers became increasingly important, while the significance of subcontracting decreased. The cluster expanded the local supply base of key parts.

Horizontal linkages. Scale merits became critical in competition. OEM orders from major foreign clients tended to concentrate on several top firms within each sub-sector. The scramble for orders from major clients led to further depressed profit margins.
In the knowledge system, mutual learning through indirect routes was an important knowledge source in the late 1990s, but openness to external sources and substantial in-house innovation of individual firms became indispensable.
The recent business environment has become increasingly difficult for small firms.

Institutional linkages. The IT industry continued to be a strategic industry in the 1990s, and some additional assistance programmes were carried out. More generally, government launched policies to support the upgrading of Taiwan as a regional high-technology and operation centre.</td></tr>
<tr><td>The second half of the 1990s

The ODM/
Global Logistics stage</td><td>Major OEM clients came to focus on core, profitable functions such as basic product planning and brand marketing, leaving others to Taiwanese producers.

Local firms experienced substantial upgrading including design and logistics as well as production, but it entailed important limitations such as squeezed profit margins and difficulty in expanding OBM.

Offshore production was accelerated largely in Mainland China, with the original Taiwanese cluster shouldering the role of regional headquarters.</td></tr>
</table>

Source: Author’s survey.

6 Conclusion

This paper began with the introduction of Porter's suggestion that the cluster's competitiveness is recovered by shedding simple production tasks elsewhere to offset local cost rises as far as the cluster succeeds in grasping more strategic functions. Next, the paper examined to what extent such dynamism can be observed in the Taiwanese PC cluster, which is one of the biggest success stories among developing and newly industrialising economies. In order to do this, we addressed two analytical advances, namely, the distinction between the production and knowledge systems, suggested by Bell and Albu (1999), and the fusion of the local cluster and the GVC approaches, proposed by Humphrey and Schmitz (2000). Based on an overview of development patterns in the Taiwanese PC industry and drawing on quantitative analysis (Section 2), this paper set out to meet its objective by examining cluster linkages in terms of production and knowledge systems respectively (Sections 3 and 4). The upgrading trajectory through forward linkages with foreign clients and interactions between it and the transformation of local cluster linkages was also examined in Section 5. These empirical sections show that the upgrading trajectory of the Taiwanese PC cluster has advanced in line with Porter's scenario to a substantial extent, although there are some important bottlenecks to further development.

A summary of each empirical section is as follows:

(1) In Section 2, it is observed that Taiwan has gradually shifted its business focus from mature sub-products to new ones. This is an evidence of product upgrading. On the other hand, Taiwan has also experienced considerable functional upgrading from OEM to ODM to Global Logistics. In tandem with this, the offshore production rate has reached a considerable level in a number of sub-products. A detailed analysis reveals that offshore production has advanced more in relatively mature sub-products, while the production of less mature sub-products (and the production of high-end product segments of mature sub-products) tends to remain in Taiwan. Thus, products requiring sophisticated skills continue to be made in Taiwan and those requiring lower skills are increasingly made offshore. In terms of the distinctions used in later sections of the paper, it can be concluded that the importance of clustering has diminished in the production system and remained high in the knowledge system.

(2) Sections 3 and 4 concentrated on those activities that remained in Taiwan. Section 3 examined the production system based on data attained from my own fieldwork. Cluster linkages were disaggregated into four categories, namely backward, horizontal, forward and institutional. Based on existing case studies and theoretical expectation, I offered a framework for assessing the quality of cluster linkages, which depicted how the quality of linkages was expected to vary between static and dynamic clusters. Based on this framework, important implications can be drawn. The Taiwanese PC cluster has obtained many features of the dynamic clusters in the late 1990s, which reflects the rising status of Taiwan in the world PC industry. The features basically include OCR type linkages with key parts suppliers and subcontractors. They have an aspect of "high road" rivalry among local firms (i.e. competing in the speed of product design and development, flexibility and cost management capabilities), forward linkages with huge overseas markets mainly through OEM, which is the basis for a high division of labour among local

producers, and a wide-range of services provided by local support institutions. At the same time, despite considerable success, we can identify some important qualifications, for example, lack of local supply bases for many key parts, harsh price competition among local producers as an aspect of "low road" rivalry, difficulty in expanding OBM and shrinking profit margins from OEM, and a limited usefulness of the role of support institutions from the viewpoint of private firms.

(3) In Section 4, the quality of cluster linkages were analysed in terms of the knowledge system. This section offered theoretical considerations regarding how clustering can promote learning/innovation in terms of four linkage categories respectively. This was then compared to the empirical analysis of the Taiwanese case during the late 1990s. Analysis revealed that the knowledge system of this cluster was high-quality in nature. For example, there was close communication with key parts suppliers, mutual learning and rapid knowledge diffusion was evident mainly through informal routes among local firms, design and production processes were undertaken by local producers largely without relying on technical assistance from foreign buyers, and various technical services were offered by knowledge institutions. At the same time, some important bottlenecks were observed, for example, a lack of profound technical cooperation with key parts suppliers, an absence of technical joint action among local producers, forefront technological trends still being led by major foreign clients and foreign key parts suppliers, and a limited role of knowledge institutions. This summarises the achievements and limitations mentioned in the previous section, in terms of the technological dimension.

(4) This paper assumes that upgrading through global linkages necessitates establishing a local base for continuous innovation and development of a unique product/service mix, which in turn requires the quality of local cluster linkages to be enhanced as a whole. The previous sections have confirmed that these requirements have been substantially realized during the late 1990s. Section 5 was concerned with explaining how the transformation of the cluster was achieved by examining the history of the Taiwanese PC industry from the early 1980s to the late 1990s. The Taiwanese PC industry has passed a series of successive development stages from the initial stage (the first-half of the 1980s), the OEM stage (the second-half of the 1980s), the ODM stage (the first-half of the 1990s), and eventually the ODM/Global Logistics stage (the second-half of the 1990s). Over these two decades, Taiwan has accumulated production skills and design capabilities and has undertaken more complicated functions. Partnerships with foreign clients have become more interdependent in nature, although it entails important qualification such as squeezed profit margins and difficulty in expanding OBM. In tandem with this process, local cluster linkages have changed in nature and increased in quality. For example, the local supply base of parts has expanded and cooperation in backward linkages has been strengthened. However, subcontracting has decreased in importance since the mid-1990s. In horizontal relations, local fellow producers competed based on low-cost and flexible production capability which was ensured by extensive division of labour and specialisation in the 1980s, while substantial in-house R&D efforts and firm scale have become crucial factors in the 1990s. In terms of the role of government and support institutions, it had modest importance for developing the PC industry in the 1980s, although the IT industry (including the PC sector) was specified as a strategic industry. The situation was basically the same in the 1990s. In

recent years, however, government has launched policies to promote the upgrading of Taiwan's status as a regional high-technology and operation centre. This section, therefore, confirmed that forward linkages and local cluster linkages have reinforced each other and the quality of linkages in all categories have increased.

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