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WHAT PERMITS SMALL FIRMS TO COMPETE IN GLOBALIZED HIGH-TECH INDUSTRIES?
The Co-evolution of Domestic and International Knowledge Linkages in Taiwan´s Computer Industry

by Dieter Ernst

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A PUZZLE

This paper addresses a *puzzle* related to *firm size* and *competition*. There is a broad consensus that only large, diversified multinational enterprises can compete in industries that combine high knowledge-intensity and a high degree of internationalization[1]. Small firms, by definition, have limited resources and capabilities and are unlikely to possess substantial ownership advantages. They are obviously constrained in their capacity for knowledge creation. They also have a limited capacity to influence pricing and shape the development of markets, market structure, and technological change. One would thus expect that small firms are ill-equipped to compete in the knowledge-intensive and highly globalized computer industry[2].

The disadvantages of small size for firms are compounded if they come, like in the case of Taiwan, from a small country. Small nations are confronted with a *vicious circle of size-related disadvantages*[3]: i) The small domestic market places tight restrictions on the ability to function as a buffer against heavy fluctuations in international demand. ii) It constrains the development of sophisticated "lead users"[4] that could stimulate innovation. iii) It also limits the scope for technological spill-overs[5]. And iv) the limited size of the national knowledge and capital base restricts the choice of industries in which such small nations might successfully specialize.

It would thus seem self-evident that small firms from a small country would not be competitive in the computer industry. Taiwan's experience however tells a different story: SMEs have been the main carriers of its rapid development. Despite the dominance of SMEs, Taiwan today has the most broadly based computer industry in Asia outside of Japan; it also has been less affected than other countries by the Asian financial crisis (Aw,

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[1] For concise statements of this consensus position, see Hymer, 1960/1976, Caves, 1982; the last chapter in Chandler, 1990, and Dunning, 1993.

[2] The impact of knowledge intensity and globalization on firm organization and competitive dynamics in the electronics industry is analyzed in Richardson, 1997; Bresnahan and Malerba, 1997; Langlois and Steinmueller, 1997; and Ernst 1997 b and 1997d. For an early analysis, see Ernst, 1983; and Ernst and O`Connor, 1992.

[3] Important contributions are Walsh, 1987; Freeman and Lundvall (eds.), 1988; and Maskell, 1996a.

[4] Von Hippel defines "lead users of a novel or enhanced product, process, or service" as those that "...face needs that will be general in the market place, but...(who) face them months or years before the bulk of that marketplace encounters them..." and who will "... benefit significantly by obtaining a solution to those needs." (Von Hippel, 1988, p.107)

[5] Technological spill-overs are assumed to be mainly domestically generated by innovation theorists (Lundvall, 1992 and Nelson, 1992) as well as by "new growth" theorists (Grossman and Helpman, 1991 and 1993). If this is so, then large countries will benefit more from an investment in R&D than smaller countries, where some of the spill-overs of R&D are likely to benefit its trading partners. (Zander and Kogut, 1995)

Chung and Roberts, 1998)[6]. Taiwanese computer firms, almost without exception, have started out small and from very humble origins; while many of them failed, a significant number was able to grow and to establish themselves as world-class suppliers for a variety of computer-related products, key components and knowledge-intensive services. The dominance of small firms has obviously not prevented this country from becoming a successful competitor in an industry that requires a broad range of fairly demanding technological and organizational capabilities.

This paper asks how this was possible and provides some explanations for this puzzle. I show how government policies facilitated the initial market entry of small firms[7]. Of equal importance however are *innovations* in *firm organization* related to the *creation of knowledge*. This is in line with the evolutionary, resource-based theory of the firm[8], and especially Nonaka´s and Takeuchi´s seminal book on "The Knowledge-Creating Company" (1995). My argument however differs in one important aspect: Nonaka and Takeuchi have focused primarily on *intra*-firm knowledge creation. A novel contribution of this paper is its focus on *inter-organizational knowledge creation, i.e. knowledge created through linkages with other firms and organizations.* A second important contribution of this paper is that it moves the analysis beyond the boundaries of a region or a nation state and that it highlights the importance of *international knowledge linkages*.

The *co-evolution of domestic and international knowledge linkages* has been a major factor of Taiwan´s success: a continuous upgrading of *international* knowledge linkages was predicated on the development of a dense and flexible network of *domestic* knowledge linkages; the latter in turn has substantially benefited from knowledge creation through increasingly sophisticated international linkages. The paper tells the story of this co-evolving upgrading of domestic and international knowledge linkages and shows how this has helped small firms to overcome some of their size-related disadvantages. An especially important feature is the *diversity* of such linkages: both the SMEs and the government have pursued many different approaches in parallel, rather than concentrating exclusively on one particular linkage. Common to all of these different arrangements is that they are attempts to *complement the speed and flexibility of smaller firms with the advantages of scale and scope that normally only large firms can reap.*

Part I introduces the *conceptual framework*. I then describe Taiwan´s *achievements* in the computer industry (part II). The *dominance* of SMEs and their role as a *source of flexibility* is documented in part III. Part IV describes some *policy innovations* that have enabled small Taiwanese firms to get onto the virtuous circle of co-evolving domestic and international knowledge creation linkages. The rest of the paper (V-VII) inquires *how inter-organizational knowledge creation has benefited from a variety of linkages with large domestic and foreign firms*; I also address some *industrial upgrading requirements* that result from this peculiar type of knowledge creation.

I. A CONCEPTUAL FRAMEWORK

[6] For an analysis of how the Asian financial is currently reshaping the Asian electronics industry, see Ernst, 1998a

[7] Industrial development policies on their own, however, are insufficient to explain Taiwan's success. This is where I differ from Robert Wade´s otherwise extremely stimulating analysis (Wade, 1990

[8] See Penrose 1959/1995; Richardson 1960/1990; Richardson, 1996; Nelson and Winter, 1982; Kogut and Zander, 1993; Langlois and Robertson, 1995; and Foss and Knudsen, 1996; Spender, 1998

Adjusting the research agenda

A basic assumption of this paper is that the theory of the firm can make an important contribution to theories of growth and innovation. In order to do so, it needs to acknowledge that *firm size matters*, and that small firms face very different opportunities and challenges than large multi-divisional and multi-national corporations. Most research on firm growth and innovation has focused on the latter. It needs to be complemented by research that asks: What permits small firms to overcome their size-related disadvantages? And can they tap into the knowledge base of other firms and organizations?

An internalist bias

This brings us to a second important weakness of the theory of the firm: a neglect of the role of *external* determinants of firm behavior, especially with regard to knowledge creation. Coombs and Metcalfe (1998) talk about an *internalist bias*: capability-based theories of the firm have focused primarily on the *internal* accumulation of knowledge and skills which underpins its productive activity[9]. Edith Penrose´s observation that "... a firm´s rate of growth is limited by the growth of knowledge within it." (Foreword, 3d edition, "The Theory of the Growth of the Firm", pages XVI and XVII) has drastically changed our perceptions of how firms develop and compete. Yet, knowledge creation within the firm requires interaction with other firms and organizations.

The neglect of research on external determinants of firm behavior is quite surprising. There is a long tradition in economic theory to argue that *firm growth is shaped by industry structure*. This goes back to Adam Smith´s theory of economic progress through the division of labour, and Alfred Marshall´s theory of internal and external economies. In the same tradition, Allyn Young (1928) concludes that increasing return is the source of economic progress, which cannot be analyzed only at the level of the firm. Probably the most powerful source for such a perception is Richardson´s important article, published in 1972, which traces firm growth in the context of the evolving organization of industry (Richardson, 1972).

It seems that the conditions are now ripe for a *re-discovery* of these ideas. Authors like Fransman (1998), Eliasson (1998), Geroski (1998), de Bandt (1998), and Malerba (1998) remind us that *industry-specific features* matter and that industry evolution shapes options for firm growth. Eliasson (1998, p.9) for instance argues that an understanding of the firm requires an understanding of the markets and industry structure in which it operates And Paul Geroski, in an extremely stimulating recent paper argues that, in order to explain why "firm size follows a random walk", we need to broaden the research agenda to include "exogenous factors like technical change and market developments" (Geroski, 1998, pages 4 and 20). Lundvall (1998, pages 2 and 3) nicely summarizes the challenge: "The units of analysis of industrial dynamics are open systems. ... (I)ndustrial dynamics is not linked to one specific level of aggregation in terms of micro-, meso- and macro-analysis… but represents a specific perspective on the firm as an open system that is affected by and affects wider systems."

[9] Ironically, this internalist bias is probably one of the few things that capability-based theories of the firm share with the more traditional proponents of the economics of organization. Take transaction cost economics. Williamson (1998) himself acknowledges that it is necessary to push the analysis "…beyond the generic level at which it now operates" (p. 15) to consider "… the strengths and weaknesses of a particular firm in relation to its rivals" (p.29), peculiar characteristics of market niches and the overall "strategic situation" (table 1).

Inter-organizational linkages

One way to overcome this *internalist* bias is to ask how firms organize *inter-organizational linkages*, especially with regard to knowledge creation [10]. This is in line with population level learning theory (Miner and Haunschild, 1995) which shows that organizational learning depends in important ways on the interaction of organizations, as opposed to feedback from trial and error events inside the organization. There is an emerging consensus that a knowledge-based theory of the firm needs to include interactions with other firms and organizations.

Spender (1998) sketches a theory in which social knowledge (both explicit and tacit) as well as localized clusters ("geography") matter. Based on a simple *taxonomy* that distinguishes *individual* and *social,* as well as *explicit* and *tacit knowledge*, Spender (ibid., p.433) demonstrates that "… each type of knowledge can, in principle, be associated with a different kind of rent and competitive advantage." Tacit social knowledge (which Spender calls *collective*) is of critical importance: "The collective knowledge which develops as key players interact under conditions of uncertainty leads to Penrose rents, so labeled because such activity-based learning lies at the core of her theory of the growth of the firm.

Lundvall (1988, 1992 and 1998) highlights the interactive nature of innovation and documents how user-producer interaction and other forms of inter-firm cooperation give rise to a national system of innovation. And **Antonelli (199X**) **as well as Coombs and Metcalfe (1998)** have convincingly argued that competitive success depends on a firm´s ability to manage *inter-organizational knowledge creation*: "The creation of new capabilities is increasingly taking place through the *combination of the capabilities of several firms and research organizations*. " (**Coombs and Metcalfe, 1998,** p.3) *Cross-organizational coordination of capability formation* thus becomes of critical importance.

Agglomeration and clustering effects

The debate on inter-organizational cooperation has focused on agglomeration and clustering effects that result in localized inter-firm networks (Scott, 1995; Storper, 1995; and Guerrieri et al, 1998). Alfred Marshall´s pioneering concept of *externalities* (1890/1916,p.271) helps to identify both static and dynamic economies of agglomeration. Marshall emphasizes three advantages of an *industrial district*: i) it provides a pool of skilled workers with industry-specific capabilities; ii) intermediate inputs, especially on-tradable ones, are provided by local suppliers; and iii) there is a continuous, intense and rapid exchange of new ideas about technical, organizational and production improvements. In Marshall´s view, the latter is clearly the decisive advantage: "…(P)eople following the same skilled trade get ….(substantial advantages)..from near neighbourhood to one another. The mysteries of the trade become no mysteries; but are as it were in the air, and children learn many of them unconsciously. Good work is rightly appreciated, inventions and improvements in machinery, in processes and the general organization of the business have their merits *promptly* (DE) discussed: if one man starts a new idea, it is taken up by others and combined with suggestions of their own; and thus it becomes the source of new ideas." (ibid.).

Much of the literature on industrial districts and social networks has focused on an analysis of micro-interactions *within* a particular localized cluster. It has shown that

[10] Another possible research agenda, not discussed here, is to *link firm behavior and industry structure* (Ernst, 1998, INTECH)

the growth of a firm depends on the environment in which it operates, which explains the importance of proximity (Malmberg, Sølvell and Zander, 1996). Agglomeration theory has traditionally focused on manufacturing. It has been argued however that clustering effects are particularly important for *knowledge externalities* and *spill-overs* (Lundvall, 1988; Porter, 1990; and Porter and Sølvell, 1998). Concentrations of companies succeed when they cooperate as well as compete; the focus of cooperation is on the sharing of knowledge, skills and technologies among the companies and with public agencies.

The impact of globalization and information technology

These are important considerations. The case of Taiwan however shows that we need to open up the debate to move beyond such endogenous factors. We need to address explicitly the impact of globalization and of new information and communication technology (ICT). Local clusters can no longer exist in isolation: they are rapidly becoming internationalized, either through acquisitions or through the increasing power of global production networks (**Ernst, 1997 b, Sloan)**. They are also prone to the challenge of *ubiquification*, a term coined by Peter Maskell (Maskell 1996b) in order to describe the erosion of existing knowledge clusters through information technology and globalization. This implies that a localized cluster should no longer be conceived as a *closed* system. Instead, localized clusters are *open* systems that depend on *external linkages* to import key inputs (intermediates; knowledge; finance) and to export outputs (either directly or through OEM arrangements).

Drivers of globalization - a stylized model

Globalization stands for the rapid increase in transnational flows of trade and factors of production which has led to a growing inter-penetration of national economies. This has drastically changed firm behavior (Ernst, 1997, Sloan Foundation). Various factors determine a firm´s exposure to globalization. A progressive liberalization and deregulation of international trade and factor markets, especially related to finance, has acted as a powerful catalyst. Of primary importance however has been the incessant search for *market expansion*. This reflects a basic dilemma of capitalism: a persistent tendency for production capacity to overshoot demand. Rapid capacity expansion and constant productivity improvements are its two most important defining characteristics. Yet there is no guarantee that demand growth will keep pace - Say´s law only applies under very restrictive conditions that are unlikely to occur in the real world[11]. Many sectors of the electronics industry for instance periodically face a vicious circle of surplus capacity, price wars, and profit squeeze[12]. Market forces cannot correct this basic imbalance. This task falls upon corporate strategy, whose main concern is to manage supply so that it matches demand, and to maintain profitability.

[11] Krugman´s claim to the contrary is not convincing. Neo-classical economists claim that *general* overproduction is impossible: "…all of the increased production in the world has as a necessary counterpart increased income -every dollar of sales must also represent a dollar of wages or profits to somebody. And there are only two things you can do with income: save it or spend it." (Krugman, Greider, p.1). The conclusion drawn is that, short of a global excess of savings compared to investment opportunities, global oversupply is logically impossible. Such a conclusion is consistent with the basic assumptions of the *maximization-and-equilibrium* paradigm. Yet, it fails to address the existence of persistent overproduction in specific industries and markets, which, as George B. Richardson (1998) has convincingly demonstrated, explains why *concurrent coordination* is the basic rationale for the existence of the firm.

[12] For a basic model of periodic overproduction in the semiconductor industry, see Ernst, 1983, chapter 1.

This is where *technology* enters the picture, especially changes in transportation, information and communication technology that have substantially reduced *proximity* constraints both with regard to markets and production: a firm can now serve distant markets equally well than local producers; simultaneously it can now disperse its value chain across national borders, in order to select the most cost-effective location. This has drastically expanded the *scope of competition*. Competition now cuts across national borders: a firm´s position in one country is no longer independent from its position in other countries; it must be present in all major growth markets. Furthermore, competition is no longer restricted to very large European, American and Japanese firms: new firms from countries like Korea and Taiwan have entered the game that differ substantially in their approaches to competitive strategy. Finally, competition now also cuts across sector boundaries and market segments: mutual raiding of established market segment fiefdoms has become the norm, making it more difficult for firms to identify market niches and to grow with them.

