WORKING PAPERS

EAST-WEST CENTER WORKING PAPERS

EAST-WEST CENTER

The U.S. Congress established the East-West Center in 1960 to foster mutual understanding and cooperation among the governments and peoples of the Asia Pacific region including the United States. Funding for the Center comes from the U.S. government with additional support provided by private agencies, individuals, corporations, and Asian and Pacific governments.

East-West Center Working Papers are circulated for comment and to inform interested colleagues about work in progress at the Center.

For more information about the Center or to order publications, contact:

Publication Sales Office
East-West Center
1601 East-West Road
Honolulu, Hawaii 96848-1601

Telephone: 808-944-7145
Facsimile: 808-944-7376
Email: ewcbooks@EastWestCenter.org
Website: www.EastWestCenter.org

EAST-WEST CENTER

Economics Series

No. 35, September 2001

Implications, Challenges, and Prospects for Taiwan in the Knowledge-Based Economy

Tain-Jy Chen, Shin-Horng Chen and Meng-chun Liu

Tain-Jy Chen is a Professor in the Department of Economics at the National Taiwan University and a consultant to the Chung-Hua Institution for Economic Research, Taiwan, China.

Shin-Horng Chen is the Deputy Director of the International Division, Chung-Hua Institution for Economic Research, Taiwan, China.

Meng-chun Liu is an Associate Research Fellow at the International Division, Chung-Hua Institution for Economic Research, Taiwan, China.

This paper was prepared for the Trends and Issues 2000 Workshop held October 25–26, 2000, Tokyo, Japan. It will be published as a chapter in *Trends and Issues 2000*. Tokyo, Japan: International Development Research Institute Foundation for Advanced Studies on International Development (FASID).

I. Introduction

The knowledge-based economy differs from a material or capital-based economy in that it recognizes knowledge as the core of competitiveness and the driving force for long-term growth. The rules of the game in the knowledge-based economy are speed, flexibility and innovation. In the 'new economy', newly starting and rapidly growing companies are, almost from their inception, selling to global markets, and thus the established companies are forced to reinvent their operations in order to stay competitive in the new game. The new knowledge-based economy has brought major changes to the organization of production, market structures, occupational choices, and so on, challenging traditional idea of national comparative advantage based on the endowment of basic resources of land, capital and labor. In the knowledge-based economy, the most important kinds of capital are human capital and organizational capital, as opposed to financial capital, and the pace of innovation is now driving the evolution of the industry with a speed unimaginable in the past.

The challenges brought about by the knowledge-based economy have also greatly affected the roles of the government. Instead of managing business cycles, the policy focus of the government has shifted to fostering innovation. The crucial infrastructure for industrial competition today does not comprise of roads, ports, and public utilities, but 'information super-highways' that facilitate the transmission of information. Technological advances in personal computers, telecommunications and the Internet have laid the foundations for this kind of infrastructure, thus the adequacy of public infrastructure is no longer measured by the length of highways and railroads, but by the penetration of broadband networks, and the like. And no longer are television or automobile ownership an appropriate indicator of the state of economic development, the Internet access rate is now probably more fitted to that purpose.

This paper addresses the implications of the knowledge-based economy on the organization of world production, focusing on Taiwan, which was previously a manufacturing-based economy serving as an international subcontractor. The innovation-driven, time-based competition of the knowledge-based economy has greatly changed the roles of Taiwanese manufacturers and their working relationships with other players in the market. We focus on Taiwan's personal computer and IC industries to illustrate the changing patterns of the division of labor, and to show that the knowledge-based economy is much more than just high-technology manufacturing.

The rest of this paper is arranged as follows. In the next section, the status of Taiwan's knowledge-based industries is discussed. In section III, we discuss the restructuring of the world production system under the knowledge-based economy, followed, in section IV, by a discussion of the changes in the market structure. In sections V and VI, the cases of personal computer and IC industries are explored. Concluding remarks are provided in section VII.

II. The Growth of Knowledge-based Industries in Taiwan

Following the OECD's (1996) guidelines on the definition of knowledge-based industry (KBI), in 1996, Taiwan's Council for Economic Planning and Development (CEPD) calculated the share of KBI in Taiwan's economy at 40.6% (see Table 1).

Table 1 Growth of knowledge-based industry in Taiwan

Unit: %

	Year	All Industries	Knowledge-based Industries	Knowledge-based Manufacturing Industries	Knowledge-based Service Industries
As a proportion of GDP (%)	1991	100.0	37.7	6.1	31.7
	1994	100.0	39.2	5.7	33.5
	1996	100.0	40.6	6.8	33.7
Growth rate in value-added (nominal)	1991-94	9.8	11.2	7.6	11.9
	1994-96	10.2	12.1	20.5	10.6
	1991-96	9.9	11.5	12.6	11.3

Note: Knowledge-based manufacturing industries include aerospace, computer and data-processing equipment, pharmaceutical, telecommunications, semiconductors, scientific instruments, automobiles, electrical equipment, chemical products, machinery, other transport equipment; Knowledge-based service industries include transport and storage, communication services, finance, insurance, and real estate, commercial services, social and personal services.

Source: Council for Economic Planning and Development, based on Input-Output Tables.

This figure is substantially lower than the average of OECD countries, which was estimated at 50.9% in the same year, but it was nevertheless much greater than the figure for Taiwan's recent past. In 1991, the share of KBI in Taiwan was only 37.7%, thus it had grown by an average of 11.5% (in nominal terms) from 1991-96, higher than the average growth rate of 9.9% for all industries combined.

The growth of KBI in Taiwan was particularly rapid during 1994-96, thanks to the phenomenal expansion of the semiconductor industry, but the lion's share of Taiwan's KBI belongs to the service industry, which may not be so knowledge-intensive after all. The level of knowledge input in Taiwan's service industry can be judged by the quantity of information services that the service industries consume during their production processes. Information services include software, Internet services, data exchange, e-commerce, and so on. According to the three-digit classification of service industries, no single industry in Taiwan consumes more than 1% of information services as its intermediate inputs. Even in the most information-intensive industry, 'other commercial services', expenditure on information services accounts for a mere 0.79% of value-added. In the lowest knowledge-intensive industries, say railroad transport, information services accounts for only 0.47% of value-added. The information content of Taiwan's service industries is, therefore, generally low (see Table 2).

Table 2 Information content of the service industries - selected 3-digit industries

Industry Code	Industry	(1) Consumed Information Service (NT$1,000)	(2) Value-added (NT$1,000)	Information Content (3) = (1) / (2) %
135	Other Commercial Service	679	86,483	0.79
128	Hotel	296	42,027	0.70
134	Leasing	202	42,342	0.48
116	Railroad Transport	81	17,305	0.47
121	Telecommunications	687	163,326	0.42
133	Advertisement	535	133,163	0.40
130	Legal accounting	101	25,421	0.40
150	Miscellaneous Services	436	118,276	0.37
129	Real Estate	751	217,122	0.35
132	Information Service	114	40,995	0.28
121	Storage	60	23,896	0.25
137	Environmental & Sanitary	83	34,614	0.24

Source: Data from 1996 Input-Output Tables (Taiwan).

