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Global Production Networks in East Asia's Electronics Industry and Upgrading Perspectives in Malaysia

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GLOBAL PRODUCTION NETWORKS IN EAST ASIA'S ELECTRONICS INDUSTRY AND UPGRADING PERSPECTIVES IN MALAYSIA

by

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Introduction

East Asia´s catching-up in the electronics industry during the late 20th century provides a fascinating example of the catalytic role that linkages with foreign firms can play for industrial development (e.g., Borrus, Ernst, Haggard, 2000; Ernst, 1997a): an early integration into GPNs has provided Asian producers with access to the industry`s main growth markets, helping to compensate for the initially small size of their domestic markets. Network participation also provided new opportunities, pressures and incentives for Asian network suppliers to upgrade their technological and management capabilities (Ernst and Kim, 2002). As a result, East Asia has emerged as the dominant global manufacturing base of the electronics industry, especially for assembly and component manufacturing.

This growth pattern has survived the 1997 financial crisis (Ernst, 2001a). The "New Economy" boom in the U.S. provided an additional boost, increasing demand for Asian electronics exports[1]. But there are limits to export-led growth and recent transformations of GPNs force us to reconsider the region's IU perspectives within these networks. The downturn in the

[1] The size of this investment-led demand boost for Asian exports can be gathered from the following data: Almost half of the U.S. capital investment since 1997 went into information technology, up from less than 24% during the early 1990s. And roughly 40% of the US consumption of computers and semiconductors is imported, largely from East Asia .

global electronics industry since late 2000 has brutally exposed the downside of export-led industrialization: a country is more vulnerable, the higher the share of electronics in its exports, the greater its integration into GPNs, and the more the country depends on exports to the US.

There is a broad consensus that an upgrading of East Asia's electronics industry is overdue (e.g., Ministry of Information and Communication, 2002, on Korea; Chen, 2002, on Taiwan; Toh, 2002, on Penang/Malaysia; Ariffin, 2000, on Malaysia; Simon, 2001). Defined as a shift to higher value-added products, services and production stages through increasing specialization and efficient domestic and international linkages, industrial upgrading (IU) necessitates a strong domestic knowledge base (e.g., Ernst, 2002d). Building on existing strengths in volume manufacturing, IU requires the development of complementary skills and capabilities in design and development (including new product introduction), as well as in "embedded" software, SOC design, IP trade, system integration, and in the management of resources, supply chains and customer relations. Of critical importance is a capacity to bring in at short notice specialized experts from overseas who can help bridge existing knowledge gaps and who can catalyze necessary changes in organization and procedures required to develop these capabilities locally.

Successful upgrading raises daunting challenges, chief among them are substantial investments in long-term assets, such as specialized skills and capabilities. This chapter explores how East Asia's upgrading perspectives in the electronics industry are affected by three important transformations in global production networks (GPNs): i) *vertical specialization*: the emergence of increasingly complex "networks of networks" that juxtapose "original equipment manufacturers" (OEMs) and global, U.S.-based "contract manufacturers" (CMs); ii) coordination *& contents*: the increasing use of digital information systems to manage these networks, and to build "global information service networks" (GISN) that complement networks centered on manufacturing; and

iii) *location*: the emergence of China as a priority investment target for GPNs in the electronics industry.

We argue that these transformations of GPNs provide new opportunities for IU, as barriers to international knowledge diffusion are gradually reduced. We also emphasize that rising requirements for participation in these networks are putting pressures on mid-sized countries and especially local small-and medium-sized Asian suppliers. We illustrate the difficulties of devising realistic upgrading strategies, and discuss policies and support institutions that could help to successfully implement these strategies.

It is difficult in one paper to consider the entire range of upgrading perspectives that face the countries of East Asia. We focus on Malaysia[2], a country that faces a particularly demanding challenge, due to four peculiar characteristics of its electronics industry: First, Malaysia exceeds most other Asian electronics producers (with the exception of Singapore), in terms of its vulnerability to the vicissitudes of export-led growth: electronics constitutes around 60% of its exports; its electronics industry is heavily exposed to GPN; and the US market absorbs 25% of its total exports (an estimated 40% for electronics exports). Second, with its focus on low-end assembly-type volume manufacturing, and a weak domestic supply base, this mid-sized country is especially exposed to the emergence of China as a new competitor. Third, with the Penang Development Centre, with its two industrial master plans[3], and with the Bill of Guarantees (developed for its Multimedia Super Corridor), Malaysia has developed one of the most aggressive sets of upgrading incentives for private companies (both foreign and domestic). And yet, fourth, despite such policies, Malaysia has failed to develop a sufficiently diversified and deep

[2] For related studies on upgrading perspectives in Korea's and Taiwan's electronics industry, see Ernst, 1994b, 2000a, and 2001b.

[3] Ministry of Trade and Industry, 1986 and 1996.

industrial structure, to induce a critical mass of corporate investment in specialized skills and capabilities.