This has forced firms to engage in complex strategic games to pre-empt a competitor`s move. Intense price competition needs to be combined with product differentiation, in a situation where continuous price wars erode profit margins. Of critical importance however is speed-to-market: getting the right product to the highest volume segment of the market right on time can provide huge profits. Being late is a disaster which quite frequently may force a company out of business (Richardson, 1996; and Langlois and Steinmueller, 1997).

The result has been an increasing uncertainty and volatility, and a destabilization of established market leadership positions. The most important prerequisite for competitive survival now is *flexibility*, i.e. a capacity to adjust strategy and organization at short notice to often unexpected changes in markets, technology and competitors` strategies. As a result, competition today centers around a firm´s ability to build capabilities quicker and at less cost than its competitors (Kogut and Zander, 1993; and Anderson, 1997). No firm, not even a dominant market leader, can generate all the different capabilities internally that are necessary to cope with the requirements of global competition. Competitive success thus critically depends on a capacity to selectively source specialized capabilities *outside* the firm that can range from simple contract assembly to quite sophisticated design capabilities. This requires *a shift from individual to increasingly collective forms of organization*, "... from the legal entity known as the firm to the contractual network of firms tied together by mutual long-term interest." (Stopford, 1995, p.21).

Global production networks

This has culminated in the spread of *global production networks* (GPN) [13], an organizational innovation that enables a firm to *gain quick access to lower-cost foreign*

[13] The concept of an global production network (GPN) is an attempt to capture the spread of broader and more systemic forms of international production that cut across different stages of the value chain and that may or may not involve equity ownership. Such networks constitute an important organizational innovation that enable multinational corporations to cope with the conflicting requirements of specialization and coordination. The concept allows us to analyze the globalization strategies of a particular firm with regard to the following four questions: 1) Where does a firm locate which stages of the value chain? 2)To what degree does a firm rely on outsourcing? What is the importance of inter-firm production networks relative to the firm's internal production network? 3) To what degree is the control over these transactions exercised in a centralized or in a decentralized manner? And 4) how do these different elements of the IPN hang together? This concept has been developed in studies prepared for the

capabilities that are complementary to its own competencies (Ernst, 1999). A multinational firm breaks down the value chain into a variety of discrete functions and locates them wherever they can be carried out most effectively, where they improve the firm's access to resources and capabilities, and where they are needed to facilitate the penetration of important growth markets. As a result of this organizational innovation, multinationals have considerably improved their capacity to source for a variety of specialized external capabilities, wherever they are located. Leading multinationals construct GPN, in order to gain quick access to lower-cost external capabilities that are complementary to their own competencies. In order to mobilize and harness these external capabilities, multinationals are forced to broaden their capability transfer to individual nodes of their GPN.

Impact on knowledge creation

The result is a *dispersion of capabilities across firm boundaries and national borders*. This poses new challenges but also opens new opportunities for inter-organizational knowledge creation. GPN create new entry possibilities for small specialized suppliers in developing countries. The key issue is how to readjust localized clusters so that they can reap the benefits of participating in GPN. While in some cases (like for instance "screw-driver" contract assembly), such entry may be short-lived, this is not necessarily so. Outsourcing requirements have become more demanding and have moved up to include a variety of high-end support services, such as engineering, product design, and research and development.

This has two important implications: First, it increases the length of a firm's value chain, as well as its logistical complexity. This creates new gaps and interstices that can be addressed by small, specialized suppliers. Over time, they may be able to upgrade their position from simple contract manufacturers to providers of integrated service packages, and hence increase the benefits that they can reap from network participation. Second, this has also led to a creeping migration of knowledge-intensive, higher value-added support activities to individual network nodes, including engineering, product and process development and supply chain coordination[14]. Overseas production frequently occurs soon after the launching of new products: key design information now needs to be shared more freely between the parent company and its overseas affiliates and suppliers. Speed-to-market is only guaranteed if engineers across the different nodes of an GPN are plugged into the lead company´s design debates (both on-line and face-to-face) on a regular basis.

As a result, multinational corporations now have a vested interest in the formation of regional clusters of specialized capabilities that are located within or in close proximity to the main growth markets. Globalization typically has led to the development of regionally integrated GPN in North America, Europe, Japan, East Asia (China, South Korea and Taiwan) and Southeast Asia (the ASEAN region) (Ernst, 1997 a, Brookings; and 1997b, Sloan). Undoubtedly, the stakes have been raised for local capability formation and regions now have to compete for investment on a global scale with other

OECD (Ernst, 1994b), the Sloan Foundation (Ernst, 1997b); and the Brookings Institution 1997 (Ernst, 1997a).

[14] This matches Hakansson`s observation (1990, p.260 ff) that in "... foreign manufacturing units...there is an almost irresistible creepage from production engineering upstream into design and development." That knowledge migrates with manufacturing is also well documented in research on East Asia: see Ernst and O´Connor, 1989, Wong Poh Kam, 1991, and Ernst, Ganiatsos and Mytelka, 1997

regions. Those regions that cannot provide such capabilities, are left out of the circuit of international production. Once however a region has developed a critical mass of specialized capabilities, this is likely to lead to a *virtuous* circle: participation in GPN can now help the regional cluster to establish the missing links to a variety of complementary assets.

All of this clearly implies that the link between GPN and local capabilities is a critical issue for industrial upgrading debates. In order to address this research agenda, we need a solid theoretical foundation that is derived from three strands of theoretical debates: industrial organization and the evolutionary theory of the firm; innovation theory; and international investment and management studies. For a long time, these debates have co-existed in isolation, with very limited interaction. Bringing them together can help to create a robust theoretical framework for explaining how globalization reshapes the dynamics of firm organization, and how this affects the growth of SMEs.

Key elements of the conceptual framework

Let me briefly summarize the main features or our conceptual framework: Inter-organizational cooperation is an important complement to intra-firm knowledge creation. Firm size matters and shapes the agenda for knowledge creation. For small firms, inter-organizational knowledge cooperation can help to compensate for size-related disadvantages. Globalization enhances the dispersion (migration) of knowledge across firm boundaries and national borders. Potentially this opens up new opportunities for international knowledge linkages.

The paper also emphasizes that benefits from international linkages do not come automatically. Industrial policies matter: they can improve the chances for small firms to benefit from international knowledge linkages. Of equal importance are a variety of *domestic linkages* that have fostered inter-organizational knowledge creation. Local capability formation is defined as "learning and knowledge creation *within* the domestic economy, by both national and foreign actors". Two additional remarks need to added concerning *organizational diversity* and *industry-specific features*. A great variety of approaches is the key to successful inter-organizational knowledge creation. Empirical research has clearly established that firms differ in how they approach both internal and inter-organizational knowledge creation. This raises questions like the following formulated by Keith Pavitt (1998): *What organizational processes are conducive for coping with challenges and opportunities that result from unexpected changes in technology and markets? Why do firms differ in their approaches to organization? And what explains changes over time?* Finally, industry-specific features matter: authors like Richardson, Fransman, de Bandt, Pavitt have convincingly demonstrated that they shape the concrete agendas for inter-organizational knowledge creation.

II. TAIWAN´S ACHIEVEMENTS: A BROAD RANGE OF CAPABILITIES

Over the last decade, Taiwan has established itself as a world-class supply source for a variety of electronic *hardware* products. It is the world's largest supplier of computer monitors, motherboards, switching power supplies, mouse devices, keyboards, scanners and a variety of add-on cards. In 1996, almost 60 percent of the world's desktop PCs were

either made in Taiwan or contained a motherboard made by a Taiwanese company.[15] Since 1994, Taiwan also has become the world's largest manufacturer of notebook PCs. Most of these computers are sold to American and Japanese computer companies which re-sell them under their own logo, but 70 percent of the computers sold under such OEM arrangements have been designed by Taiwanese companies. Taiwanese computer firms have clearly developed significant design capabilities.

Progress has been equally impressive in the field of electronic components. Taiwan today has hundreds of passive component makers that have established a strong position relative to leading Japanese and US competitors. Taiwanese firms have also improved their position in the capital-intensive mass production of precision components, such as large-scale CRT picture tubes for computer monitors and sophisticated display devices (like active -matrix TFT-LCDs) for laptop computers. The same is true for integrated circuits. While Taiwan's semiconductor industry at present accounts for hardly more than 3 percent of the world market, some of its firms have developed a strong position for a number of higher value-added integrated circuits (IC), like chip sets, static RAM memories, mask ROMs, and EPROMs. In addition, Taiwan today has one of the world's leading silicon foundry companies, TSMC, that is able to produce leading-edge ICs on very short production cycles both for major international semiconductor firms and smaller design firms. Overall, Taiwanese semiconductor producers have a much better balanced product portfolio that the Korean chaebol which are heavily reliant on the highly volatile DRAM market segment. As a result, Taiwanese producers today are less exposed to high debt and falling equity prices than their Korean counterparts (**Ernst, 1998, Korea**).

Two recent structural changes show how Taiwanese firms have upgraded their capabilities: a rapid *diversification* beyond hard core PC-related products; and a shift from stand-alone manufacturing services to *integrated service packages* that cover a wide range of value chain activities, including higher value-added support services. Taiwanese computer companies now have established themselves as competitive suppliers in a variety of complementary, high-growth market segments, some of which display considerably higher profit margins. Such diversification is evident in three areas: the development of so-called PC network products,[16] especially modems and network interface cards; multimedia accessories, such as CD-ROM drives and add-on cards, and a variety of information services industries, such as multimedia software, system integration, turnkey systems, and network services. Most of these information services owe their existence to the convergence of previously separated technologies used for computing, communicating and digital consumer applications, and require the capacity to combine various strands of technology to generate new applications and markets.

Taiwanese firms have also developed a capacity to provide a package of services across a wide range of value chain activities, sustaining their position as preferred OEM suppliers to the industry. With the exception of R&D and marketing, practically all other stages of the value chain can now be performed by Taiwan's OEM contractors. Moreover,

[15] If not indicated otherwise, data on Taiwan´s computer industry are courtesy of the Market Intelligence Center of the Institute for Information Industry (III), Taipei.

[16] "PC network products" are defined as "products that are used for LANs (Local Area Networks), PSTN (Public Switched Tellephone Network), ISDN (Integrated Services Digital Network), ASDL (Asymmetric Digital Subscriber Loop) and cable modems. Main products include "network interface cards, hubs, bridging switches, modems and routers." Definitions are taken from: Electronic Computer Glossary. Add-on cards include sound, video and graphics cards. Of these, video cards display higher-than-average profit margins.

Taiwanese firms are beginning to shoulder essential coordination functions for the *global supply chain* management of their OEM customers.

Three characteristic examples of these processes of diversification and the provision of integrated service capabilities are scanners, computer monitors, and turnkey production arrangements. Scanner production demands optical, mechanical and electronic technologies and capabilities. Taiwan has accumulated expertise in all three, and has become the world's largest supplier of scanners. With a firm grip on all stages of the value chain, from R&D and production to marketing and after-sales service, Taiwan is positioned to defend its leadership position as a "one-stop shopping center" for scanners.

Since 1993, Taiwan has been the world's largest producer of monitors. Monitor production is highly sensitive to scale economies. Not surprisingly, Taiwan is now faced with intense competition from Korean chaebol which are clearly superior in terms of standard mass production. Some firms have tried to establish themselves as suppliers of higher-end and environmentally friendly monitors, with limited success. Much more successful has been a second response: to move beyond manufacturing to the supply of integrated service packages. Taiwanese monitor producers are now able to provide their leading OEM customers with global manufacturing and sales support more rapidly than the slow-moving Korean chaebol. This shift to global support service packages has been driven by external developments, particularly IBM's decision in 1996 to pull out of monitor production and to transfer large orders to two leading Taiwan-based monitor producers. In order to accelerate speed-to-market, IBM requested that Taiwanese suppliers directly ship the monitors to the relevant markets and that they also provide a complex package of local support services that cover sales, distribution and after-sales services.

A third example is the spread of "turnkey production arrangements" in the PC industry. In a recent contract with Taiwan's Mitac International, Compaq has out-sourced all stages of the value chain except marketing: Mitac is responsible for the design and development of new products, as well as for manufacturing, transport and after-sales services at its manufacturing facilities in Taiwan, China, Britain, Australia and the US. For Compaq, Mitac's greatest attraction is its network of plants and sales subsidiaries located in most of the world's key computer markets.

Taiwan's achievements would be impressive for any country; they are even more impressive for a small island, about one-third the size of New York State. With a population of about 21 million people, roughly half the size of South Korea, Taiwan lacked a large and sophisticated domestic market, specialized capabilities and support industries, and the science and technology infrastructure necessary for developing a broad set of electronics products. From the outset, Taiwan's PC industry depended heavily on international markets and access to foreign technology. Penetrating foreign markets and absorbing imported technology, however, requires conscious efforts to develop a variety of domestic resources and capabilities through deliberate knowledge creation management[17]. How do small enterprises develop such capabilities?

[17] There is a rich body of research, based on the assumptions of evolutionary economics, that specifies what type of capabilities are required and how the development of such capabilities affects firm organization. In addition to the references in note 8, see Lundvall, 1988 and 1992; Carlsson and Stankiewicz, 1991; Teece, Pisano and Shuen, 1995; Christensen, 1996; Foray and Lundvall, 1996; Foss, 1996; Llerena and Zuscovitch, 1996; and Malerba and Orsenigo, 1996. For an application of this theoretical approach to research on developing countries, see Ernst, Mytelka and Ganiatsos, 1998, and

III. THE DOMINANCE OF SMEs

Small-and-medium-sized enterprises (SMEs) have been the main carriers of Taiwan's rapid development and remain important today. In 1993, SMEs accounted for 96 percent of the total number of companies, 69 percent of total employment and 55 percent of Taiwan's manufactured exports (Chen, Tain-Jy et al, 1995)[18]. Taiwan today is home to more than 4,000 electronics firms that produce a broad mix of PC-related products and electronic components. With a few exceptions like the Tatung group, almost all of these companies started out as small enterprises.

The role of SMEs as engines of growth and industrial transformation sets Taiwan apart from South Korea, where huge and highly diversified conglomerates, (*chaebol*), have been the main carriers of the development of the electronics industry **(Ernst, 1994 a and 1998 a, Korea)**. Almost without exception, the chaebol have targeted those segments of the electronics industry that require huge investment outlays and sophisticated mass production techniques for fairly homogeneous products like microwave ovens, TV sets, VCRs, computer monitors, picture tubes and computer memories, especially DRAMs. The result has been a heavy focus on assembly-type mass production activities related to lower-end consumer products and standard electronic components, and a weakness in more design-intensive sectors of the computer industry.

A source of flexibility

Why did Taiwanese firms succeed in the computer industry, while their much larger and resource-rich Korean counterparts have largely failed? The answer lies in the fundamental characteristics of an industry in which high volatility and uncertainty put a premium on flexibility and the capacity to adjust to abrupt and frequently unexpected changes in demand and technology. Small firm size can foster such flexibility[19] . By combining incremental product innovation with incredibly fast speed-to-market, Taiwanese firms have been able to establish a strong international market position relatively early in the product cycle.