Taiwan has done much better in the knowledge-intensive manufacturing sectors, however. According to Wu's (2000) calculations, the high-technology manufacturing sectors in Taiwan grew by an average annual rate of 11.79% in real terms from 1991 to 1997, higher than most OECD countries. Even Korea - the region's high-flyer - was only able to register an annual growth rate of 3.81% during the same period (see Table 3).

Table 3 Distribution and growth of manufacturing sectors by technology intensity (selected countries)

Unit: %

Country	high		Upper Medium		lower medium		low	
	1997 share	1991-7 growth	1997 share	1991-7 growth	1997 share	1991-7 growth	1997 share	1991-7 growth
USA	16.0	1.37	31.9	2.91	21.7	1.63	30.4	0.19
Japan	14.7	0.03	34.1	0.32	27.6	0.17	23.9	-0.41
Germany	9.7	-4.59	38.0	-1.69	32.1	-0.61	20.2	-3.09
France	12.2	0.61	28.8	0.14	28.8	-0.23	30.2	0.07
UK	13.9	-0.08	30.7	1.35	21.1	0.66	34.3	0.60
Korea	18.5	3.81	29.0	1.14	30.9	-2.23	21.6	-5.96
Taiwan	19.5	11.79	25.2	3.01	34.0	1.23	20.9	-1.95

Source: Wu, Rong-I, (2000), 'Competitiveness Analysis of Taiwan's Industrial Technology', paper presented at the Conference on the Measurement of Industrial Technology Competitiveness in the Knowledge-Based Economy, Taipei, 23rd - 24th August 2000.

The total value-added of Taiwan's high-technology manufacturing sectors accounted for 19.5% of the total manufacturing value-added, rivaling the share of OECD countries. However, even greater development has occurred since 1996 in some service industries that are closely related to the provision and transmission of knowledge. For example, the telecommunications industry grew dramatically as a result of market liberalization in 1996, which removed the monopoly power of the state-owned telecommunications bureau. By the end of 1999, the number of cellular-phone users in Taiwan had climbed to 11 million, half of the entire population. In terms of Internet penetration ratio, about 22% of all households in Taiwan had hooked up to the Internet, ranking Taiwan second in Asia behind Singapore (whose penetration ratio was 48%; Japan's was just 18%) (*APROC Newsletter*, August 2000).

Nevertheless, Taiwan still lagged behind most OECD countries in the areas of broadband installation and e-commerce. In 1999, broadband accounted for only 4% of the island's communication networks and e-commerce was virtually negligible. The government does, however, have an aggressive plan aimed at increasing broadband coverage to 96% by 2004 and to encourage e-commerce business to reach 9% of GDP at the same time (*APROC Newsletter*, July 2000). The International Data Corp. (IDC) recently ranked Taiwan in 21st place in the world in terms of the information society index (*APROC Newsletter*, July 2000).

However, the Taiwanese government has in fact been implementing the Asia-Pacific Operations Centers (APROC) plan since 1996, aimed at liberalizing and modernizing Taiwan's outmoded service sectors. As a result of this effort, the service industry has become increasingly important to Taiwan's economy. In 1999, services accounted for 60% of Taiwan's GDP and 3.85% of economic growth, as compared to the 1.76% contributed by the manufacturing sectors (the overall economic growth rate was 5.7% in 1999). Amongst the various service sectors, transport, storage and telecommunications registered the highest growth rates. These are also, incidentally, the sectors that provide the important logistical support to Taiwan's manufacturing industries, and which are therefore, heavily affected by the restructuring of the world's production systems in the knowledge-based economy.

In a knowledge-based economy, speed is the essence of competition. The increased accessibility of knowledge and the increased speed of knowledge diffusion have made the speed of innovation faster than ever before. Faster innovation shortens product life cycles and makes inventory an unbearable burden in production. In order to cope with the competition of speed, firms have to find ways of cutting the time to market in every facet of production. Hence, the often-neglected elements of production, i.e., logistic services, have taken center stage in the competition. Take personal computers (PCs) as an example; the product life cycle for every generation of PCs, which was about one year in the 1980s, was reduced by 1999, to around four months.

In this time-based competition, firms have to organize a global logistics network, such that components and parts can be procured and assembled efficiently, and so that final products can be rapidly assembled and delivered to the market. Modernization of the shipping and storage system becomes a crucial factor in national competitiveness. From air cargo to containers, to bark-commodity shipping, all kinds of transport vehicles need to speed up, and barriers to shipping, such as customs procedures, have to be lowered. Of even greater importance, is the necessary upgrading of mechanisms for the transmission and exchange of information to facilitate the efficient organization of production and prompt decision-making. Therefore, both traditional and modern means of communication enter the center court of competition. As a direct result of its APROC plan, Taiwan now operates a 24-hour customs clearing service for air-cargo at its international airports, and is currently working on paperless customs documentation. The final touch for the APROC plan, which was unveiled in August 2000, was the reduction of overall shipping and handling costs to 10%-11% of GDP (from the current 13.1%) through the enhancement of transportation facilities and electronics-based transactions. (APROC Newsletter, September 2000).

III. Restructuring of Worldwide Production Systems

The greatest impact of the knowledge-based economy has been the reorganization of world production. In a knowledge-based economy, a firm is seen as a producer, repository and user of knowledge, producing or acquiring knowledge and putting it to use in the most efficient way. A firm’s stock of knowledge underlies its competitive advantage, and all firms are likely to be heterogeneous because they possess idiosyncratic knowledge. A firm engages in the production activities where the knowledge it possesses provides it with a competitive advantage, and a transaction of products implies an exchange of knowledge. In comparison to the rare and uneven distribution of knowledge, non-knowledge inputs to production, which include labor and capital, are available to all firms on equal terms. And non-knowledge inputs may even have lost their country specificity, as capital markets have become globalized, and although wage differentials remain, cheap labor is accessible through foreign direct investment. Thus, a firm’s sustainable competitive advantage has to be built on its possession of knowledge rather than on primary inputs.

In a knowledge-based economy, the separation between innovation and production becomes the norm. This is because innovation and production are only slightly correlated. Although knowledge used in inventing a product can be useful in the manufacturing of the product, and vice versa, it does not pay an innovator to invest in the manufacturing capacity unless it is unable to realize the value of its innovation through outsourcing. In fact, contract manufacturers can perform the production function at a lower cost than the innovators themselves because they exploit economies of scale through sharing their manufacturing capacity with more than one client.

In order to make a perfect product, the innovator usually needs to share some knowledge with manufacturers, and conversely, some of the manufacturer's knowledge can aid in product innovation. However, the sharing of knowledge is best arranged in a cooperative relationship, because knowledge is intangible and sharing entails organizational learning. Therefore, alliances have become an important form of business organization in a knowledge-based economy, and an important source of learning and innovation (Powell, Kogut and Smith-Doerr 1996). Sharing knowledge with someone may be more efficient than accumulating such knowledge internally because of the 'non-rivalry' nature of knowledge, which allows the one who partakes of the knowledge to pay only a small marginal cost to compensate the owner. Acquisition of knowledge through exchange or alliance may also be more efficient than acquiring a firm that owns the knowledge because when acquiring the firm, one also acquires non-essential assets. In sum, a knowledge-based economy is characterized by alliance capitalism.