The primary source of this flexibility appears to be the specific organization of the *domestic supply base* in Taiwan, especially for parts and components. Two main features of this domestic supply base have contributed to the flexibility of Taiwanese producers, the first being an extreme form of *specialization*. By engaging in single tasks and by producing, purchasing and selling in small lots, subcontractors avoid heavy fixed capital costs. This, in turn, makes it relatively easy to shift production at relatively short notice, and with a minimum of costs. The second feature is a certain *network* structure of *multiple, volatile* and *short-term* links that involve only limited financial and technology transfers. Spot-market transactions play an important role, but so do "temporary spider

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Ernst and Lundvall, 1998. Much of the literature on firm capabilities however focuses on large multi-divisional corporations and fails to discuss how small enterprises can develop such capabilities. Exceptions are Acs and Audretsch, 1992; and Maskell 1996 a and 1996b.

[18] According to more recent figures, quoted by The Economist (November 7, 1998, p.9), SMEs make up 98.5% of Taiwan´s companies, 75-80% of all employment and "47% of the total economy". As neither the source nor the methodology is explained, it is difficult to judge the validity of these figures.

[19] For the underlying argument, see Acs and Audretsch,1992. For a critical assessment, see Harrison, 1994.

web" arrangements that are assembled for the duration of a particular job.[20]The result of these characteristics is an extreme form of open and volatile production networks, arguably even more so than the highly flexible production networks that characterize California's Silicon Valley.[21] Firms maximize the number of jobs in order to compensate for the razor-thin profit margins; as a result, they avoid being locked into a particular production network. Domestic supplier networks thus have been highly *flexible* and capable of *rapid change*, but *short-lived* and *foot-loose*.

Capability requirements

If flexibility constitutes one prerequisite for Taiwan's competitive success in computers, economies of scale and scope and speed-to-market have been of equal importance.[22] Entry barriers have increased for those stages of the value chain which are of critical importance for competitive success, including particularly component manufacturing where production-related scale economies remain important. But the epicenter of competition has shifted beyond manufacturing to R&D and other forms of intangible investment required to complement price competition with product differentiation and speed-to-market. Only those companies can survive that are able to get the right product to the highest volume segment of the market at the right time. Being late is a disaster, and often forces companies out of business.

In sum, what really matters for competitive success are substantial investments in the formation of a firm's *technological and organizational capabilities*. How were Taiwanese computer companies able to successfully compete in an industry where size-related advantages are of critical importance? And, more specifically, what kind of organizational innovations have enabled Taiwanese firms to overcome their size-related disadvantages?

The specialization dilemma

In order to answer these questions, we need to examine issues of *specialization* and *coordination*. Andersen (1996) has recently provided an interesting theoretical explanation why excessive specialization may involve substantial trade-offs. He shows that, as an economy becomes more specialized, this increases the pressure for standardization. In turn, this may constrain innovation[23]. The solution to this dilemma is the establishment of tight linkages between firms along the supply chain that enhance the prospects for inter-organizational knowledge creation, for instance between end product manufacturers and component suppliers.[24]

To understand how Taiwan avoided the dangers of excessive specialization and established tight inter-firm linkages, it is important to correct some popular misconceptions of the Taiwanese model. This is not an economy characterized by

[20] For details, see Shieh 1990; and Lam and Lee 1993, p.112. Individual firms often bid for contracts beyond their own capacities; once a supplier gets the contract, it calls on other firms, often competitors, to help fill the order.

[21] For an analysis of Silicon Valley-type production networks, see Saxenian, 1990.

[22] Chandler, 1990, remains the most authoritative source. Economies of scale and scope in the computer industry are analyzed in Flamm, 1988 and 1990; Ferguson, 1990; Ernst and O`Connor, 1992; and Ernst, 1997b

[23] "While standardization appears to be a necessary consequence of the attempts of economic agents to exploit economies of scale and to avoid dealing with impossible amounts of information, this may also lead to difficulties for innovative activities." Andersen, 1996, p.98.

[24] The primary source for such "user-producer linkages" remains Lundvall, 1988.

atomistic competition. SMEs do play an important role, yet they survive due to a combination of four forces: government policies that facilitated market entry and upgrading; strong linkages with large Taiwanese firms and business groups; the presence of foreign sales and manufacturing affiliates; and early participation in international production networks.

IV. THE ROLE OF INDUSTRIAL DEVELOPMENT POLICIES

Peculiar features

Though Korea and Taiwan share many similarities, the two countries have chosen very different policy approaches. In the early 1960s, the Taiwanese government introduced aggressive programs to encourage investment by domestic as well as foreign companies.[25] In line with similar programs in Korea, these statutes provided generous tax incentives and laid down rules to facilitate the acquisition of land for industrial use by investors and access to utilities. Five features however distinguished Taiwan's approach: First, no limits were set on the number of firms within each industry group, with the exception of a few mining and utility industries. Any domestic firm could invest and enjoy the same tax and other privileges. This open policy gave rise to intense domestic competition, and was conducive to a *diversified* industry structure.

Second, the government actively promoted the development and modernization of Taiwan´s SME sector. The first of such policies, "The Rule for Promotion of Small and Medium Enterprises", was promulgated in 1967 and was subsequently revised several times as Taiwan's SMEs grew. Government assistance to SMEs included market promotion, management rationalization, cooperation and promoting strategic alliances, loans and upgrading technology and labor training (Ministry of Economic Affairs (MOEA), 1991). Third, there was no discrimination against smaller firms *within* the SME category. Any firm, irrespective of size, could participate and was treated equally. This *neutral* policy was an important foundation for the development of Taiwan´s large pool of vibrant and entrepreneurial SMEs. Fourth, virtually equal treatment was granted to domestic and foreign investment, with the exception of some majority share-holding regulations applicable to foreign firms and strict foreign exchange control regulations governing domestic firms. This balanced policy attracted foreign investment without producing the "crowding-out" that occurred in Singapore, where domestic firms have played a minimal role in the manufacturing sector[26].

Finally, an important difference that sets apart Taiwan´s industrial policies from those pursued in Korea is that directed credit has played a much less important role, at least until the early 1980s. This can be seen from the high real interest rates for secured loans that Taiwanese firms had to pay during this period.[27] This has changed only since

[25] The Statute for Investment by Foreign Nationals was first promulgated in July 1954 to attract foreign companies. In November 1955, this was followed by the Statute for Investment by Overseas Chines whose purpose was to tap into the experiences and capital of the Overseas Chinese communities in Hong Kong and Southeast Asia. Finally, the Statute for the Encouragement of Investment was enacted in September 1960. (San Gee and Kuo, 1998)

[26] For an analysis of such crowding-out affects on potential domestic investment in Southeast Asia, see Lim, Linda and Peng Eng Fong, 1991.

[27] San Gee (1995), table 4. The real interest rates for secured loans in Taiwan were 14.14%, 9.0 %, 8.05% and 9.7% respectively in 1965, 1970, 1975 and 1985. There was only one exception: in 1980, the

the mid-1980s, when the focus of industrial policy shifted to industrial upgrading. Any firm, irrespective of size, could participate in industrial promotion programmes, including concessionary credit. In contrast to the Korean government which used its control of the finance sector to direct credit to a handful of chaebol, the Taiwanese government did not try to promote large national champions. One should also mention that curb markets have arguably played a more important role in Taiwan than in Korea as an alternative source of debt finance relative to bank credit (**Pyung Joo Kim 1994**: 284 following). The result is that Taiwan`s corporate debt-equity ratio is substantially lower than in Korea[28]: Taiwan´s net debt-equity ratio for 1998 is forecast to be around 30%, compared with more than 180% for Korea(ING Barings estimate, quoted in The Economist, November 7, 1998, p.13).

Differences in industrial policy have led to very different firm behavior in the Korean and in the Taiwanese electronics industries. Arguably, some of these differences explain why Taiwan has been less vulnerable than Korea to the impact of the financial crisis **(Ernst, 1998a, Korea)**. Taiwan´s industrial policy is focused on flexibility and competition: relatively low entry barriers and non-discriminatory policies enable small firms to enter targeted sectors and to grow. At the same time, the legal system puts relatively few obstacles in the way of bankruptcy. This has forced incumbents to stay trim; they have also accelerated the spread of information, skills and knowledge. The result is that Taiwan´s smaller companies had to rely more on equity markets and corporate retained earnings than the chaebol: Taiwanese firms find it more difficult to raise capital for large-scale volume production and they are under much greater pressure to submit investment decisions to short-term financial considerations.

Dynamics of Change

In sum, Taiwan's development strategy generated forward and backward linkage effects, while relying on "market-augmenting" policies that reduced risk and uncertainty rather than market-repressing policies that increased fragmentation and rent-seeking (Johnson, 1987, p.141). Taiwan's policy approach was not a static one, however; as the requirements of industrial upgrading changed over time, so did the nature of state intervention. This *continuous upgrading* of industrial policies has been an important defining element of Taiwan´s approach to knowledge creation.

Policy requirements keep changing over time for two simple reasons: increasing complexity and a greater exposure to the international economy. As Taiwan´s industry moves up from simple and labor-intensive to more complex products, much more sophisticated policies are required. The main reason is that *entry barriers rise with increasing complexity*: investment thresholds increase and knowledge requirements become more demanding. For small enterprises this implies that they need to have access to *externalities* that would enable them to overcome their size-related disadvantages[29].

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rate fell to -2.80, which was primarily due to the second oil crisis in that year. Note that these figures are adjusted for inflationary effects.

[28] Scitovsky (1986: chart 1) shows that, in most years between 1971 and 1980, Korea´s corporate sector debt to equity was between 310 and 380, while Taiwan´s ratio was much lower between 160 and 180. This is consistent with more recent figures quoted in Fields (1995: table 4-5) which show that in 1985, the debt-equity ratio of Korean manufacturing firms was nearly 350, relative to a ratio of 120 for Taiwan. See also the figures quoted in Patrick and Park (1994), and in Ranis (1998).

[29] Externality requirements vary, depending on the market segment and the stage of development of a particular industry. For consumer electronics, they are obviously less demanding than for semiconductors. And within the same product group, i.e. semiconductors, such requirements become much more complex,

A greater *exposure* to the *international economy* is a second reason why industrial development policies need to develop over time. An increasing complexity of the domestic industry necessitates more international linkages. Such linkages are necessary to facilitate local capability formation. They encompass not only critical imports of key components and capital equipment and inward FDI. Such linkages also involve participation in global production networks (GPN) as well as in a variety of specialized and informal "international peer group" networks that are essential carriers of knowledge creation, especially in the computer industry. Left on their own, small enterprises are ill-equipped to reap the benefits of such international linkages. Again, the market needs to be complemented by selective policy interventions that can provide some of the necessary externalities

The evolution of Taiwan´s industrial policy

This process of change can be traced through Taiwan´s industrial policies that affected the electronics industry.[30] In 1958, the US Aid Mission announced that it would phase out US aid to Taiwan in the 1960s, forcing Taiwanese policy-makers to find alternative ways to earn foreign exchange[31]. The US contracted Stanford Research Institute (SRI), a commercial consultancy company to select priority industries for export promotion that were of potential interest to foreign investors. Not surprisingly, SRI chose those product groups where American companies had strong interests: certain petrochemical intermediates, plastic resins, synthetic fibers, transistors radios, electronic components, watches and clocks.

At the time, the most widely publicized "breakthrough" was an investment by General Instruments, in 1964, producing transistor radios. The irony is that, soon after, General Instruments pulled out of consumer electronics altogether. Two years later, however, in 1966, General Instrument's Microelectronics Division established its semiconductor assembly line, marking the beginning of Taiwan´s semiconductor industry.[32] Over time, this affiliate acted as an important incubator for local start-up companies: eleven local companies were founded by former GI employees.[33] The Taiwanese government did not blindly follow SRI`s advice, however; it simultaneously discussed opportunities with Japanese and European firms. Taiwan´s entry into the television industry began with investments in the early 1960s by Philips, Matsushita, Mitsubishi, NEC and Sanyo.

In the early 1960s, the Taiwanese government introduced a series of path-breaking *institutional* and *policy innovations* that were instrumental in the shift to export promotion. The first was the statute for technical cooperation, issued in 1962, under which re-investment and the remittance of technology fees accompanying joint ventures were permitted; this had the effect of attracting technology from foreign companies. Much better known is the second innovation: the 1965 Law on the Establishment and

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once the focus shifts from low-end discrete devices for consumer applications to higher-end design-intensive devices.

[30] The following is based on San Gee and Wen-jeng Kuo, 1998; San Gee, 1995; Kobayashi, 1995; Meaney, 1994; Kajiwara, 1993; Liu, 1993; Schive, 1990 and 1993; and Wong Poh Kam, 1995

[31] The following is based on Gold, 1986, chapter 6.

[32] Between 1969 and 1973, Taiwan experienced a wave of offshore chip assembly investments, with Philips, Texas Instruments and RCA being the lead actors. See Ernst, 1983.

[33] San Gee and Kuo, 1998. Furthermore, Morris Chang, one of the main drive forces behind the development of Taiwan´s semiconductor industry and now the president of ITRI, had been before the CEO of General Instruments in the U.S.

Management of Export Processing Zones, first implemented in December 1966 in Kaohsiung, a port city in the south of the island.

Once the policy focus shifted to secondary import substitution, the provision of *external economies* becomes critical. In 1973, the Industrial Technology Research Institute (ITRI) was established as part of the Ministry of Economic Affairs. ITRI soon moved beyond its original task, which was to develop applied industrial technologies for key components and capital equipment. Equally important tasks now included international technology scanning and acquisition; technology transfer from foreign sources to the domestic SME sector; the development of a nation-wide infrastructure; and the formation of specialized clusters of support industries. ITRI and its specialized divisions[34] also proved a source of "migratory knowledge"[35] for the electronics and computer industries: top researchers and engineers were continuously encouraged to move out into the private sector and to establish innovative start-up companies. Typical examples of such spin-offs include UMC and Winbond, both of which today have become serious competitors in the integrated circuit industry.

During the 1980s, policy shifted toward *industrial targeting*, especially for the computer industry. In 1980, the government established an industrial park almost entirely devoted to IC manufacturing and computer design, the Hsinchu Science-Based Industrial Park (HSIP). Hsinchu offered a large range of fiscal and related investment incentives to attract qualified investment[36]. In turn, companies that have invested in the park must spend a certain proportion of their revenues on R&D and a minimum percentage of their work force must be scientists and engineers. Located close to ITRI and two well-known technology-oriented universities, Hsinchu was able to replicate to some degree a "Silicon Valley"-type informal network that helped to quickly diffuse new technology to Taiwan´s computer industry. The park's close links with Silicon Valley—many of the top executives and engineers of Hsinchu-based companies have worked in the US—facilitated a rapid response to changing technology and international markets.

Overcoming size-related disadvantages

Throughout these various policy changes, however, the government maintained a willingness to assist Taiwanese SMEs in overcoming their size-related disadvantages. In the computer industry, the best example is the case of the notebook PC consortium, established by CCL/ITRI in April 1990.[37] Against strong protest of the leading domestic PC manufacturers, like Acer, the government refused to set any entry requirements, except an initial entry fee of $48,000 - a sum which even an SME could well afford to pay. The result was that 46 firms became members of this consortium, and thus had equal access to design specifications and prototypes, detailed technical reports for each stage of

[34] Two such divisions have played a critical role for the development of Taiwan´s computer industry: the Electronic Research Service Organization (ERSO) that has focused on the development of key components (especially ICs and LCDs); and the Computer and Communications Research Laboratories (CCL) that focuses on the development of new architectural designs for computers, communications and consumer electronics.