Product innovation entails an assortment of knowledge that is relevant to various stages of production. Knowledge applied to manufacturing, marketing and customer services is complementary to the knowledge used in product innovation. However, vertical integration in the value chain is only justified if the internalization of such activities is the best way to acquire relevant knowledge, which is often not the case. As product innovation caters to the needs of customers, knowledge obtained from interactions with the customers, i.e., marketing, is most valuable to product innovation. Therefore, a combination of product innovation and marketing may be the optimal mix of services to be offered by a firm. Merchandisers such as Nike, Reebok and Calvin Klein are typical examples of an innovator-marketer combination in the traditional industries of footwear and apparel.

Even in the high-technology industries, we have observed the trend towards making innovation and marketing the core functions of the firm. Integrated Device Makers (IDMs) in the information industry such as Apple, Compaq, Dell and Motorola, have each partitioned themselves from manufacturing and designated such activities to contract manufacturers. Even in the semiconductor industries, fabless designers have been the driving force of product innovation, working closely with the providers of foundry services.

Meanwhile, we increasingly observe that contract manufacturers are required to perform customer service functions in addition to making and delivering the products. So-called 'global logistics' has prevailed in the knowledge-based economy mainly because the knowledge of the organization of production is also useful in the arrangement of shipping and warehousing, and the knowledge of making products is also useful in fixing the products. Therefore, we observe a new division of labor in the knowledge-based economy where firms endowed with heterogeneous knowledge perform production activities in line with the knowledge-content of production; country-specific advantages become secondary factors in the determination of production pattern.

As a manifestation of this thesis, we have observed a resurgence of manufacturing activities in the US, taking the form of consigned production (Sturgeon 2000). The contract manufacturers that maintain global production facilities divide their labor within the firm in line with the location-specific advantages. Similarly, R&D is also globalized (OECD, 1997). Foreign investment has become an increasingly important source of innovation (Zender, 1999), and the new division of labor has boosted the role of contract manufacturers. In the electronics industry, for example, the revenue of the world's largest 20 contract manufactures grew at an annual rate of 30.7% in 1988-92, and at an even higher annual rate of 46.4% in 1992-95 (Sturgeon 2000).

III. Market Structure in a Knowledge-Based Economy

As early as 1942, Schumpeter observed that productivity increases in the US economy were largely attributable to innovation delivered by the R&D laboratories of large American firms in an environment of high barriers to market entry. Schumpeter argued that large firms enjoying stable profits in an oligopolistic market structure have the financial resources to build up the 'knowledge base' required to apply scientific principles to ever more complex innovations. This argument implies that 'a market structure involving large firms with a considerable degree of market power is the price that a society must pay for rapid technological advancement' (Nelson and Winter 1982, p.278). Two major building blocks of Schumpeter's argument have been broken down by the new economy, however. First of all, financial resources to support innovation do not have to come from the innovators themselves, as new financial developments, such as venture capital, can provide the mechanism to support innovative activities. Secondly, market power is not necessarily correlated to firm size, especially if a firm's size is measured by its scale of production. Instead, it is knowledge that forms the cornerstone of market power.

The breakdown of the Schumpterian innovation manifests itself in an increasingly important role played by small firms in product innovation. A start-up company with good innovative ideas has the capacity to attract both financial and human resources to become a large company within a short span of time. In fact, even monopoly power created by innovation is often short-lived because it will soon be nullified by further new innovations. There is, therefore, no effective way for a monopoly firm to erect entry barriers without the assistance of the government. Market power can only be maintained with continuous innovation, as exemplified in the case of the central processing units (CPU) of personal computers.

On the other hand, there seems to be increasing concentration in the manufacturing stage of production. Our explanation of this phenomenon is that large manufacturing firms enjoy economies of scale, economies of scope, and economies of speed in the application of knowledge. Such benefits do not exist at the innovation stage. The knowledge needed for manufacturing includes product engineering, processing technologies, tooling, quality control, the organization of production, and so on. This kind of knowledge can be applied to the same product with different designs, and to different production locations. Therefore, we have observed that a contract manufacturer may work for multiple designers and produce similar products from various locations around the world.

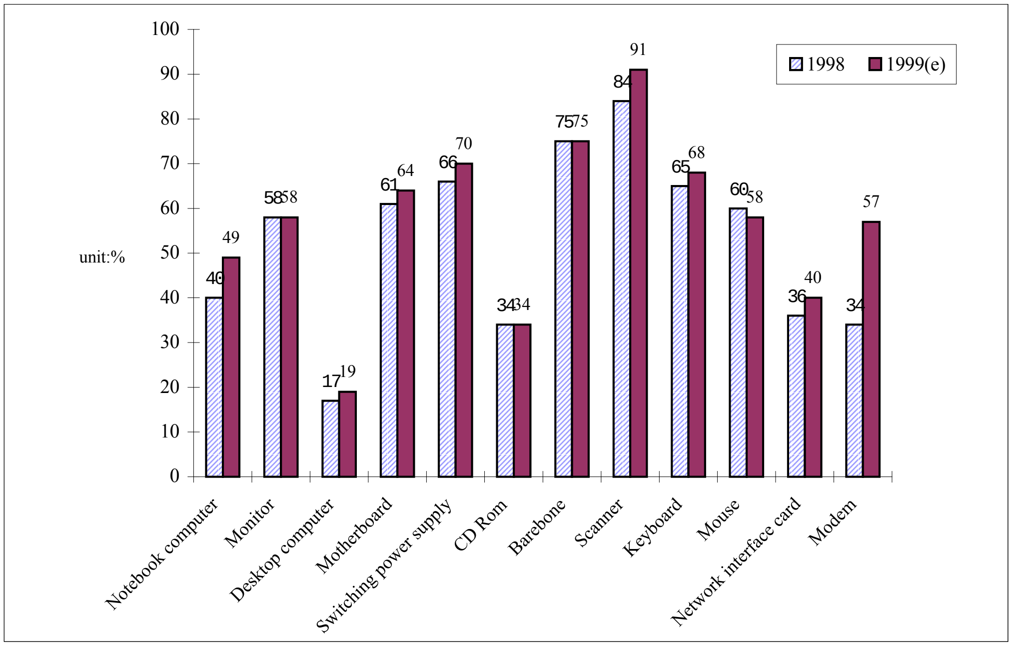
For a manufacturer, the advantage of being large increases with the knowledge content of manufacturing. Knowledge can be thought of as a sunk fixed input. The more costly this knowledge is, the greater the advantage that can be gained from a larger scale of production. Therefore, manufacture of the newly-invented products tends to be more concentrated than the manufacturing of mature products. Thus small firms without the requisite knowledge endowment to engage in the production of innovative products can only participate in mature product markets. But even there, the prospects for small firms remain bleak in a knowledge-based economy because large firms still enjoy economies of scope in applying their superior knowledge.