[35] This term was coined by Joseph L. Badaracco Jr. (1991, pages 33-47) who defines it as knowledge, both explicit and tacit, embodied in individuals who migrate from one organization or country to another.

[36] Liu, 1993, pages 306 and 307. This includes low-interest loans, the right to retain earnings of up to 200 percent of paid-in-capital, a five-year income tax holiday within the first nine years of operation, accelerating depreciation of R&D equipment, and low-cost land.

[37] Interview with Dr. Cheng, Director, CCL (Computer and Communications Laboratories)/ITRI, May 1995. See also the excellent analysis in San Gee, 1995, pages 173 passim.

development, motherboard designs, mass production samples and training classes. This example illustrates a peculiar feature of industrial policy making in Taiwan noted above; the government supports multiple firms in any technology initiative, constantly putting pressure on existing players by bringing in new companies or lower-tier firms. This has created a powerful vehicle for inter-organizational knowledge creation.

Of course, such a government policy to stimulate knowledge creation through market entry and competition comes at a cost. Some of these SMEs later fail due to a lack of sufficient resources and capabilities. Acer's Stan Shih claims that by supporting smaller firms, "...[t]he government has become our major competitor."(Callon, 1994, p. 27) The consortium also failed to distinguish the different capabilities and needs of member firms. As all firms were able to share the common design, "...[t]he only way a member could compete with other alliance members was to reduce the sales price of the common product, which resulted in a price war."(San Gee, 1995, page 175)

Yet, such costs have to be measured against the substantial benefits of these policies, which helped integrate parts of Taiwan's SME sector into the computer industry and generated a critical mass of knowledge. This particular type of industrial policy has also helped to develop Taiwan's flexible and low-cost domestic subcontracting system and its linkages with large domestic and foreign firms; it is to these network relations that I now turn.

V. THE ROLE OF INTER-ORGANIZATIONAL LINKAGES

The limits of family-owned SMEs

We have seen that small, family-owned firms have played an important role in the development of Taiwan´s electronics industry. This had considerable advantages, both in terms of cost and flexibility: transaction costs were low, as family-run enterprises cooperated on the basis of informal social contacts. Outsourcing could be performed at much lower cost, risks could be substantially reduced, and information circulated much more quickly.

This type of arrangement is now coming under increasing pressure, and appears to be ill-equipped to deal with the new competitive requirements. Family bonds erode, especially when the firm has to move production overseas and loose networks between family-owned SMEs are unable to raise the capital required for increasing fixed investments and R&D outlays. As a result, Taiwanese SMEs had to develop a variety of linkages with more powerful third parties. Such linkages include informal peer group networks; the government´s Center-Satellite program; the integration of small firms into loose cross-sectoral business groups; and variations in the business group model, centered around a holding company. It is difficult to say which of these different linkage arrangements are most effective to cope with the dual challenge of knowledge creation and internationalization. We find that Taiwanese SMEs as well as the government have pursued a *plurality* of approaches in parallel, rather than concentrating exclusively on one particular linkage. In this section I focus on domestic linkages; yet, as Taiwan´s electronics industry is deeply rooted in global production networks, I cannot avoid dealing now with some of these international linkages[38].

[38] This reflects the intrinsic *global* character of the electronics industry, which is especially pronounced in the computer industry (Ernst, 1998, HTCP)

Informal "peer group" networks

Taiwanese SMEs have always relied heavily on *informal social networks* for access to resources, capabilities and knowledge that they are unable to mobilize on their own. Over time, the focus of these networks has shifted from labor, capital and basic market information to technological knowledge and brand name recognition. Originally, these networks were restricted to family and kinship relations. They are now rapidly being substituted by *professional* "peer group" networks. This is especially true for the electronics industry where resource and capability requirements are much more demanding than in traditional industries, and where participation in international knowledge networks is of the essence.

Informal peer group networks come in a variety of forms. Typically, class mates (especially in elite schools) and former colleagues (especially in foreign affiliates) form tight networks that can be instrumental in the creation of start-up companies. For example, Taiwanese SMEs rely heavily on informal information exchange with former classmates for the generation of tacit knowledge on specific engineering and marketing problems and when they need confidential information on potential partners or competitors. Interviews at Acer for instance showed that even today, when this company has long moved beyond its earlier SME status, senior managers still prefer to contact former teachers or class mates when they have to deal with a specific engineering, marketing or management problem rather than a commercial consultancy firm or a technology research institute.

Acer actually has been a master in the formation of such informal networks; much of its success arguably is due to the scope and depth of its peer group linkages. Founded in 1976 as Multitech International Corp., with a registered capital of just $25,000 and 11 employees, the company's first activity was to run a training center for computer engineers. In the first three years, more than 3,000 engineers were trained who later were to occupy important positions in Taiwan´s nascent computer industry. As a result, Acer was able to establish early on an extensive network of social contacts within Taiwan´s computer community. These contacts have become an important asset. Since 1986, Acer Sertek Inc, the company's domestic sales, marketing and service arm, has trained more than 170,000 Taiwanese students in computer use[39].

A hierarchical Center-Satellite system

Another attempt to overcome the disadvantages of small firm size has been the government's *Center-Satellite Program* (CS), launched in 1984, in response to the private sector's reluctance to vertically integrate production through either merger or inter-firm cooperation. The objective of this program has been to eliminate cutthroat competition and destructive price cutting practices by encouraging closer, interdependent and long-term ties between larger "center" firms (upstream suppliers, final assemblers, large trading companies) and their "satellites" (especially component suppliers).

The CS program is an attempt by the Taiwanese government to copy the Japanese *keiretsu* system. It is run by the semi-official Center-Satellite Development Industrial Coordination Center (San Gee, 1995). In each CS system, the central plants assume the responsibility to coordinate, monitor, and upgrade the operations of their satellite plants. In order to strengthen these links, the government provides a variety of financial,

[39] Similar stories abound for foreign companies as well: RCA, the incubator of Taiwan´s semiconductor industry, Philips, IBM Taiwan, AT&T Taiwan, Matsushita, Toshiba, Sanyo, and Fujitsu.

manpower training and technical engineering assistance to both the central plants and the satellites.

On paper, the CS-system is attractive, as it addresses the needs of both large and smaller companies. For center companies, the expected benefits include a lower fixed investment burden due to outsourcing and the sharing of investment outlays; access to the specialized capabilities of satellites; cost reduction due to lower wages paid by satellites; economies of scale and scope, especially if satellites supply the needs of several central firms; and the use of satellites as a buffer against market fluctuations. For satellites, expected benefits include assured orders; access to materials and components; access to technology and improved learning possibilities; and access to markets.

Most assessments conclude that the CS program so far has been only partially successful (San Gee, 1995 and Wade, 1990, p.167). Yet, these assessments need to be placed in a broader context. Over the last few years, the CS program has generated an increasing variety of linkages between SMEs and large firms, linkages that frequently extend beyond national boundaries. Government policies to promote CS networks were particularly successful in accelerating the outward investment of SMEs to Southeast Asia and China. Once a foreign lead company of an OEM network had invested in these regions, this exerted a powerful pressure on Taiwanese satellites to follow suit and to move their production offshore. In many cases, this has had the unanticipated effect of "hollowing-out" the domestic supplier system.

Internationalizing institutional innovations

In order to correct and avoid such negative impacts, both government policies and firm strategies are currently being adjusted. Government policies now pay more attention to assisting SMEs to upgrade their domestic activities. This applies especially to incentives for technology diffusion and product-related R&D; incentives for training; policies to improve infrastructure and access to telecommunications services: and policies to improve financial services. For their part, firms are striving to diversify and internationalize their ownership, and to reap broader benefits from international specialization and the building of proprietary assets.

I have argued earlier that industrial parks and, later on, science parks played a major role in the development of Taiwan's locational advantages. This organizational innovation is now being *transferred abroad*, especially to the Southern Coastal provinces of China and South East Asia. Over the last few years, there has been a rapid proliferation of special business zones and industrial estates that are geared primarily to the needs of Taiwanese small - and medium - sized computer companies.

The original role models are the “shoe city” and the “textile city” established in the Southern Coastal Chinese province of Fujian. This has been followed by similar arrangements in the electronics industry, such as two “Cities of Electronics” (in Fujian and Guangdong provinces of China), the Penang Scientific Park in Malaysia, the Kung-Hua Industrial Park on Batan Island (Indonesia), and the Subic Bay Industrial Park in the Philippines.

Since the Taiwanese government cannot openly act as a third party for political reasons, we find a variety of intermediary institutional approaches that provide similar services. The largest project so far has been the conversion of Subic Bay, the former US naval base in the Philippines, into a major industrial park, primarily for Taiwanese and American electronics firms. The idea is to enable Taiwanese subcontractors to move jointly with their large Taiwanese lead contractors and major American OEM clients. The

provision of low-interest loans by the International Economic Cooperation and Development Fund (IECDF), Taiwan's foreign aid program, is designed to help Taiwanese SMEs to invest in Subic Bay and other neighboring locations[40]. The goal is to transfer parts of the domestic Taiwanese supply base for components and sub-assemblies to Southeast Asia, so that final assemblers of monitors, motherboards and PCs and other PC-related products can have access on the spot to low-cost and flexible support industries.[41]

At the same time, this creates new mechanisms for inter-organizational knowledge creation. Take the case of Advanced Semiconductor Engineering Inc., the world's second-largest independent contract assembler of ICs, which already has a plant in Penang, Malaysia, to supplement its parent facility in Kaohsiung. ASE now wants to expand in Subic Bay as well. The company already uses Filipino workers in Kaohsiung and has given them intensive training. Since the Taiwanese government allows foreign workers to work in Taiwan for two years only, ASE will send them to Subic Bay as trainers of its workforce there.

Linkages with large domestic firms: cross-sectoral business groups

Contrary to conventional wisdom, large firms have played a central role in the coordination and development of the Taiwanese production system. They have also facilitated knowledge creation in small firms. After the second world war, the Taiwanese government took over the Japanese enterprises that had been established during the 50 years of colonial rule (1895-1945). In contrast to Korea, the government did not privatize these firms. Instead, they were run as public enterprises. By developing a strong public enterprise sector, Taiwan developed companies large enough to enter the highly capital-intensive production of basic materials, while at the same time avoiding the dominance of private conglomerates (San Gee and Wen-jeng Kuo, 1998. See also Schive, 1990).

Linkages with large firms have played an important role in the development of Taiwan´s SME sector. To start with, SMEs depend on the supply of basic materials provided by large public enterprises at low cost and high quality (Wade, 1990) . Large firms have also acted as an important intermediary source of capital for SMEs. Taiwan's banks direct most of their funds to large domestic public and private firms who then on-lend money for equipment and working capital to smaller customers, subcontractors and suppliers at higher rates through trade credit and loans on the informal curb market (Ministry of Economic Affairs (MOEA), 1991).

It is important to emphasize that many SMEs are for all practical purposes members of a particular *business group*.[42] The growing capital requirements and

[40] For the first stage of the development of the Subic Bay Industrial Park, $23.5 million has been provided as seed money by the International Economic Cooperation and Development Fund (IECDF) to develop the required infrastructure and support services. By July 1995, 46 Taiwanese companies had signed lease agreements with the Park, with total committed capital investments exceeding $180 million. Prominent among them are some of the leading Taiwanese computer and consumer electronics firms like Acer (roughly $24 million investments committed), Elite Computer Co. ($20 million) and Teco Electric and Machinery Co. ($24 million).

[41] A related policy instrument are are large-scale investments by companies affiliated with Taiwan's ruling KMT party and by state-owned enterprises. Their main purpose is to supply basic materials and infrastructure services that are used in the production of semi-finished products in Subic Bay and other Southeast Asian locations for shipment back to Taiwan and to other export markets.

[42] Liu, Liu and Wu, 1994. The spread of such business groups partly reflects the impact of government policies; starting in the late 1950s, the government shifted its emphasis away from public enterprises to

technological complexity that accompanied the rapid industrial transformation of the island produced new forms of business organization. When electronics took over from textiles as the leading industrial sector, this led to an erosion of Taiwan´s traditional form of business organization: the loose networks of family-owned SMEs. In order to retain profitability, family firms were forced to venture across product lines and to move from industries with declining margins, like textiles, to the much more profitable electronics sector. In most cases however they were unable to raise the capital required for increasing fixed investment and R&D: as late as 1992, only 20 percent of a sample of Taiwanese manufacturing firms were engaged in R&D.[43]

Attempts to cope with these two conflicting pressures produced a peculiar Taiwanese form of business organization: *cross-sectoral business groups*. These business groups are very different from the large, hierarchical conglomerates, the *chaebol*, that are typical of South Korea[44], but they also differ from the *keiretsu* system that has dominated much of Japan's industry. In Taiwan, business groups typically consist of a *loose network* of mostly *medium-sized* companies that produce a variety of products for different markets, with one core company exercising financial control. This type of firm organization reflects the need to *combine* the *scale advantages of large firms* with the *speed* and *flexibility* of *smaller* firms.

The ADI business group provides a typical example. Founded in 1979, the company is run by the Liao Jian-cheng family. From trading and construction it first moved into shoe manufacturing for international mass merchandisers. Around the mid-1980s, the family decided to move into electronics. The breakthrough came in 1993, thanks to big orders from Compaq. Despite success in computer monitors, the owners maintain their diversification strategy. ADI has continued to expand its position in shoe manufacturing, while at the same time investing in a number of new small start-up companies in software, system design, and in a variety of unrelated commercial activities.

The shift to business groups has been most pronounced in the electronics industry. This is hardly surprising, given the critical importance in this industry of economies of scale and scope. But in Taiwan's case, there are two additional reasons why SMEs became integrated into larger business groups: linkages with foreign customers through international subcontracting and OEM arrangements; and linkages with international supply sources, especially for key components. As a result of these linkages, size became essential to secure economies of scale and scope and achieve sufficient bargaining clout with foreign customers and suppliers.

To fulfil an OEM contract, large Taiwanese companies like Tatung, First International Computer (which is part of the Formosa Plastics group), Mitac and Acer rely on hundreds of loosely affiliated domestic suppliers to which they can pass on an endless variety of low-margin, yet quite demanding manufacturing and design tasks. The

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the private sector, providing guidance and essential externalities. This has set the stage for the growth of private firms.

[43] Questionnaire survey, conducted in July 1992, for the Ministry of Economic Affairs, covering a sample of 4,137 private manufacturing companies in Taiwan. See Liu, Liu and Wu, 1994, p. 51

[44] Note however that changes occur even in Korea. In response to the collapse of a number of major chaebol and a severe banking crisis, all chaebol are now forced to reconsider basic features of their organization. Take for instance the Daewoo group: its officially declared debt currently is more than three times its equity, and it has committed itself to more than 100 foreign investment projects, worth at least $ 3billion. It is hardly surprising that the group`s chairman, Kim Woo Choong, now declares that Daewoo will evolve " in a cluster of independent firms, each led by professional managers." Financial Times, December 10, 1997, p.4

typical Taiwanese small computer company thus often gets involved with foreign firms only in an *indirect* way; large Taiwanese business groups dominate the direct interface with foreign customers. The same is true for the affiliates of foreign multinationals like Philips, Matsushita, DEC and others that have substantial production platforms in Taiwan.