Small firms, therefore, can only retreat to those niche markets that are immune from the dominance of economies of scale and economies of scope by these large firms. The large firms also enjoy the benefits of globalized production from the common governance of knowledge application in various locations, and from being able to deliver products to consumers at a higher speed than small firms that cannot afford multinational production. Increasingly, speed has become more important than cost in global competition.

IV. The Case of Personal Computers

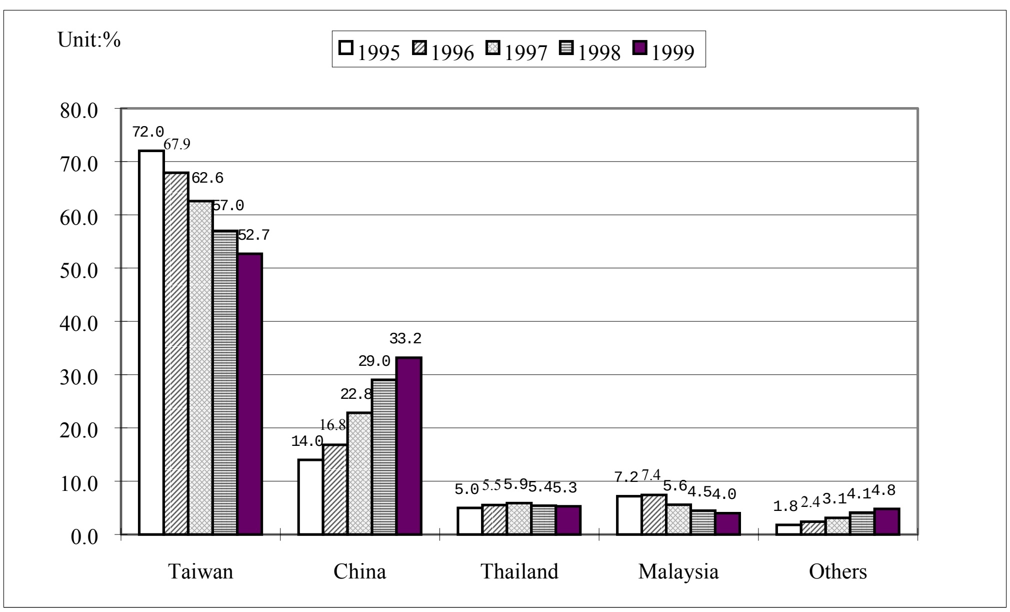
Taiwan is known as one of the major players in the personal computer (PC) industry, and currently ranks third largest producer of PC products worldwide with a substantial number of Taiwanese-made products, such as motherboards, scanners, monitors, and notebook computers, enjoying a significant global market share (see Figure 1).

An important milestone in the development of Taiwan's PC industry has been the outreach of its firms starting from the late 1980s. Their outward investment was initially directed towards Southeast Asia, and more recently towards China and elsewhere in the world. As a result, the offshore production of Taiwan-based PC firms grew from US$973 million in 1992 to US$18.86 billion in 1999, accounting for 47.29 percent of the production by the Taiwan-based firms (Figure 2).



Source: Institute for Information Industry.

Figure 1. Taiwanese Firms' World Market Share in PC-Related Products



Source: MIC, Institute for Information Industry

Figure 2. The locational distribution of IT production by Taiwan-based firms

As the ability to manufacture PCs has been diffused widely throughout the world, price competition has intensified and profit margins have narrowed for most mature computer technologies, with the result that the PC industry has witnessed profound changes in terms of inter-firm competition and manufacturing systems. During this process, PC firms in the US have sought to establish new sources of competitive advantage by accelerating the pace of new technological developments and increasingly using external subcontractors. As a result, whilst components are now sourced from a global network of suppliers, the final assembly of PCs tends to be carried out in each of the major market areas of North America, Europe and Asia (Angel and Engstrom, 1995; Borrus and Borrus, 1997).

More specifically, recent developments have led to the emergence of a variant of global production networks: global logistics (Chen and Liu, 1999). In their efforts to withstand market encroachment by low-cost clone suppliers, brand marketers in the US, led by Compaq, Hewlett Packard, and IBM, now concentrate on R&D and marketing, whilst outsourcing their production and logistics operations, for example, to Taiwan-based firms. In specific terms, Compaq pioneered the so-called optimized distribution model, which, in essence, aims to provide customers with options as to what, when, and how they want, at the lowest available prices. This operational model has three facets. First of all, in order to narrow the gap between supply and demand, production is required to meet orders (build-to-order) rather than forecasts (build-to-forecast). Secondly, in order to meet the variety of customer demands, build-to-order practices are extended to configuration-to-order practices, within which customized products are produced in specific quantities. Thirdly, Compaq's vendors are required to undertake final assembly, bringing together a set of subassemblies both produced and delivered by Compaq's subcontractors. From Compaq's perspective, the new production method enables it to concentrate on its core competencies of R&D and marketing whilst leaving the rest of the value chain to its subcontractors and vendors in Taiwan. Meanwhile, the latter two types of firms have come to resemble members of Compaq's 'virtual business', providing the ammunition for Compaq to compete in the global market.

But what does such a new model of contract manufacturing mean when it comes to the development of Taiwan's PC industry? Underlying the new relationship is the drive to reduce production costs, lead-time to market and inventory costs; it is therefore imperative for the Taiwanese firms to establish international production and logistics networks to serve their customers. For example, by implementing these new production methods, Compaq has completely handed its inventory costs over to its subcontractors. The latter are also required to produce and deliver subsystem products in line with tight schedules, and to meet the demand from a variety of markets. Therefore, they have to ensure that everything is synchronized up and down the supply chain. In order to do so, these subcontractors, such as those based in Taiwan, have had to establish a well-structured, fast-response global production and logistics network by means of foreign direct investment or by the formation of strategic alliances. Furthermore, they may invariably ask their suppliers of components and parts to follow suit in order to link up smoothly, the overall supply chain. As a result, the entire PC production process has increasingly come to resemble a 'just-in-time' system on a global scale, bringing together the cross-national elements of the value chain into a competitively effective production system.

Therefore, the relationship between Taiwanese PC firms and their customers - owners of world-class PC brand names - has gone beyond that of the traditional original equipment manufacturing (OEM) arrangement. Under OEM contracting, Taiwanese PC firms acted merely as providers of finished products to their customers. In contrast, emergent global logistics contracting requires Taiwanese subcontractors to take on much greater responsibility by participating in supply-chain management, global logistics operations, and after-sale services. In addition, both sides of the contractual relationship now have to work closely together and link up electronically in order to create 'across-the-board' competitive advantages in the industry, engendering escalating interdependence between them, and hence, a 'locked-in' relationship. Aided by such relationships, Taiwanese firms are able to broaden the scope of their value chains, integrating upstream to R&D and downstream to distribution and logistics. Moreover, with a global production and logistics network at their disposal that adequately meet the needs of their customers, Taiwan-based PC firms may preempt the entry into the network of their competitors from other countries. In other words, the network relationship serves as an entry barrier. From a Taiwanese perspective, the owners of these world-class PC brands, which are the international core firms of the industry, can be successfully ‘anchored’ to Taiwan’s economy (Chen and Liu, 2000).

Looking back to the evolution of the industry, Taiwanese firms could previously rely on mainly local-firm networks, stretching from Keelung to Hsinchu, in their production of PCs (Kawakami, 1996; Kraemer, 1996). However, under the global logistics system, they now have the ability to mobilize resources from global networks in order to pursue their modes of production. PCs delivered by Taiwan-based firms become the product of the innovative and productive efforts of a variety of players and economies around the world. Admittedly, PC firms in the US remain in the driving seat, but Taiwan-based firms may act as an essential node of the global production network.

As a result of the disintegration of innovation and production, the market for contract manufacturing has now become increasingly concentrated. Table 4 shows the four-firm concentration ratio of some PC-related products in Taiwan’s production.

Table 4 Four-firm concentration ratio of PC-related products

Unit: %

Product	1992	1993	1994	1995	1997
Desktop PC	63.30	62.34	74.17	91.23	81.69
Notebook PC	48.72	41.93	64.06	50.31	61.94
Mouse	69.55	73.58	75.63	84.97	71.04
Motherboard	37.78	42.54	56.02	40.73	44.33
Color monitor	-	44.79	50.81	52.92	45.15

Note: Concentration ratio is measured in terms of quantity produced by top-four firm

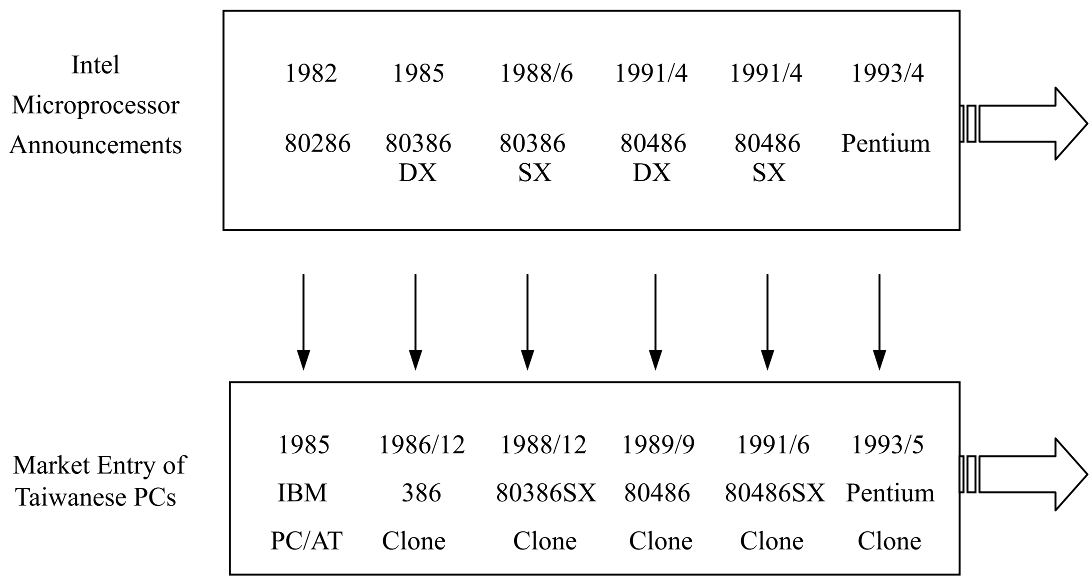
Source: Census of Manufactures, various years, Ministry of Economic Affairs, Taiwan.

In terms of desk-top PCs, for example, the ratio was 63.3% in 1992, but rose to 81.69% in 1997; for notebook computers, the concentration ratio rose from 48.72% in 1992 to 61.94% in 1997, and although there have been some fluctuations, the trend is clear. This concentration ratio, together with Taiwan’s dominant share in the world PC market, indicates a high degree of concentration of worldwide production. Note that the figures presented in Table 4 only count production in Taiwan. Most of these manufacturers also own offshore production facilities and warehouses in order to provide global logistic services to their clients. For example, the world's largest SPS producer, Delta, owns factories in China, Thailand, Mexico and Taiwan, and operates 27 warehouses around the world. For major clients, which include the world's top-10 PC and top-5 cellular phone handset producers, products are shipped from their warehouses to their assembly lines twice a day in a typical 'just in time' fashion.

Taiwanese contract manufacturers are, in fact, not pure contractors; they also engage in product design and share the results with brand-name marketers who perform system integration. Delta, for example, maintains five R&D centers around the globe, and nowadays, they call themselves original design manufacturers (ODMs). Compared to the pure contract manufacturers such as Solectron and SCI of the US, Taiwan's ODMs are more specialized and less globalized. Solectron, for example, produces all kinds of electronic products, ranging from computers, aerospace and medical equipment, to Internet and telecommunications equipment. Selectron possesses production facilities in North and South America, in Europe and in Asia, with 1999 sales revenue of US$8.4 billion (Huang 2000:80-81). Economies of scope are, therefore, more apparent amongst these contract manufacturers.

In addition to R&D, Taiwan's ODM producers have also strived to enhance the value of their manufacturing services by integrating forward into consumer services. For example, Taiwan's largest notebook computer subcontractor, Quanta, has offered a 'Taiwan direct ship' (TDS) service to its customers in a 'build to order' arrangement. With TDS, end consumers can monitor the status of the product that they have ordered through the electronic data interchange (EDI) service provided by the brand-name marketers or sales agents. A customer can follow the progress of the product from 'day 1' to 'day 7', as the production process goes from materials preparation to final assembly. It is estimated that the TDS service has increased the value of Quanta's product (notebook computer) by US$30-50 a piece (Huang, 2000:73-74.).

The evolution of the worldwide personal computer industry was driven by the innovations of Intel and Microsoft. As a leading hardware producing country, Taiwan has needed to maintain an ever-ready capacity to offer new products incorporating Intel's new innovations in advance of its competitors. As Figure 3 shows, this has indeed happened. Back in 1982, it took 3 years for Taiwan's PC industry to offer a new motherboard with Intel's 80286 CPU inside. In 1993, this lag had shrunk to just one month, implying a much closer working relationship with Intel, as well as a stronger technological capability to follow-up from Intel's innovations.



Source: Information Industry Institute, Taiwan.

Figure 3. The Developmental Process of the PC Industry in Taiwan

It should be noted that the close working relationship between Taiwan's hardware producers and Intel did not emerge naturally. In 1995, Intel offered the world's PC makers its own motherboards containing 'genuine' Intel CPUs in an attempt to stretch its market power and intercept Taiwan's motherboard business. Produced by the Intel subsidiary in South America and Solectron's factory in Malaysia, the Intel motherboards sold at a premium over the Taiwanese products. Taiwan's motherboard producers endured the Intel challenge, however, with their superior quality and dominant market share in hardware manufacturing. In 1999, Taiwanese firms were still producing 64% of the world's motherboards, with the rest split amongst Korean, US firms, and others. If pushed into a corner, Taiwanese motherboard producers would have had no choice but to team up with Intel's rivals, such as AMD, in order to stage a counter-attack. In fact, there was talk in 1995 that Taiwan should develop its own CPU to prepare for a showdown with Intel.