A similar mechanism also works on the *procurement* side, especially for high-end key components like DRAMs, microprocessors, CRT picture tubes for computer monitors and liquid crystal displays (LCDs) for laptop computers. The insecurity of supply plays an important role in the formation of inter-firm linkages. Roughly 85 percent of all semiconductors used in Taiwan are currently imported. Under "normal" circumstances, Taiwanese SMEs rely on the "spot market": they purchase these components from the branch offices or agents of foreign component vendors. But normal circumstances are rare in these component markets. When a serious component supply shortage occurs, Taiwanese SMEs will be the worst hit. Foreign vendors will either require sharp price mark-ups or refuse to deliver.

For SMEs, the only hope is to survive in the shadow of the large Taiwanese PC manufacturers. During a typical supply shortage, the large Taiwanese manufacturers will expand their procurement orders well beyond their real needs. By buying large quantities of components before price wars actually materialize, firms seek to buffer their effects; one could call this the *"component future trading"* effect. Firms also seek to hedge against opportunism on the part of foreign suppliers. Major Taiwanese PC companies simply must keep large safety inventories of key components as a risk minimization strategy. Third, during shortages, foreign component suppliers normally only supply their strategic customers. For Taiwanese PC makers it is of critical importance to get on such "strategic customer" lists. The way to do this is to inflate their component orders above their real needs to convince foreign suppliers that the Taiwanese customers are big and important.

As a result of these purchasing strategies, Taiwanese PC makers regularly get bogged down with large inventories of key components. The product composition of these inventories keeps rapidly changing, with newer component generations vying for precious inventory space with older ones. Taiwanese PC makers are thus under strong pressure to resell parts of their component inventories to local SMEs. Most of these re-sales are components that are "one-generation-behind-the-leading-edge". Prices charged are higher than the prices paid by the large PC maker to the foreign supplier, but lower than those charged on the spot market.[45]

In sum, the only way for Taiwanese PC-related SMEs to survive periodic supply shortages for key components is to stay in the shadow of the large domestic PC makers and to accept the crumbs that the big guys are willing to share with them. The prices charged for these crumbs are substantial. Yet, what matters from the perspective of the SME is that they can get access to these vital components and that the prices they pay are lower than those they would pay in the spot market. This situation obviously puts a tremendous pressure on the existing Taiwanese SME population: only those SMEs can survive that succeed in ruthlessly cutting cost and overhead, while accepting the most exacting contract conditions in terms of delivery times. The result is a high *turnover* of

[45] A similar system apparently works for leading-edge components: while price levels, of course, are substantially higher than for the more vintage-type components, they still tend to be below price levels on the spot market.

the existing SME population: at any given point in time, a large number of firms goes bankrupt, while an equally large number of firms emerges as new start-up companies.

Over the last few years, the importance of big business groups has further increased, blurring the division between small and large firms. Taiwan's electronics industry has recently witnessed a rapid increase of *concentration*. In the PC industry, the top 10 firms today control roughly 80 percent of total production, and some of the most powerful Taiwanese business groups (Formosa Plastics, HwaHsin, China Steel, YFY Paper) have now also entered the production of key components, like DRAMs, CRTs and displays.

Business groups centered around a holding company

Many Taiwanese computer companies have experienced very rapid growth since the last industry shake-out in 1992; the challenge now is to develop an organization that enables them to improve *organizational learning*. For PC manufacturers, the main role model is the *Client-Server* model. A rapidly growing company like Acer or Mitac spins business units into independent profit centers, creating a *federation of loosely connected companies* united by four factors: access to *common core technologies*; access to the holding company's *financial* resources; access to its *knowledge base, market intelligence* and *technology scanning* capabilities; and a common *brand name*. This type of organizational innovation makes it possible to keep high value-added operations and core capabilities in Taiwan, while dispersing sales, marketing, procurement, product integration and service operations around the world, in close proximity to the main growth markets.

Each of the different members of a “Client-Server Organization” are separated by product lines and by geographic region, and each operates independently from the other. This allows them to make decisions quickly in response to market changes and to define the market segments where they feel fit for leadership. At the same time, however, all of these businesses have ready access to the lead company`s knowledge base.

One important element of this re-organization is a new approach to overseas PC assembly. Acer provides an example[46]. In order to reduce cost and increase speed-to-market for new products, Acer has established 15 modular assembly sites around the world. Each of these assembly subsidiaries is located close to important markets and performs only very limited activities: it receives PC housings and floppy disk drives by sea, with motherboards flown in directly to ensure delivery of the newest technologies. Central processing units (CPUs), hard drives and memory are sourced locally to fill individual user requirements, and the modular components are assembled quickly according to a standardized procedure. This strategy allows Acer to maintain control over product quality and keep inventory to a minimum, while providing fast assembly of competitively priced PCs that always contain the latest microprocessor generation.

The Taiwanese "client-server" model comes strikingly close to the basic philosophy of many proponents of corporate re-engineering, especially the model that IBM's previous chairman John Akers had tried to implement for the ailing giant before he was ousted.[47] Yet, the basic motivation of firms like Acer has been fundamentally different from those of IBM; the goal is not to reduce the cost of excessive centralization,

[46] Based on author´s interviews at Acer. Similar approaches have been developed by other leading Taiwanese computer manufacturers like Mitac and FIC.

[47] Acer hired an IBM executive to assist its reorganization in 1988, with little success; however, the crisis of 1991 spurred a new round of organizational innovation. Business Week, November 27, 1995, p. 73.

but *to overcome some size-related barriers to knowledge creation and internationalization*, without repeating the mistakes of excessive integration characteristic of US, European and Japanese firms.

VI. THE CATALYTIC ROLE OF INWARD FDI

Inward FDI played an important catalytic role for knowledge creation during the critical early phase of the development of Taiwan´s electronics industry. It exposed Taiwanese workers and managers to new organizational techniques, which, while not necessarily "best practice", contributed to a gradual erosion of traditional, highly authoritarian and ultimately inefficient management practices. The need to comply to some minimum international quality standards gave rise to learning effects that spilled over to a wide spectrum of local enterprises due to the high turnover in Taiwan´s skilled labor market. A questionnaire survey of 318 Taiwanese electronics firms found that 104 of these companies had high-level managers and engineers with work experience in foreign electronics firms (San Gee, 1990). Of these, roughly 43 percent felt that their working experience with foreign firms was helpful for their management skills, 31 percent said that it was useful for product design and development, and almost 30 percent that it enhanced their capacity to generate market information.

Inward FDI also contributed to the development of local suppliers, at least for domestic market-oriented production. A combination of protection and local content requirements, directed especially at Japanese consumer electronics manufacturers, forced these companies to pull along their main Japanese component suppliers. Together, they systematically groomed local vendors and established a broad range of local supplier networks.

Consumer electronics

FDI-related linkages first emerged in consumer electronics. The pioneer was Philips which in 1961 established a large local manufacturing affiliate that produced TV sets, audio equipment, picture tubes and a variety of other related components. Originally, this production facility was geared to the heavily protected local market, but by the mid-1960s, domestic market-oriented production had been supplemented by export platform production. Philips Taiwan is now the exclusive production source for picture tubes for computer monitors within the entire Philips group, and it is among the three largest producers worldwide[48]. Similarly, Philips played a critical role in the successful launching of Taiwan Semiconductor Manufacturing Corporation (TSMC) which today is the world's leading silicon foundry.

In 1962, Matsushita followed suit with a large majority-owned joint venture in Keelung that produced both household appliances and consumer electronics, primarily TV sets.[49] Until the mid-1980s when the group established a network of huge export platform affiliates in Malaysia and Thailand, this was one of Matsushita's main outposts

[48] Philips Taiwan´s integrated monitor facilities were singled out by Cor Boonstra, Philips` president, as one of the core activities of the group, as it "supplies leading brands." Quoted from: "Philips strategy on electrical goods a year away", Financial Times, February 14, 1997

[49] NEC actually was the first Japanese electronics company to set up a production affiliate in Taiwan: in March of 1958 it established a small plant assembling communication equipment for the local market.

in East Asia.[50] Matsushita´s affiliate has been a *trend-setter* for Taiwan in factory automation (especially for printed circuit board assembly) and for the introduction of fastidious quality control management (The Japan Economic Journal, December 9, 1989, p.37). In addition to being an incubator for local suppliers, Matsushita established Matsushita Electric Institute of Technology in 1981. With a work force of around 40 researchers, the institute's main functions are ASIC design and software engineering, especially the development of Chinese-language application programs.

Matsushita has also given rise to a broad range of knowledge spill-overs to local companies, through both employment mobility and the formation of local start-up companies. One particularly interesting example is the case of Fulet Electronics Industrial Co. Ltd., a producer of high-end consumer electronics (Author´s interviews and Gold, 1986). The owner of this company is the son of C.C. Hong, Matsushita´s original local joint venture partner. For many years, C.C. Hong served as the chairman of Matsushita Electric (Taiwan). Yet, despite his 40 percent share in the venture's capital, Japanese managers were clearly running the show. Hong was given a free hand to build up close technical and business ties with several hundred local suppliers. Building on his father's unbeatable connections within the local Taiwanese supplier community, Hong Junior (Hong Ming-t`ai) pursued a niche market strategy. By sourcing out a large part of manufacturing, Fulet can concentrate on design and product development. Two figures are revealing: Fulet claims to spend roughly 15 percent of sales on R&D; and it classifies 15 percent of its 800 employees as R&D personnel.[51] This example shows how a Taiwanese start-up company can exploit the domestic supplier networks that were originally established for Matsushita, in order to further its knowledge creation.

Matsushita´s smaller rival Sanyo[52] established its own production line in 1963, with a roughly similar product mix as Matsushita's, followed by Hitachi in 1965 and Sony in 1967. These Japanese firms also developed close links with local suppliers, but focused much longer on the domestic market; export platform production remained the exception.[53] Because the domestic market strategy could tolerate a certain degree of inefficiency and lower quality standards, Japanese consumer electronics affiliates in Taiwan had considerable decision autonomy not only for employment, work practices and salary, but also on how to organize production and procurement. A considerable amount of local linkages was generated by these investments: local content was substantial, and gave rise to some domestic support industries, especially for low-end

[50] Until March 1989, Matsushita had invested roughly $500 million in its Taiwan affiliate which then employed 5,300 local workers and recorded sales of Yen 73.7 billion. The Japan Economic Journal, July 1, 1989, page 4.

[51] While these figures may be somewhat exaggerated, industry insiders confirm that Fulet does concentrate on higher-end support services relative to manufacturing. The company adds value through sophisticated design features and thus is able to charge premium prices.

[52] Sanyo's founder was the brother-in-law of Konosuke Matsushita, who took over most of the operations of the Matsushita group when it was broken up under the U.S. Occupation Authority. In Japan, Sanyo always remained a second-tier competitor. One way of compensation has been an aggressive shift early on into international production. Sanyo´s move to East Asia preceded that of Matsushita. It also started much earlier with fully integrated local assembly. Ernst, 1997a.

[53] This is in line with a general tendency of Japanese electronics firms to postpone the shift from exports to offshore export platform production till the catalytic effect of the Yen appreciation in 1985 finally forced them to establish export platform production lines in Southeast Asia. See Ernst, 1997a.

general purpose components[54]. All of these were powerful mechanisms for inter-organizational knowledge creation.

Toshiba pursued a different strategy[55]. During the 1950s, it acquired a five percent equity share in Tatung Co., Taiwan´s only integrated electronics company. Originally Tatung served as an agent of Toshiba, selling its home appliances, consumer electronics and telecommunications equipment. In the 1960s however, Toshiba granted a number of technology licenses to Tatung, which became a supplier of key components, such as high-end compressors, CRT picture tubes and LCDs. This, in turn, led to other forms of cooperation. In the mid-1970s for instance, Toshiba helped Tatung to capture OEM orders from Sears (the large US mass merchandiser), with the result that Tatung became one of the largest Taiwanese television exporters to the US. Tatung and Toshiba are now also engaged in a variety of OEM and technology cooperation agreements, involving monitors and other PC-related products.

During the 1970s, Fujitsu followed with a similar approach: in 1973, it established a joint venture with Tatung to sell and service Fujitsu computer systems and peripherals. This subsequently led to a variety of manufacturing joint ventures and OEM contracts, including FDK Tatung (Thailand) Co. LTD/Bangpakong, an affiliate of Tatung's joint venture with Fujitsu, called Tatung Fujidenka Co. Taiwan. The mother company is in Yangmei, Taiwan and produces high-end soft ferrit cores for TV sets, video display terminals and a variety of electronic devices. FDK Tatung today is one of the market leaders for the capital and knowledge-intensive production of soft ferrit cores. The sales of this affiliate are mainly destined for affiliates of National (Matsushita), JVC, Murata and Tatung's Makolin affiliate in Thailand and Malaysia.[56]

Components

The first round of investment in consumer electronics and telecommunications equipment gave rise to a rapid growth in demand for electronic components. While most of the high value-added key components were imported, stringent local contents requirements and increased local capacities resulted in the growth of local production. Starting from the mid-1960s, Taiwan received substantial Japanese FDI in the production of electronics components.

The pioneer was Mitsumi Electric Corp., a medium-sized component producer. In 1967, its first affiliate was established in Kaohsiung, producing condensers, transformers (including coils), connectors, electro-mechanical subassemblies and other components. Two years later, in March 1969, this was followed by a second affiliate in Taipei, producing magnetic heads, small motors, plus a variety of subassemblies and other components. Similar investments were undertaken by TDK in 1968 (condensers, transformers and other components); by Hosiden in 1969, an Osaka-based producer of electromechanical components; by Mitsubishi Materials in June 1970 (condensers); and

[54] This however came at the expense of cost efficiency and quality which, due to the heavy protection provided to the domestic market, were only of secondary concern.

[55] This arguably results from the fact that Toshiba resembles the Siemens and Hitachi model in its relatively broad -based product mix that covers heavy electrical equipment, industrial electronics as well as consumer electronics.

[56] Tatung´s Makolin affiliate in Malaysia is an interesting case which indicates what unusual forms of international cooperation are possible today. It is a joint venture between Tatung's affiliate Chunghwa Picture tubes and the Korean Dugo Electronics Company. Its main products are deflection yokes for 14, 20 and 21-inch color tubes. Again, this affiliate supplies Tatung's affiliates in the region as well as affiliates of Japanese TV set makers.

by Alps in 1970 (resistors, magnetic heads and other devices). In the 1970s, most of the leading Japanese component producers set up shop in Taiwan or were engaged in consignment assembly with a growing share of output going to Japan or Japanese affiliates in Asia. In response to the combined effect of the Yen appreciation and the domestic recession, Japanese electronics firms developed a regional supply base in the early 1990s that now include higher-end components (Ernst, 1997a). These investments played an important catalytic role for knowledge creation in Taiwan´s domestic supplier industry, through intense on-the-job training and employment turnover as well as through close linkages with local subcontractors.