In a knowledge-based economy, the business alliance is contingent on the complementarity of knowledge, which can be affected by innovation. Some innovations reinforce existing relationships whilst some loosen them. The rise of the Internet, for example, where internet service providers (ISPs) control the marketing channels, has impacted upon the PC industry with increasing demand for low-priced, simple-function computers. In response to this challenge, the Taiwanese firms, which had excelled in high-value PCs, have had to restructure themselves. In reality, the rise of low-priced PCs has provided a golden opportunity to Korea's PC industry for a comeback war with Taiwan. In 2000, the export of Korean PCs was expected to reach US$6.3 billion, doubling the volume of 1999. However, Taiwan's PC industry was already responding to the challenge with a new production scheme. ACER, Taiwan's largest PC maker, for example, announced that it planned to ship its low-priced PC *en masse* by sea rather than by air (Huang, 2000:72). Whether such a strategy is good enough to sustain Taiwan's dominant position in the world PC production remains to be seen.

V. The Case of the IC Industry

Taiwan's IC industry is currently ranked fourth largest in the world, behind the US, Japan and Korea. Of interest are the differences between Taiwan and these forerunners in a couple of aspects. Unlike Korea, which specializes in the production of dynamic random access memory (DRAM), Taiwan produces a much greater variety of IC chips, and provides IC design houses and IDM firms with foundry services, a strategy which has succeeded in capturing around 70% of the global market share. In addition, Taiwan's IC industry comprises of many small firms, each specializing in a narrow range within the value chain, such as IC design, mask production, foundry service, and packing and testing, in contrast to the dominance of the vertically integrated conglomerates of Korea and Japan. In a sense, Taiwan's IC industry is organized by industrial networks with a strong connection to Silicon Valley, the global technology center.

For one thing, the development of Taiwan's IC industry has been driven by the organizational innovation of creating foundry services as a product. This was a deliberate choice made by local entrepreneurs to avoid the risks associated with the market volatility of DRAM. Whilst there are some brand name producers in Taiwan, foundry services still accounted for 53% of local IC production in 1999. By separating fabrication from other parts of the value chain, the emergence of foundry services in Taiwan has facilitated a proliferation of small- and medium-sized firms in other market segments, such as IC design, testing and packaging. In 1999, there existed in Taiwan 127 firms engaged in IC design; 5 in mask production; 21 in wafer fabrication, 42 in packaging; and 33 in testing. This flock of firms constitutes a balanced and vertically disintegrated industrial structure.

However, despite this vertically disintegrated structure, there is arguably a trend towards 'virtual' vertical integration amongst local firms in a number of ways. Firstly, the domestic sales ratio for Taiwan's IC industry has increased from 39.5% in 1996, to 54.7% in 1999, which is higher than that for all the major countries, such as North America (44.8%), Japan (51.8%) and Europe (43.6%). Secondly, subcontracting relationships tend to be localized. For example, local contracts accounted for 91.2% of the revenues of Taiwan's IC design houses in 1999, as compared to 72.3% in 1998. Likewise, around 98% of the products designed by Taiwan's fablesses were packaged locally in 1999. Thirdly, almost 70% of the ICs designed by local fablesses are for the local information industry, signifying a strong connection between Taiwan's IC and PC sectors.

In essence, the development of Taiwan's IC industry has, to a large extent, come to resemble the scenario of the flexible specialization thesis of Piore and Sable (1984). Fabless IC design houses have proliferated in Taiwan partly because their access to external fabrication capacity has lowered the entry barriers to the market. In addition, the geographical concentration of Taiwan's IC and computer-related firms in the Hsin-Chu Science-based Industrial Park has generated agglomeration effects, allowing these firms to explore the benefits of geographical proximity and outsourcing. Therefore, whilst specializing in one segment of the value chain or another, IC firms in Taiwan are interconnected through social and business networks. Moreover, it is also argued that the

IC industries in Taiwan and Silicon Valley are closely connected. Table 5 presents data on the R&D intensity and capital expenditure intensity of the IC industries in the US, Japan, Korea and Taiwan from 1995 to 1999.

Table 5 IC Industry's R&D intensity[1] and capital expenditure intensity[2] in the US, Japan, Korea and Taiwan

Unit: %

		1995	1996	1997	1998	1999
US	R&D Intensity	9.7	11.6	12.1	13.9	-
	Capital Expenditure Intensity	20.7	22.8	17.5	18.0	14.0
Japan[3]	R&D Intensity	6.6	6.5	6.6	6.5	-
	Capital Expenditure Intensity	16.1	20.8	20.2	18.0	16.0
Korea	R&D Intensity	-	7.9	11.6	12.9	-
	Capital Expenditure Intensity	25.7	40.1	51.0	26.0	26.0
Taiwan	R&D Intensity	7.0	6.9	8.8	9.1	-
	Capital Expenditure Intensity	31.9	63.4	63.4	73.0	68.0

Notes:
1. the ratio of R&D expenditure to sales at percentage.
2. the ratio of capital expenditure to sales at percentage
3. fiscal year

Source: IT IS (1999) and IC Insight (2000).

It is evident that in terms of R&D intensity, the US is the highest among the four largest IC producing countries, whereas, in contrast, Taiwan comes top, whilst the US is ranked fourth, with regard to capital expenditure intensity. This points to an interesting pattern emerging in the international division of labor between the IC industries of Taiwan and the US. On the one hand, Taiwan's strength lies in its foundry services, the development of which requires substantial investment in fabrication capacities. On the other hand, the US IC firms tend to devote themselves to R&D, design and marketing, which is then backed up by their access to Taiwan's foundry capabilities.

This argument seems to be supported by the data in Table 6, which presents details of the geographical distribution of the clients of Taiwanese foundry services over the past five years. In 1988, more than half of Taiwan's foundry capacities served customers in the US, whilst local contractors claimed only about 35% of the capacity. In fact, most of the top ten fablesses in the US were clients of Taiwanese foundry companies.

Table 6   Geographical breakdown of Taiwan's foundry service clients

Unit: %

	Taiwan	North America	Western Europe	Others
1994	30.5	55.1	5.1	9.3
1995	36.6	55.5	4.0	3.9
1996	40.8	42.8	11.7	4.7
1997	47.5	31.2	6.3	15.0
1998	34.9	51.4	7.2	6.5

Source: IT IS (1999)

Considering its customers as its partners, TSMC, the world's largest foundry service provider, shares its resources and information with them. Every year, TSMC regularly makes known to its customers its plan for developing new process technologies over the next five years. The distributed information is useful for their customers to ensure that the process technologies of TSMC can support the development of their products. As a result, the sharing of resources and information not only facilitates the development of a close relationship, but also helps to reduce the uncertainty associated with technological development on both sides.