Taiwan however has also now become a critical market for components and production equipment, especially for the computer industry and for the production of semiconductors, CRT picture tubes and displays. One consequence is that Japanese component manufacturers have extended the mix of products that they produce in Taiwan to include an increasing variety of computer-related components. This has helped to upgrade knowledge creation. For instance, both Sharp and Casio are today producing substantial volumes of mid-level STN-LCDs[57] in Taiwan. Similar developments have occurred in semiconductors: second-tier Japanese DRAM producers like Oki and Mistubishi Electric Corp. (MELCO) have recently concluded important technology licensing, second-sourcing and joint development projects with some of the newly established Taiwanese DRAM producers. The same is now happening for large-size CRT picture tubes.

As Taiwanese component manufacturers have broadened their knowledge base, Japanese firms are willing to engage in joint ventures and co-development projects; this has led to substantial investments by Japanese production equipment vendors. For example, Japan's Shinetsu Handotai Co. has a 40 percent share of Taiwan's market for silicon-wafer chips. The company's customers in Taiwan no longer want to depend on imports from Japan or from Shinetsu's affiliate in Malaysia, and insisted that Shinetsu establish a wafer fabrication plant in Taiwan. Given the huge demand from Taiwanese customers, Shinetsu complied and established a majority-owned $110 million joint venture in silicon-wafer fabrication. A second stage involving an additional $70 million investment is already planned. Shinetsu claims that, in terms of the technology used, "..there will be no difference between the factories in Taiwan and in Japan".[58]

FDI in the computer industry

All of the investments reviewed so far have been in consumer electronics and component manufacturing. But what about FDI in the computer industry itself? In the early 1960s, IBM established an affiliate in Taiwan, where a few thousand people were employed wiring core frames by hand.[59] IBM´s move to Asia did not occur in isolation: its competitors also established core plane wiring operations in Taiwan and Hong Kong (Harman, 1971). IBM thus gave rise to a new model of international production for

[57] The super-twist-nematic liquid crystal display (STN-LCD) has lower contrast, a worse viewing angle, and a slower response time than the more advanced thin-film-transistor (TFT) LCD, but is less expensive to produce.

[58] Interview with Richard Kuo, president of Topco Scientific, the Taiwan agent for Shinetsu, in FEER, 10/12/95, p.66

[59] Pugh, 1984, pages 250-251 "It was slow, tedious, meticulous work, stringing wires in just the right manner through each of the thousands of tiny cores in each core plane. But the cost of labor there was so low that it was actually a few dollars [per unit] cheaper than with full automation in Kingston (New York state)."

American electronics firms: the redeployment of labor-intensive stages of final assembly to Asia. These investments however consisted of primitive "screw-driver" assembly and thus generated very limited localized knowledge (Ernst, 1983).

The next round of computer-related FDI did not take place until the early 1980s. In 1982, DEC established a large integrated affiliate in Taiwan to produce a broad range of products: PC motherboards and chassis, monitors, terminals and printers. Today, DEC Taiwan is the company's largest assembly line for desktop PCs. It is also Taiwan´s largest foreign-owned PC manufacturer, employing 1600 people in March 1995. For Taiwan, DEC´s investment had important positive effects on knowledge creation, through training as well as through the development of local suppliers. For instance, DEC Taiwan is a major OEM buyer of monitors from both Philips Taiwan and the Lite-on Group. DEC also sources a broad range of peripherals and components from local Taiwanese companies.

DEC´s investment was followed two years later, in 1984, by Hewlett Packard which established a joint venture with Taiwan´s Nanya Plastics (part of the Formosa plastics group) for producing multi-layered printed circuit boards. This venture involved a substantial transfer of technology and capabilities. On the basis of this successful project, HP has transferred more complex technology and thus has given a major boost to the development of Taiwan´s capabilities in motherboard production. In cooperation with the Ministry of Economic Affairs and with large local conglomerates like the President Enterprises Group,[60] HP Taiwan has aggressively promoted the spread of computer-based factory automation.

Despite these and a few other cases of inward FDI in the computer industry, it is fair to say that such investments have played only a marginal role for the development of Taiwan´s computer industry. Foreign computer companies did make an important contribution. Yet such linkages worked primarily through the rapid proliferation of international outsourcing arrangements: these arrangements include subcontracting, consignment assembly and various forms of OEM contracts,[61] and are no longer confined to parts and components but involve high-value added support services such as product customization, product design and production technology. It is to these global production networks (GPN) that I now turn.

VII. KNOWLEDGE CREATION THROUGH GLOBAL PRODUCTION NETWORKS

[60] President Enterprises is a huge conglomerate that started out in the retail sector and with food processing and that now has established a major presence in China and South East Asia. In 1995, the group acquired the Taiwan operations of the once powerful U.S. Wang computer company. Through its Wang affiliate, President Enterprises has established a joint venture with HP with the purpose of developing Taiwan´s market for factory automation and information networks. (Computergram, April 20, 1994.

[61] Definitions of what constitutes an *OEM* (original equipment manufacturing) contract keep changing. Probably the most widely accepted definition refers to arrangements between a brand name company (the customer) and the contractor (the supplier) where the *customer provides detailed technical blueprints and most of the components to allow the contractor to produce according to specifications*. Using this definition of OEM arrangements, we can then distinguish *ODM* (original design manufacturing) as arrangements where the *contractor is responsible for design and most of the component procurement, with the brand name company retaining exclusive control over marketing*.

American computer companies like Apple, IBM, DEC, Compaq and HP have been pioneers in the subcontracting of component manufacturing, contract assembly, the spread of OEM, and more recently ODM arrangements that enable them to concentrate on what they do best. Japanese computer companies only followed suit during the early 1990s, once their tight grip over their domestic market was challenged by the aggressive price war strategies of American computer companies.[62]

Spatial dispersion

Today, it is normal that the *supply chain* of a computer company spans different time zones and continents. For instance, final assembly is most likely dispersed to major growth markets in the US, Europe and Asia; microprocessors are sourced from the US; memory devices from Japan and Korea; motherboards from Taiwan; HDDs from Singapore; monitors from Korea, Taiwan and Japan: keyboards and power switch supplies from Taiwan, and so forth.

The picture gets blurred however as many of these suppliers in turn ship their products from widely dispersed overseas affiliates. Taiwanese OEM suppliers have shifted a growing share of their production to low-cost production sites in Southeast Asia and China. Since 1992, Taiwan's PC industry has experienced an extremely rapid expansion of overseas production. In value terms, the ratio of overseas production out of Taiwan's total PC production has increased from 10.4 percent in 1992, to 14.9 percent in 1993, 20.6 percent in 1994, and 27.2 percent in 1995.[63] For 1996, this ratio has increased to almost 30 percent. Throughout this short period, annual growth in overseas production value was consistently over 70 percent, which implies that overseas production today plays a critical role for the success and failure of Taiwan's PC industry.

Most of the overseas production of Taiwanese computer companies is concentrated in neighboring regions in China (most of it in China's southern coastal provinces) and in Southeast Asia. For instance, out of the 95 overseas production sites of Taiwanese PC firms that have been registered by the Market Intelligence Center (MIC) of Taiwan´s Institute for Information Industry (III), 75 production sites, i.e. almost 80 percent have been located in East Asia (exclusive of Japan). China alone has attracted 41 investments, i.e. 43 percent of the total (Questinnaire survey by MIC/III, conducted in 1996).

The logistic complexity of the new GPN is not simply a result of their geographic spread; it is also a function of an increasingly *complex division of labor*. Each GPN combines different, hierarchically structured and closely interacting sub-networks. For example, an American computer company such as IBM or Compaq is linked to first-tier contractors, say an American disk drive producer like Seagate with its GPN, or large Taiwanese OEM contractors like Acer. At the next level, we find medium-sized, specialized Taiwanese contractors like Delta Electronics, a major producer of switching power supplies that has production facilities in Thailand, China and Mexico. At the lowest levels, we find a myriad of sub-production networks each centered around a small

[62] Until the mid-1980s, Japanese computer firms were actually major OEM suppliers to American computer companies. We will see in a moment what factors have enabled Taiwanese firms to bypass Japanese companies as leading OEM suppliers.

[63] In 1995, keyboards had the highest overseas production ratio (OPR), with 86 percent of Taiwan´s total production value being produced overseas. Other products with high OPRs are: power switching supply (77%), monitors (almost 50%), motherboards (37%), and mouse devices (24%). For 1966, the greatest increase in overseas production was expected for CD-ROMs and mouse devices.

Taiwanese subcontractor many of which have redeployed production to China or Southeast Asia. The complexity of such arrangements becomes clear when we look at the major customers list of a firm like Delta Electronics (Interview at Delta Electronics, June 7th, 1995). This list reads like a Who's Who in the computer industry and covers 24 leading computer companies from the US, Japan, Europe and Taiwan.[64]

In sum, Taiwanese firms in the electronics industry are deeply embedded in complex global production networks that involve transactions between a large number of different national production systems. The increasing complexity of GPN, however, has also allowed small enterprises from a small nation to participate and upgrade their knowledge base.

Key features of global production networks

What factors have induced computer companies to increase their reliance on outsourcing and hence to establish GPN? For a typical lead company in the PC business, the cost of components, software and services purchased from outside, has increased from less than 60 percent to more than 80 percent of total (ex factory) production costs[65]. As external sourcing relations become geographically dispersed and increasingly complex, they are fraught with very high coordination costs: some firms report that the cost of coordinating such outside relations can exceed in-house manufacturing costs[66]. As a result, the focus of *cost reduction* strategies is shifting from scale economies in manufacturing to a reduction of the cost of external sourcing through rationalization and internationalization.

Outsourcing is also motivated by a *strategic* concern: In order to survive the extremely intense competition that is characteristic of the electronics industry, global competitors are forced to concentrate on product development (architectural design), while at the same time remaining a low-cost producer. In order to meet these goals, firms tend to focus on R&D, the production of some key components, limited involvement in the final assembly of higher value-added products and marketing. By outsourcing most of the other activities, the lead company expects to reduce the high fixed capital costs and risks that result from large in-house production facilities. Finally, the lead company may exploit competition among potential suppliers to reduce production costs.

What are the interests of small suppliers from Taiwan? Participating in a GPN can provide various advantages, despite the continuing pressures for cost cutting (Ernst and Ravenhill, 1998; Ernst and O`Connor, 1989 and 1992; and Ernst 1994b). Manufacturing on an OEM basis is a significant source of knowledge creation for affiliated firms. Not only do foreign purchasers supply specifications for OEM suppliers, they also frequently send their engineers to help local manufacturers to meet quality specifications. Knowledge is thus transmitted in OEM production not only through the supply of blueprints, but also through the interaction of personnel and the transfer of more elusive, tacit dimensions of technology (Bell and Pavitt, 1993; and Ernst and Lundvall, 1998).

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[64] Acer, Alcatel, AST, Apple, Canon, Compaq, DEC, Epson, Hewlett Packard, Hitachi, IBM, Intel, Microtek, Matsushita, Mitsubishi, Motorola, NCR, NEC, Philips, Rockwell, Synoptics, Tatung, Thomson, and Toshiba.

[65] These and the following figures are based on company interviews, as reported in Ernst and O'Connor, 1992, pages 34 and 37.

[66] Such costs are typically defined as "... all incremental cost associated with dealing with suppliers remote from the initial design site and/or the final assembly site", with communication costs and administrative overheads absorbing the largest share (Ernst and O'Connor, 1992, ibid.)

Once the supplier has acquired the relevant technology and technical expertise, he may be able to use them in manufacturing components or final products on an OEM basis for other multinationals. Taiwanese firms often participate in more than one GPN. By manufacturing for a number of assemblers on an OEM basis, they can achieve economies of scale; longer production runs in turn justify the installation of capital equipment (and thus often better quality control) which otherwise would not be warranted. Furthermore, the provision of letters of credit by the foreign purchaser can enable the local manufacturer to borrow additional capital that can be invested in knowledge creation.

Another advantage for small suppliers is that participation in a production network avoids the expense of building distribution, sales and service networks. The costs of acquiring knowledge about foreign consumer preferences, and of setting up the distribution and service networks that are essential for penetrating foreign markets, pose a formidable challenge even to large multinationals. This is particularly true in Japan. Moreover, a move to own-brand production risks a disruption of the technological links with purchasers established under OEM relationships. Firms seeking to produce under their own brand name frequently find it more difficult to obtain technical advice from companies that increasingly perceive them as rivals.

Manufacturers may gain a price premium from marketing under their own brand name, but this premium may be negative if consumers associate the brand with poor quality. Korean exporters of consumer electronic products appeared to suffer this fate in the Japanese market in the late 1980s, when inferior products coupled with inadequate service networks damaged the reputation of Korean manufacturers. Regardless of the quality of the product, the identity with Korea or Taiwan may itself impose a penalty on manufacturers, while the location of manufacture is much less transparent when another firm's brand appears on the product.

Marketing products under the firm's own brand name may place a company at the apex of the pyramid of technological and marketing capabilities, but Taiwanese companies have found that the costs incurred in setting up distribution, sales and service networks can outweigh the higher unit profits from OBM. In the 1990s, there have been significant examples of a retreat from OBM, one of the most notable being the Taiwanese computer company, Acer, which sustained significant losses in its efforts at own-brand sales in the US market.[67]

As they upgrade their production skills and capabilities, small suppliers are often able to change the bargaining relationship with the multinationals. There is evidence of Taiwanese firms moving from OEM to ODM, although still producing components or final products for sale under another company's brand name. In such circumstances, the balance of bargaining power between supplier and purchaser shifts with the buyer becoming increasingly dependent on the skills of the local company. The ideal scenario from the perspective of the OEM supplier would be that the transfer of skills from the purchaser eventually lead to the hollowing out of the core competencies of the distributing company in the particular product line. This has been alleged to have occurred in the case of Samsung's manufacture of microwave ovens for GE (Magaziner and Patinkin, 1989).

Taiwan’s participation in global production networks

Participation in international production networks has been of critical importance for the development of a highly flexible domestic supply base and its continuous

[67] This will be discussed later.

upgrading. Manufacturing on an OEM basis has been the most important of such linkages. Taiwan´s involvement in the OEM business has gone through different incarnations, from very simple arrangements to highly complex ones. Each of these has displayed a peculiar pattern of knowledge creation.

Taiwan´s entry as a supplier for the international computer industry dates back to the mid-1960s. The breakthrough came in 1966 when IBM set up its International Procurement Office (IPO) and started to purchase computer parts and components from Taiwan. IBM's demanding procedures for product development, production ramp-up and quality control as well as its grueling 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. These visits included countless missions by IBM engineers sent from the US or other affiliates of IBM's global production network.[68]

Being an IBM supplier has been a great asset to many Taiwanese firms: buyers feel that they can trust a supplier who has been able to cope with the stringent IBM procurement requirements. Going through an IBM apprenticeship thus has helped Taiwanese firms to overcome their negative image of unreliability and shoddy quality. It has helped them to win more orders from other foreign computer companies.