The connection between Taiwan and the US in the IC industry also takes the form of an intensive interface between the experts in both countries. Underlying this interface are Taiwanese and Chinese expatriates abroad who have played important roles in bridging the gap between overseas social networks and engineers, and Taiwan, and who have proved crucial in connecting the Taiwanese production system with advanced market knowledge and technology (Saxenian, 1997; Kim and Tunzelmann, 1998). According to Saxenian (1997), in the 1990s, one out of three specialists working in Silicon Valley came from overseas. There were also in excess of 1,300 firms (or 17%) re under the directorship of emigrants from Taiwan.

It is worth noting that such industrial networking as exists in Taiwan's IC industry has benefited from recent innovations in information technology, as information technology has reduced the uncertainty and transaction costs of purchasing from outside suppliers. Moreover, technological changes have made feasible small production runs and frequent changes of models, providing more room for small and specialized firms to work in fragmented markets with a flexible response capability.

The innovation-driven semiconductor industry is a classical showcase of the split between innovation and production. In the age of 6-inch wafer processing, foundry service providers accounted for only 6% of worldwide IC production. In the age of 8-inch wafer processing, foundry service providers accounted for 14% of worldwide production. Many analysts now predict that in the upcoming age of 12-inch wafer processing, foundry service providers will account for 30% to 50% of global output (Huang 2000:37). In the past, foundry-service firms produced mainly logic ICs, in which economies of scope could be realized through pooling a large variety of designs together, and using similar processing technologies. Increasingly, memory ICs, particularly DRAM, have entered the foundry service market. In Japan, for example, Mitsubishi, Fujitsu and Toshiba have all become major subscribers to Taiwan's foundry services for DRAM manufacturing.

The increased speed of innovation has shortened the product life cycle of IC chips, making economies of scale an increasingly important factor in market competition. It is well known in the IC industry that a new 12-inch wafer processing facility will cost around US$2.5 billion to establish, and there is no telling how long this particular generation of technology will survive the new innovations. Only those who are able to amass a large volume of production can afford the risk of such a big-ticket investment. Therefore, only the largest DRAM producers like Micron, Samsung, NEC and Hyundai will build their own fabs. The rest have to outsource from foundry service providers who pool a number of small producers together to reach the minimum efficient scale.

Driven by rapid innovation, and shortening product life cycles, the IC industry is characterized by high rates of capital expenditure as equipment rapidly becomes obsolete. As Table 5 demonstrated, Taiwan's IC industry exhibits the highest capital expenditure ratio amongst the major semiconductor nations. This is partly because Taiwan had the lowest base of IC output and partly because Taiwan is specialized in foundry services, the most capital-intensive segment of IC production. Between 1996 and 1999, capital expenditure in Taiwan's IC industry exceeded 60% in each year. This was possible only because the operation of foundry service was very profitable and, at the same time, the capital market favored growth-oriented companies. The former implies high entry barriers to the market as knowledge applied in foundry operations takes time to be learned and accumulated, as the major competitor to Taiwan's foundry service industry - Singapore's Chartered Semiconductor - found to its cost; it took until 1999 before it was able to report a profit, after several years of losses.

Despite their large size and dominant position in foundry services, Taiwan's two leading foundry service providers have never attempted vertical integration. United Microelectronics (UM) had spun off its IC design operations before it entered the foundry service market, and neither UM nor TSMC attempted to enter the field of IC assembly or testing. As innovation has become increasingly globalized, and knowledge has spread around the globe, so the increasing need is for knowledge integration. The emergence of the 'system on a chip' (SOC) in the IC industry is a response to this call. SOC integrates several single chips, which contain distinctive intellectual properties (IP), to perform systemized functions, such as those used in cameras or computers. Knowledge integration differs from knowledge creation, and it spawns different kinds of organizations.

The increased complexity of SOC designs has induced the modularization of various design technologies, called silicon intellectual property (SIP), which can be repetitively used as a building block to SOC. Most SIPs are owned by the fablesses. The foundry service provider is a natural place to verify the value and fabricability of SIPs. Taiwan's TSMC, for example, has offered a free library and verification service of SIPs for its clients. The emergence of SOC has also given rise to 'chipless' IC firms, which do business without a fab and without owning a chip. The 'chiplesses' only provide IC designs that incorporate various intellectual properties, services that are valuable because they provide an array of SIPs, saving transaction costs for their clients in dealing with individual owners. Taiwan's largest SOC firm, VIA has bought the CPU design departments of Cyrix and IDT and turned them into 'chipless' units (*Commonwealth*, May 25, 2000:132-133).

VI. Conclusions

The knowledge-based economy has presented several challenges to Taiwan's economy that had traditionally stressed manufacturing capability and de-emphasized service and R&D. Firstly, both producer and consumer services have become important factors of international competition. Producer services in the form of shipping, warehousing and telecommunication are crucial components of time-based competition. The costs of handling and shipping can determine the competitiveness of manufacturers, whilst telecommunication services and other electronics-based information exchange mechanisms are important tools in every facet of the organization of production, such as supply chain management. The ability to service consumers also enters the center stage of competition. Providing better services to customers is an effective way of enhancing the value of their products, even for specialized manufacturers such as those in Taiwan. Nevertheless, Taiwan lags far behind advanced countries in the service industry.

Secondly, in order to be a world-class competitor, a manufacturer needs to build the capacity to offer products and services around the globe. This means that globalized production is a prerequisite to worldwide competition. Being hampered by size constraints, and its lack of managerial resources to run truly global operations, Taiwanese firms have only a limited capacity for internationalization. They have, however, sought to enhance their capabilities in other areas, notably in R&D, to offset their weaknesses in terms of internationalization. The competition between Taiwan's ODM producers and other contract manufacturers will intensify in the future as the market for manufacturing services becomes increasingly concentrated, where only the largest will survive. It is envisaged that Taiwan's ODM producers will remain highly specialized in product lines, but that their knowledge base will have to be elevated. Their ability to process and combine knowledge from various origins also needs to be strengthened.

Thirdly, Taiwan's industry has been particularly good at knowledge application, but not at knowledge creation. Until now, Taiwan has depended on a social network between its specialists and those within the innovation centers to fetch and diffuse the technology. It will become increasingly difficult for such a mechanism to function because knowledge will be guarded more and more intensely in the future. As knowledge becomes more dispersed and more disintegrated, it is important for firms to own some knowledge of their own in order to trade or share it with others. Knowledge creation is an important leverage for acquiring knowledge. Taiwan currently spends only around 1.8% of its GDP on R&D, much lower than the expenditure of the advanced countries. Worse still, the major source of R&D is contributed by the public sector, rather than the private sector. Clearly, more R&D is called for from the private sector if Taiwan is to remain competitive in the new knowledge-based economy.

References

Atkins, R., (2000), 'New Measures for the New Economy', paper presented at the Conference on the Measurement of Industrial Technological Competitiveness in the Knowledge-based Economy, Taipei, August 23-24.