Over the years, IBM has considerably expanded its OEM purchases from Taiwanese sources, especially for monitors, motherboards, power supplies, mouse devices and laptop computers; other American computer manufacturers followed suit. IBM now procures around $500 million annually from Taiwanese computer companies.[69] Nonetheless, Taiwan had to wait until the early 1980s before it was able to establish itself as a credible supplier. Through the 1970s, Japanese firms continued to control the higher-end of the international OEM market, and Korean chaebol occupied the lower-end market segments. Two external developments served to change this situation.[70]

The first occurred in 1982 when the Taiwanese government responded to American pressure and declared the cloning of Apple II computers and video games illegal. With the benefit of hindsight it is obvious that this move actually accelerated the move of Taiwanese firms to clone IBM PCs, which remained legal. These developments coincided with dramatic changes in the computer industry that created a window of opportunity for low-cost producers.[71] In contrast to mainframe and mini-computers, PC design is based on standard microprocessors and operating systems. As a result, computers became *mass-produced, standardized products (commodities)*. Barriers to entry to final assembly are low and the key to success for any "cloning" strategy lies beyond manufacturing. A critical factor is *time-to-market*: the PC vendor needs

[68] According to one source at IBM Taiwan, the mother company dispatched over 400 such missions during the 1980s in order to assist Taiwanese suppliers. (Author´s interview at IBM Taiwan)

[69] It buys monitors from Philips Taiwan and Sampo; motherboards from GVC, Elite and Lung Hwa; power supplies from Delta and Sun-Moon-Star and laptops from ASE.

[70] The following is based on Callon, 1994; Wong Poh Kam, 1995 and author´s interviews in the Taiwanese computer industry since 1987.

[71] The following account is based on Flamm, 1988; Ernst and O´Connor, 1992, chapters II and IV; Langlois, 1992 and Ernst 1997b.

guaranteed access to reasonably priced key components and the most up-to-date operating system; and its supply base for motherboards and other components must be able to respond fast and flexibly. Coping with the first prerequisite required close links with Intel and Microsoft, while the second prerequisite was perfectly matched to Taiwan's domestic supplier structure.

A second external factor facilitated Taiwan´s entry into the international OEM business. In 1987, the US government imposed punitive tariffs of 100 percent on Japanese PCs, both in response to US-Japanese trade conflicts in semiconductors and as a reaction to a perceived violation of COCOM rules by Toshiba.[72] The punitive tariff on Japanese suppliers allowed the Taiwanese to demonstrate to American computer companies that they could replace the Japanese suppliers with good products at good prices, and that they could even deliver more quickly. Although the tariff was removed one year later, it was by then too late for Japanese computer companies to recover their lost share in the rapidly moving OEM market.

Evolutionary aspects of knowledge creation: opening the blackbox of OEM

Taiwan´s subsequent involvement in the OEM business has gone through different stages. Each of these stages displayed a peculiar pattern of knowledge creation. In order to understand these different knowledge effects, we need to open the balckbox of OEM arrangements. An important finding that runs counter to established wisdom (e.g., **Hobday, 1995**) is that successful upgrading does not necessarily require a shift from OEM to OBM (=original brand-name manufacturing). At the beginning, OEM arrangements were very simple, both in terms of the products and the required capabilities. The focus was on low-end desktop PCs and labor-intensive peripherals, like computer mouse and keyboards. The OEM customer provided detailed technical "blueprints" and technical assistance to allow the Taiwanese contractor to produce according to specifications.

There is a broad consensus that Taiwanese firms were able to reap substantial benefits from this *easy* phase of OEM. For example, in a late 1980s survey of 43 Taiwanese OEM suppliers (27 domestic and 16 foreign invested), roughly 70 percent acknowledged that OEM contracts were useful in transferring production technologies and in acquiring product design capabilities (San Gee, 1990, table 4.1). Yet, these simple forms of OEM also had substantial drawbacks. Suppliers became "locked into" OEM relationships that hindered independent brand name recognition and marketing channels. Profit margins are thinner in OEM sales than in own brand sales, which in turn makes it difficult for suppliers to muster the capital needed to invest in R&D required for the development of new products.

In response to these draw-backs, a number of Taiwanese computer companies tried to expand their share of own brand-name manufacturing (OBM) sales. In 1988, for example, the share of Taiwan brand-name to total PC sales stood at roughly 28 percent; by 1989 it had risen to 40 percent (Eurotrade, Taipei, Vol 2, January 1990, p.32). Yet, the transition to OBM turned out to be difficult, and only a handful of companies were able to succeed; most others failed and are now content to consolidate and upgrade their position as OEM suppliers. The result has been a drastic decline of OBM sales out of total Taiwanese computer sales. Most recent figures show that the share of OBM has declined from 34% of all Taiwanese computer hardware sales in 1995 to less than 25% in 1997.

[72] Toshiba`s clandestine sale of a complex numerically controlled machine tool to the Soviet Union, judged to be of high value for arms production, provoked the action.

The story of this upgrading process can be seen through the lens of Taiwan's best-known computer company, Acer.

Acer´s peculiar upgrading experience

Acer's involvement in the PC cloning business dates back to 1983, when it was among the first Taiwanese companies to introduce an IBM XT/PC compatible. In the same year, Acer had organized Taiwan's first International Distributor's Meeting, attended by delegates from over 20 countries. Building strong links with foreign distributors and OEM customers subsequently became an important priority, complementing Acer's strong domestic roots.

The years following 1986 brought a number of early successes. 32 bit microprocessors (MPU) were just beginning to appear on the market, and Acer was able to beat IBM in announcing a 32-bit PC based on Intel's 386 MPU. During the same year, Acer's subsidiary Continental Systems, Inc. (now Acer Peripherals) received two successive Excellence Rewards from ITT, acknowledging the high quality of its OEM products. After changing the company name to Acer in 1987,[73] the company got approval to list on the Taiwan stock exchange in 1988.

Acer's export success was wholly dependent on OEM sales, however. These early triumphs led Acer's management to believe it could reduce this dependence and jump to producing its own brands. In 1988, Acer hired a senior IBM executive to reorganize the company with the explicit goal to transform it into a global competitor. Expectations were running high. IBM was still considered the industry's role model; by copying key features of IBM, Acer expected to speed up its leap-frogging effort. In particular, the idea was to increase the company's vertical integration and generate a critical mass of proprietary assets that would enable Acer to develop its own brand name image.

This effort failed miserably. The IBM manager assumed that change could be imposed from above by forcing consensus on the local management. Such an aggressive top-down approach ran into stubborn opposition by Acer's managers and engineers, who were used to a substantial amount of decision autonomy. Furthermore, Acer simply did not have the resources that are necessary to implement such a strategy.

The peak of leapfrogging euphoria came in 1989, when Acer shipped its one millionth computer, was ranked for the first time by DATAMATION among the top 100 IT companies in the world, was chosen as one of the "corporate stars of the future" by the *Wall Street Journal*; and was chosen by Texas Instruments as its joint venture partner for DRAM production in Taiwan. Insiders knew that TI's decision was based on the lavish financial package that Acer, in cooperation with the Taiwanese government, was able to offer.[74] For a broader public, however, the tie up with T.I. conferred tremendous prestige.[75]

The shift in strategy was supposed to occur quickly. Acer projected that the share of OEM sales would decline from 40 percent of total sales in 1988 to 25 percent in 1992. Not only did Acer intend to compete through its own brand, but it also wanted to broaden its product portfolio. This led to a rapid succession of acquisitions which almost ended in disaster. Acer acquired Counterpoint Computers with the intention of using it to build a

[73] Acer is Latin for "sharp, acute, able and facile".

[74] Texas Instruments` strategy is to choose wafer fabrication locations where most of the investment costs are shouldered by local governments. See Ernst, 1994b.

[75] By 1989, Acer's consolidated sales revenues were less than $690 million and it had around 5,500 employees.

strong position in minicomputers, but the follow-up costs of technology development and marketing were way above Acer's expectations. Counterpoint lost $15 million in 1989 alone, almost as much as the $17 million that Acer had paid for the firm, and the firm was closed down. Undeterred, Acer tried again the following year, by acquiring Altos, an American producer of UNIX-based multi-user systems. At the time, the expectation was that Altos' UNIX experience and distribution channels would help Acer to speed up its product diversification (Business Times (Singapore), 2/11/1992). Bought for $94 million, the firm recorded a mere $125 million in sales in 1990, and was incurring heavy losses. Such losses continued for a few more years, but this time, Acer also benefited. By acquiring Altos, the company was able to develop its computer networking capabilities and to enter the PC server market.[76]

The awakening came in 1991 when Acer posted a loss ($23 million) for the first time. Acer's over-ambitious diversification strategy came at the worst possible moment. The PC industry worldwide was swept by a crippling price war, as a result of which almost all companies faced a serious profit squeeze.

Taiwan's computer industry was particularly hard hit and went through a major shake-out. During the second half of 1991, 50 to 60 Taiwanese computer companies went out of business each month (*China Economic News Service*, 12/4/1991). Most of these firms were small companies. One could argue that this was a healthy development, as it indicated a long overdue consolidation of this industry. Moreover, the disappearance of small firms from a sector under pressure seems to be a fairly normal occurrence in Taiwan; many of them reappear making something else or at a foreign location. Since 1991, however, a number of larger Taiwanese PC companies like Acer were in serious trouble too; some, such as Autocomputer, actually went out of business.

The spread of intense price wars constituted a major challenge for the Taiwanese computer industry, and readjustment came at a heavy cost. The big players pursued aggressive price-cutting strategies, with the result that cost reduction became the most critical issue in the computer industry. This posed a serious challenge for Taiwanese firms. In order to sustain their position as OEM suppliers, they had to implement drastic additional cost reductions at a time when Taiwan's traditional cost advantages were rapidly eroding. Fueled by the appreciation of the NT$, the cost of land and labor in Taiwan exploded in the early 1990s, with the result that *Taiwan lost its comparative advantage as a low-cost production site*. At the same time, Taiwan faced serious competitive threats both from *below* and from *above*. New low-cost competitors have entered the fray in Southeast Asia and China, while South Korea has strengthened its position as a supplier of scale-intensive components, like DRAMs, monitors, CRT picture tubes and display devices. Furthermore, Japanese firms, which have lost market share both at home and in export markets, have now started to fight back and to develop much more aggressive global market penetration strategies.

As a result, Taiwan´s OBM products came under fierce attack. The OBM share of Taiwan´s PC exports fell from 30 percent in 1992 to 22 percent in 1993. Taiwan´s computer industry thus did not have much choice but to fall back on its strength as OEM suppliers: most firms made a conscious effort to consolidate their position in this field.[77]

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[76] A review of high-quality servers for small workgroups concludes that the Acer Altos 800/P is "a solid choice with somewhat weak software" that compares well with the products offered by such industry majors as Compaq, Hewlett Packard and DEC. "Centralized storage. Small workgroup servers—Hardware Review", PC/Computing v.8, n.11 (Nov, 1995):140

[77] See our discussion below.

Acer pursued a different approach. While it consolidated its position as an OEM supplier, it simultaneously continued to pursue an aggressive OBM strategy. Rather than trying to reduce its reliance on OEM contracts, the objective now is to quickly increase the OEM share to 50 percent. This part of the strategy has worked well. For desktop computers, Acer is one of the five Taiwan-based producers that have collectively come to dominate the OEM market: Tatung, Acer, DEC's Taiwan affiliate, FIC and AST's local affiliate. In addition to its strong position in desktop PCs, Acer has also become a major OEM supplier of notebook computers for Apple and Canon. The result has been that, in 1994, the OEM share of Acer's PC sales had risen again to 35 percent.

Acer's strategy is to leverage its OEM business to generate the necessary financial resources to pursue its OBM strategy and to further upgrade Acer´s capabilities, especially in design and computer networking. The logical consequence is a *focus on mass production rather than on niche markets*. Acer´s goal is to become one of the world´s highest-volume producers of peripheral equipment, key components, sub-assemblies and design services, both for Acer's worldwide computer assembly plants and for leading international computer companies like Apple, Canon and Fujitsu. Acer describes its own competitive strength as "...the ability to market affordably-priced products quickly due to innovative production and distribution strategies, a component supply approach, a flexible and independent organization and economies of scale in manufacturing." (The Acer Group Profile 1994, p.4)

Meanwhile, Acer´s OBM strategy tries to combine the following, not always consistent goals: to establish a credible global brand image for a broad mix of "affordably-priced products"; to improve its ability to market such products quickly and to adapt them in response to changing market requirements; to penetrate secondary markets in Asia, Latin America, and elsewhere in order to gain economies of scale; and to use these countries as a test-ground for refining its globalization strategy. In these markets, Acer aims to price its products 10 to 15 percent below Compaq's prices. Gradually, Acer would build its product and marketing capabilities in a few very limited *market niches*. Acer's acquisition of some American computer companies, like Altos, was one element of this approach, but much more important is the shift to digital consumer electronics, and possibly, Acer's pioneering role in the field of software design and distribution. These objectives serve the over-riding concern of developing an independent global brand image.

Until 1995, this dual strategy worked reasonably well: between 1993 and 1995, Acer's share price has almost quintupled.[78] And in 1995, the group's consolidated sales revenues were $5.8 billion, up from $690 million in 1989. This quick and impressive turn-around owes a great deal to sheer luck, and to industry-specific factors that were beyond Acer's control. Probably of greatest importance has been the strong demand for DRAM chips which has pushed up profit margins for this product. Without the windfall profits of TI-Acer's DRAM joint venture, Acer would probably still suffer from its over-ambitious diversification strategy. In 1993, 90 percent of Acer's net earnings were generated by TI-Acer, and its share in Acer's 1995 net earnings was still as high as 45 percent. This however has drastically changed since 1996. As a result of the free fall of DRAM prices, TI-Acer has ceased to act as a cash cow for Acer´s OBM strategy[79].

[78] "Acer's Edge: PCs to Go", Fortune, 10/30/95

[79] In response to the accelerating fall of DRAM prices, Texas Instruments, in 1998, withdrew from this joint venture, and from the DRAM business altogether.

As for Acer's core PC business, profit margins have improved. The surprise success of Acer's multi-media home personal computer in 1994 has helped to improve the company's position.[80] In 1995, Acer became one of the top ten PC suppliers to the US market. Since then however not much has moved. In 1995, the US market still accounted for roughly 26 percent of Acer's worldwide sales, and in 1996 Acer America went into the red again.[81] While Acer retained its top position in a number of rapidly growing, yet still quite secondary markets like Indonesia, Malaysia, Mexico and South Africa, the overall growth of sales revenues for computers has slowed down and Acer has still not succeeded to expand its OBM market share in Japan and China. Margins in the computer business are also low—4 percent—and as a result, Acer´s 1996 net profits were substantially lower than Acer´s own forecast. These results are simply too meager to support Acer's ambitious upgrading strategy (BZW Securities estimate, quoted in the Financial Times, February 10, 1997).

All of this does not imply that Acer´s strategy has failed altogether. Rarely has a company grown so fast, and rarely has a small firm from a small nation been able to build up such a broad range of capabilities and to introduce far-reaching organizational innovations during a relatively short period of time. Yet, it also shows that there is no easy and quick short-cut to success and that leap-frogging is an illusionary concept that should be discarded[82]. Developing a firm's knowledge base is a time-consuming and laborious process: at each stage of its growth, new barriers arise that require a period of consolidation. The more Acer progresses and grows, the more demanding will be the barriers with which it has to cope. This precludes a frontal attack on the market leaders. Attacking from the sidelines is the only realistic option. This is certainly true as long as Acer has not yet reached a size that qualifies it for Fortune 500 membership. The key to Acer´s success is that it has pursued a gradual market penetration strategy: it avoids direct confrontation and pursues markets where the market leaders are not present[83]. Acer´s OBM strategy thus remains primarily focused on non-OECD markets, while at the same time it continues to upgrade its capabilities as an OEM supplier. This shows that Chandler is right in emphasizing the difficulties to overcome the *first mover* advantages of large multinationals (Chandler, 1990). Yet, Acer´s story also shows that a small firm from a small nation can enter and grow in the rapidly moving computer industry, provided that it pursues a realistic market penetration strategy.

The dynamics of knowledge creation in OEM arrangements

Developing a global brand image is costly and involves extreme risks. Acer´s approach to "attack from the sidelines" and to focus its OBM strategy on non-OECD

[80] Its U.S. affiliate was among the first firms to anticipate the demand for home multimedia computers - high-end systems with CD-ROM drives that play compact disc-based software with sharp graphics and stereo sound. Much of this was good luck. Acer just happened to have the right product at the right time ready for the right market. Zielinger, M. "Ace in the Hole. Taiwan's Acer makes surprising comeback in America", Far Eastern Economic Review, 1/26/95, p.52

[81] Sales of its heavily promoted Aspire multi-media PC have stagnated (Far Eastern Economic Review, February 6, 1997, p.60). The Aspire was launched, amidst great fanfare, in September 1995. It was praised for its innovative design which includes a monitor integrated with a stereo speaker system and microphone, and was meant to herald Acer´s successful transformation into a global consumer electronics company. For a description of these aspirations, see cover story on Acer, Far Eastern Economic Review, July 25, 1996, pages 74-80.

[82] For an early critique, see Ernst and O`Connor, 1989, chapter II

[83] Kotler et al, 1985, remains the classic source.

markets is one realistic response to this dilemma. As for market penetration in the US, Japan and Europe, Taiwanese computer firms will have to rely however for quite some time on OEM contracts. This is why upgrading Taiwan´s OEM position is currently the appropriate strategic priority. Let us look at some examples.

Since 1993, Taiwan became the main OEM supplier of PC-related products for leading American and European computer manufacturers and distributors. Compaq for instance now sources its monitors from ADI, Philips Taiwan and TECO; notebooks from Inventa, power supplies from Lite-on and Delta, and mouse devices from Logitech Taiwan and Primax. Probably the most interesting arrangement is that with Inventa, a company that has earned a reputation for innovative notebook design and that has already supplied notebooks on an ODM basis to Dell and Zenith, now an affiliate of the French computer firm Bull. Inventa is part of the family-owned Inventec business group that is involved in a wide range of products and services, but is most well-known for calculators and telephones. In 1994, the group's consolidated revenues were $450 million, with Inventa contributing more than one third. Inventa has only a few hundred employees in Taiwan, with a large share of engineers.

As part of the Inventec group however, Inventa has access to low-cost volume production facilities that the group has established in China and Southeast Asia, primarily Malaysia. A second attraction of such networks are the sophisticated quality control procedures characteristic of Inventec´s manufacturing facilities. For the last 15 years, Inventec has made Texas Instrument's calculators and had to cope with TI´s stringent quality requirements. But probably the most important reason for Compaq to link up with Inventa are the company's specialized design capabilities for notebook computers (Wall Street Journal, February 3, 1995, p.B69). In 1994, Compaq was only fourth in the notebook market behind IBM, NEC and Toshiba. By using Inventa´s notebook design, Compaq expected to be able to leapfrog the market leaders, without being forced to commit its own limited engineering resources.

Logitech Taiwan provides another illustration of how complex global production networks have become in the computer industry; it also highlights the high volatility of the OEM business and the need to continuously upgrade product mix and capabilities (Jolly and Bechler, 1992 and author´s interviews). Founded in 1981 in Switzerland and incorporated a few months later in the US, Logitech is the world's largest producer of computer tracking devices (mice and trackballs). In 1987, Logitech shifted production to Taiwan and established a large volume production line in Hsinchu Science Park. Taiwan´s main attraction was that it offered a well-developed supply base for parts, qualified people, and a rapidly expanding PC industry. In 1995, however, Logitech shifted all of its production from Taiwan to China. The result has been a drastic decline of Taiwan´s share of the global mouse market from almost 75 percent in 1994 to 65 percent in 1996. At the same time, Logitech continues to use the same Taiwanese suppliers that have now set up shop close to Logitech`s new location in China.

Compaq provides another example of the increasing complexity of Taiwan´s OEM arrangements. In a recent *"turnkey production"* contract with Mitac, Compaq has out-sourced all stages of the value chain for some of its desktop PCs, except marketing for which it retains sole responsibility. Other foreign computer companies have followed Compaq's example. For instance, IBM has recently signed a preliminary agreement with the Acer Group where Acer will use its global production network in developing countries to assemble lower-end IBM desktop and laptop PCs and to distribute and service them. *Turnkey production* arrangements constitute an important innovation, and show how

rapidly OEM relationships have moved beyond production to encompass an increasing variety of knowledge-intensive, high-end support services. The spread of such broad cross-value chain arrangements shows that leading foreign computer companies are confident that Taiwan´s computer industry is now sufficiently well integrated to serve as a one-stop shopping center.[84]

Japanese PC manufacturers have also drastically increased their OEM contracts with Taiwanese firms for desktop PCs, motherboards, terminals and monitors, and a variety of other PC-related products. NEC for instance gets monitors and motherboards from Tatung and Elite, Fujitsu has relied primarily on OEM supplies from Acer, and Epson, Canon, Hitachi, Sharp and Mitsubishi have all become major OEM customers. In 1994, this was followed by a massive increase of OEM contracts for notebook computers.

As a result of these developments, the share of OEM/ODM out of Taiwan's total desktop PC production has increased, in volume terms, from 37 percent in 1995 to 53 percent in 1996. For notebook PCs, the share of OEM/ODM reached 82 percent in 1996.

Upgrading is possible *within* the OEM trajectory

It is important to emphasize that these developments benefit rather than harm Taiwan´s computer industry. This reflects important changes in the competitive dynamics of the computer industry: Paradoxically, an *increasing concentration* of the global computer industry has been accompanied by a *growing reliance on global outsourcing:* the top five industry leaders, which are all Taiwan´s OEM clients have increased their global market share from roughly 20% during the early 1990s to almost 50%. Their main strength is the definition of architectural standards and their global brand image. These global market leaders are at the cutting-edge of product development, but they outsource almost everything else. Close interaction with these industry leaders provides Taiwanese firms with a constant flow of precious feedback information on product design, new architectural standards, leading-edge production technology, and sophisticated quality control and logistics procedures. Close links with these industry leaders acts as a powerful vehicle for a further strengthening of the learning and innovation capabilities of Taiwanese computer firms.

We have seen that OEM contracts have now become much more demanding: they require a broad range of sophisticated capabilities that cover most if not all stages of the value chain. Taiwanese firms now need to provide more sophisticated services, including design and global supply chain management.[85] While in 1993, roughly one half of all PCs supplied by Taiwanese OEM suppliers were based on Taiwanese designs, this share today has increased to more than 70 percent.[86]

Of even greater importance is a tendency to extend OEM contracts to comprise an integrated package of higher-end support services, as illustrated in the *turnkey production* contracts of Compaq with Mitac, and of IBM with Acer. This implies that, with the exception of hard-core R&D and strategic marketing, Taiwan's OEM

[84] For IBM, Acer´s main attraction is its "global operations", its strong presence in developing countries, and its "ability to tailor its products to each market." IBM intends to buy in up to $2 billion worth of PCs over a period of three years. The Wall Street Journal, December 6, 1996

[85] For the concept of *global supply chain management*, see Lee and Billington, 1995, and Levy 1995

[86] Design, in this context, includes the capacity to make quick changes in the configuration of motherboards in order to be able to integrate the latest microprocessor generation. While this is a very demanding requirement, it is quite different from the capacity to define architectural standards and create new markets.

supplier community must be able to shoulder all steps in the production chain and the coordination functions necessary for global supply chain management.

A major prerequisite for Taiwanese firms is a capacity to assist foreign OEM customers in the management of their global supply chain. All the leading computer companies have drastically rationalized their global supply chain and are moving rapidly toward order-based production. In their choice of OEM suppliers, they demand a capacity for just-in-time delivery: for Taiwanese suppliers, this implies that speed and flexibility of response are critical; Taiwanese suppliers also must establish their own global network of plants and sales affiliates in close proximity to major computer markets. In other words, organizational innovation is of increasing importance and can go a long way in compensating for weaknesses in technological innovation (Pavitt, 1998).

Impact on industry structure

These fundamental changes in OEM relationships are producing a new division of labor between large Taiwanese computer majors and SMEs. Large firms appear to rely more on OEM contracts, while SMEs are much more active in ODM. For instance, OEM orders for desktop computers are all concentrated on a select group of large companies, i.e. Tatung, Acer, DEC Taiwan, FIC and MITAC. The same is true for other scale-sensitive products such as monitors and modems. This sounds counter-intuitive, but OEM contracts come in large orders; they typically generate razor-thin profit margins. Economies of scale and scope are of critical importance, and large firms are better placed to reap such economies. Time and again, we thus find that Chandler's insistence on the continuous importance of scale and scope economies makes perfect sense, even in a fast moving sector like the computer industry (Chandler, 1990, last chapter). Moreover, only a large firm can avoid becoming overly dependent on one particular customer.

Smaller firms may find it too risky to depend on large OEM contracts, as each of these contracts normally surpasses their maximum production capacity. They prefer to shift to ODM contracts where they have greater chances to sustain a diversified customer base and charge higher prices. In other words, SMEs are under *greater pressure relative to large Taiwanese firms to improve their design capabilities to become credible niche market players* within the overall OEM market. Many of these SMEs will not succeed, but those that do have good chances to grow and to improve their competitive position.

CONCLUSIONS

This paper has introduced an alternative conceptual framework that centers on the *co-evolution of domestic and international knowledge linkages*. This framework allows us to analyze what permits small firms to compete in globalized high-tech industries. The paper demonstrates that *inter-organizational* knowledge creation is critical for small firms that compete in the computer industry. If well organized and managed, such external knowledge linkages can effectively compensate for some of the original size-related disadvantages of small firms, at least for a certain period of time. The paper however also shows that external linkages are *no substitute for intra-organizational knowledge creation*. This confirms Edith Penrose´s observation that "... a firm´s rate of growth is limited by the growth of knowledge within it." (Penrose, 1959/1995, Foreward to the 3d edition, pages XVI and XVII.

The paper also emphasizes that inter-organizational knowledge creation is *not confined to regional clusters or to the nation state*. In industrialized countries, many of these external knowledge linkages are with *domestic* organizations. This is very different for a small developing country. When Taiwan began to enter the computer industry during the late 1970s, domestic linkages did not exist or were at best embryonic. International linkages thus were initially of primary importance. This is in line with the findings of research on technological learning in developing countries[87]. Two types of international linkages have been distinguished: inward FDI and the participation of Taiwanese firms in global production networks established by foreign electronics companies. Inward FDI has played an important catalytic role for knowledge creation during the early phase of the development of Taiwan´s electronics industry.

Participation in global production networks has been of critical importance for the development of a highly flexible domestic supply base and its consequent rapid internationalization. Manufacturing on an OEM basis has been the most important of such linkages. Taiwan´s involvement in the OEM business has gone through different stages. Each of these stages displayed a peculiar pattern of knowledge creation. It started with very simple OEM arrangements that covered low-end desktop PCs and labor-intensive peripherals. The OEM customer provided detailed technical "blueprints", components and technical assistance to allow the Taiwanese contractor to produce according to specifications.

Most of the literature has focused on this easy phase of OEM: there is a broad consensus that, during this phase, Taiwanese firms were able to reap substantial benefits. In response to their draw-backs, a number of Taiwanese computer companies have tried, during the early 1990s, to expand their share of own brand-name manufacturing (OBM) sales. Most of them failed and are now content to consolidate and upgrade their position as OEM suppliers. This is hardly surprising: developing a global brand image is costly and involves extreme risks; it is way beyond the reach of most Taiwanese companies, with the possible exception of some larger companies like Acer. The paper tells the story of these truncated upgrading attempts. It is shown that, *paradoxically, this increasing reliance on OEM arrangements has had positive effects for knowledge creation in Taiwan´s computer industry*. Contrary to established wisdom, successful upgrading does not necessarily require a shift from OEM to OBM.

All of his implies that requirements for knowledge creation have become much more demanding: Taiwan's OEM supplier community must now be able to master all steps in the production chain, with the exception of hard-core R&D and strategic marketing. In addition, Taiwanese OEM suppliers must be able to perform for their customers *coordination* functions that are necessary for global supply chain management.

The paper also emphasizes that benefits from international linkages do not come automatically. Of critical importance are *government policies* that have created a set of innovative institutions and incentives conducive for inter-organizational knowledge creation. Of equal importance were a variety of *domestic linkages* that range from informal peer group networks to a variety of innovations in firm organization that attempt to combine the scale advantages of large firms with the speed and flexibility of smaller firms. It is shown that, contrary to conventional wisdom, large firms have played a central

[87] This research has clearly established that successful late industrialization critically depends on the international sourcing of knowledge. Examples include Dahlman, Ross-Larson, and. Westphal,[1987; Bell and Pavitt,1993; Nelson. and Pack, 1995;Kim Linsu 1997; Lall, 1997; Ernst and Lundvall, 1998; and Ernst, Ganiatsos and Mytelka, 1998.

role in the coordination and development of the Taiwanese computer industry; they have also acted as important sources for knowledge creation in small firms.

Future industrial upgrading requirements

The great advantage of Taiwan´s computer industry has been the incredible *speed* with which it has been able to respond to changes in markets and technology. Such quick response and flexibility now needs to be supplemented with *industrial deepening*—the development of a domestic supply base for key components and improved product differentiation capabilities. The rapid expansion of production capacity and international market share for PC-related products has not been fully matched by industrial deepening. For most of the key components that determine the price and the performance features of its major export products, Taiwan continues to rely heavily on imports, primarily from Japan.

Picture tubes for computer monitors provide an example: nearly two thirds have to be imported, either from Japan or from Japanese affiliates in Southeast Asia. The situation is equally severe for display panels, a key component for Taiwan´s thriving portable PC industry. Taiwan has to import virtually all of the high-end flat panel displays that are used in its portable PCs, and the supply of these devices is controlled by a tightly knit oligopoly consisting of Sharp, a Toshiba-IBM joint venture and NEC, with Hitachi and Matsushita being important second-tier producers. This heavy dependence on component imports from Japan has been the root cause for Taiwan´s exploding electronics trade deficit with Japan: Taiwan´s trade deficit in components is currently responsible for around 70 percent of its total electronics trade deficit with Japan (Ernst and Guerrieri, 1998)

Obviously, this is a crucial challenge for Taiwan´s electronics industry: it requires a further upgrading of Taiwan´s knowledge creation management. Apart from strengthening their domestic R&D capabilities, Taiwanese firms also need to locate R&D labs as listening posts abroad in the relevant centers of excellence in the US, Japan and Europe. To do this requires a variety of joint ventures and strategic alliances with major international electronics firms. Simultaneously, a concerted effort is required to move beyond an exclusive focus on hardware production and to complement this with attempts to strengthen domestic capabilities in software and information services industries.

All of this will require time. What matters is that Taiwan has succeeded to developing a critical mass of knowledge and capabilities that will help this small island economy to cope with future challenges. The Taiwanese model in the computer industry provides clear evidence that small enterprises can succeed in global competition, provided they can rely on inter-organizational knowledge creation.

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