Angel, D.P. and J. Engstrom, (1995), 'Manufacturing systems and technology change: The US personal computer industry', *Economic Geography*, Vol.71, No.1, pp.79-102.

Antonelli, C., (1998), 'Localized technological change, new information technology and the knowledge-based economy: The European evidence', *Evolutionary Economics.*

Borrus, M. and Z. Borrus, (1997), 'Globalization with borders: The rise of Wintelism and the future of global competition', *Industry and Innovation*, Vol.4, No.2, pp.141-66.

Cantwell, J. and G.D. Santangelo, (1999), 'The frontier of international technology networks: Sourcing abroad the most highly tacit capabilities', *Information Economics and Policy*, Vol.11, pp.101-123.

Chen, S.H. and D.N. Liu, (1999), *Strategic Alliances in the Context of Competition Policy*, final report to Industrial Development Bureau, Chung-Hua Institution for Economic Research: Taipei. (in Chinese).

Chen, S.H. and D.N. Liu, (2000), 'Taiwan's active role in the global production network', in P. Chow and B. Gill (eds.), *Weathering the Storm: Taiwan, Its Neighbors, and the Asian Financial Crisis*, Brookings Institution Press: Washington D.C.

Cohen, W.M. and D. Levinthal, (1989), 'Innovation and learning: The two faces of R&D', *Economic Journal*, Vol.99, pp.569-596.

David, P.A., (1993), 'Intellectual property institutions and the panda's thumb', in *Global Dimensions of Intellectual Property Rights in Science and Technology*, National Academy Press: Washington D.C.

Delapierre, M. and L.K. Mytelka, (1998), 'Blurring boundaries: New inter-firm relationships and the emergence of networked knowledge-based oligopolies', in M.G. Colombo (ed.), *The Changing Boundaries of the Firm: Explaining Evolving Inter-Firm Relations*, Routledge: London and New York.

ERSO (2000), *Almanac of the Semiconductor Industry in Taiwan*, Industrial Technology Research Institute: Hsin-Chu.

Etzkowitz, H., A. Webster, C. Gebhardt, and B. Terra, (2000), 'The future of the university and the university of the future: Evolution of ivory towert to entrepreneurial paradigm', *Research Policy*, Vol.29, pp.313-330.

Freeman, C. and C. Perez, (1988), 'Structural crises of adjustment, business cycles and investment behavior', in G. Dosi *et al*., (eds.), *Technical Change and Economic Theory*, Pinter: London.

Hakansson, H., (1987), *Industrial Technological Development: A Network Approach*, Croom Helm: London.

Hauknes, J. (1998), *Services in Innovation - Innovation in Services*, SI4S Synthesis Paper, STEP Group: Oslo.

Huang, Chin-yung, (2000), *E-Economy*, Taipei: China Times publication.

Institute for Information Industry, (2000), *The Upgrading of Taiwan's Information Strength*, final report to the Council for Economic Development and Planning, Institute for Information Industry: Taipei.

Jovanovic, B. and R. Rob, (1989), 'The growth and diffusion of knowledge', *Review of Economic Studies*, Vol.56, No.4, pp.569-82.

Kawakami, M. (1996), *Development of the Small- and Medium-sized Manufacturers in Taiwan's PC Industry*, CIER discussion Paper Series 9606, Chung-Hua Institution for Economic Research: Taipei.

Kim, S. and N. Tunzelmann, (1998), *Aligning Internal and External Networks: Taiwan's Specialization in IT*, SPRU, University of Sussex: Brighton.

Kraemer, K.L., J. Dedrick, *et al.,* (1996), 'Entrepreneurship, flexibility, and policy coordination: Taiwan's Computer Industry', *The Information Society*, Vol.12, pp.215-49.

Michalet, C., (1991), 'Strategic partnerships and the changing internationalization process', in L.K. Mytelka (ed.), *Strategic Partnerships: States, Firms and International Competition*, Pinter: London.

Nelson, R. and S. Winter, (1982), *An Evolutionary Theory of Economic Change*, Cambridge: Harvard University Press.

OECD, (1996), *The Knowledge-Based Economy'*, Organization for Economic Cooperation and Development: Paris.

OECD, (2000), *Is There a New Economy?*, first report to the OECD Growth Project, Organization for Economic Cooperation and Development: Paris.

Quinn, J.B., (1988), 'Technology in services: Past myths and future challenges', in Guile, B. and J.B. Quinn (ed.), *Technology in Services: Policies for Growth, Trade and Employment*, National Academy Press: Washington D.C..

Piore, M. and C. Sable, (1984), *The Second Industrial Divide*, Basic Books: New York.

Rauch, J.E., (1999), 'Networks versus markets in international trade,' *Journal of International Economics*, Vol.48, pp 7-35.

Romer, P., (1986), 'Increasing returns and long-run growth', *Journal of Political Economy*, Vol.94, No.5, pp.1102-1037.

Saxenian, A., (1994), *Regional Advantage*, Harvard University Press: Cambridge, Massachusetts and London.

Saxenian, A., (1997), 'Transactional entrepreneurs and regional industrialization: The Silicon Valley-Hsinchu connection,' Paper presented at the Conference on Social Structure and Social Change: International Perspective on Business Firms and Economic Life, Academia Sinica, Taipei, Taiwan.

Schumpeter, J. A., (1942), *Capitalism, Socialism and Democracy*, Harper and Brothers: New York.

Senker, J. and W. Faulkner, (1993), 'Networks, tacit knowledge and innovation', paper presented at the Second International Conference on Advances in Sociological and Economic Analysis of Technology, April, UMIST: Manchester.

Sigurdson, J., (1990), 'The internationalization of R&D-An interpretation of forces and responses', in J. Sigurdson (ed.), *Measuring the Dynamics of Technological Change*, Pinter: London.

Windrum, P., (1999), *The MERIT Report on Innovation Networks in E-commerce*, prepared for SEIN Workpackage 4, EU TSER Programme.

Wise, R. and P. Baumgartner, (1999), 'Going downstream: The new profit imperative in manufacturing', *Harvard Business Review*, September-October, pp.133-141.

Wu, Rong-I, (2000), 'Competitiveness Analysis of Taiwan's Industrial Technology', paper presented at the Conference on the Measurement of Industrial Technology Competitiveness in the Knowledge-Based Economy, Taipei, August 23-24.

Powell, W.W., K.W. Kogut and L. Smith-Doerr, (1996), 'Inter-organizational Collaboration and the Locus of Innovation: Networks of learning in biotechnology', *Administrative Science Quarterly*, 41, pp.116-145.

Sturgeon, T., (2000), 'Turn-Key Production Networks: A New American model of Industrial Organization', Industrial Performance Center, MIT, working paper.

OECD, (1997), *Internationalization of Industrial R&D: Patterns and Trends*, Paris: OECD.

Zender, I, (1999), 'Where to the multinational? The Evolution of Technological Capabilities in the Multinational Network', *International Business Review*, 8, pp.261-291.