A focus on Malaysia helps to highlight three important propositions that should inform the study of upgrading perspectives in East Asia's electronics industry: First, as long as peculiar characteristics of industry structure constrain the incentives for firms to invest in long-term assets (e.g., specialized skills), upgrading perspectives will remain limited. Second, while investment incentives and infrastructure matter, the key to success is the development of specialized skills and innovative capabilities, *ahead* of what the market would provide. Of critical importance are incentive alignments for university professors, researchers and students that encourage close interaction with private sector (through, e.g., company internships and sabbaticals). Equally important are training institutions, jointly run by the private and public sector, like the Penang Skills Development Centre (PSDC).

Third, in countries where the domestic industry structure keeps constraining upgrading efforts, international linkages through participation in GPNs can play an important catalytic role. In such a situation, it is critical to understand whether and how the current transformations of GPNs can help to bypass the above domestic upgrading constraints. We argue that there is now greater scope for diversifying international network linkages, beyond the erstwhile exclusive linkages with OEMs, and that this could facilitate the upgrading into more knowledge-intensive production and services.

Section 1 sketches key characteristics of GPNs and introduces an operational definition of industrial upgrading (IU). In sections 2 to 4, we outline the aforementioned transformations of GPNs in East Asia`s electronics industry. Finally, in section 5, we ask how the upgrading prospects of Malaysian electronics firms are affected by the above transformations of GPNs.

Specifically, we explore whether these transformations provide new opportunities for relieving domestic upgrading constraints, outline feasible responses and identify options for further analysis.

1. Conceptual Framework: Global Production Networks and Industrial Upgrading

1.1. Characteristics of GPNs[4]

Trade economists have recently discovered the importance of changes in the organization of international production as a determinant of trade patterns (e.g., Feenstra, 1998; Jones and Kierzskowski, 2000; Navaretti, Haaland, Venables, 2002). Their work demonstrates that (i) production is increasingly "fragmented" with parts of the production process being scattered across a number of countries, hence increasing share of trade in parts and components; and (ii) countries and regions which have been able to become a part of the global production network are the ones which have industrialized the fastest. And leading growth economists (e.g., Grossmann and Helpmann, 2002), are basing their models on a systematic analysis of global sourcing strategies.

This chapter builds on this work, but uses a broader concept of GPNs that emphasizes three characteristics: i) *scope*: GPN encompass all stages of the value chain, not just production; ii) *asymmetry*: flagships dominate control over network resources and decision-making; and iii) *knowledge diffusion*: the sharing of knowledge is the necessary glue that keeps these networks growing.

A GPN covers both intra-firm and inter-firm transactions and forms of coordination: it links together the flagship´s own subsidiaries, affiliates and joint ventures with its subcontractors,

[4] For details, see Ernst, 1997b, 2002a,Borrus, Ernst and Haggard, 2000, and Ernst, forthcoming.

suppliers, service providers, as well as partners in strategic alliances. While equity ownership is not essential, network governance is distinctively asymmetric. A network flagship like IBM or Intel 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. The main purpose of these networks is to provide the flagship with quick and low-cost access to resources, capabilities and knowledge that are complementary to its core competencies. As the flagship integrates geographically dispersed production, customer and knowledge bases into GPNs, this may well produce transaction cost savings. Yet, the real benefits result from the dissemination, exchange and outsourcing of knowledge and complementary capabilities (Ernst, 2002c)..

GPNs typically combine a rapid geographic dispersion with spatial concentration on a growing but still limited number of specialized clusters. To simplify, we distinguish two types of clusters (Ernst, 2002c): "centers of excellence" that combine unique resources, such as R&D and precision mechanical engineering, and "cost and time reduction centers" that thrive on the timely provision of lower-cost services[5]. Different clusters face different IU perspectives, depending on their specialization, and on the product composition of the GPNs. The dispersion of clusters differs across the value chain: it increases, the closer one gets to the final product, while dispersion remains concentrated especially for high-precision and design-intensive components[6].

[5] "Cost & time reduction centers" include the usual suspects in Asia (Korea, Taiwan, China, Malaysia, Thailand, and now also India for software engineering and web services),but also exist in once peripheral locations in Europe (e.g., Ireland, Central and Eastern Europe and Russia), in Brazil, and Mexico in Latin America, in some Caribbean locations (like Costa Rica), and in a few spots elsewhere in the socalled RoW (= rest of the world).

[6] On one end of the spectrum is final PC assembly that is widely dispersed to major growth markets in the US, Europe and Asia. Dispersion is still quite extended for standard, commodity-type components, but less so than for final assembly. For instance, flagships can source keyboards, computer mouse devices and power switch supplies from many different sources, both in Asia, Mexico and the European periphery, with Taiwanese firms playing an important

In short, agglomeration economies continue to matter, hence the path-dependent nature of upgrading trajectories for individual specialized clusters.

Flagships

GPN typically consist of various hierarchical layers, ranging from network flagships that dominate such networks, due to their capacity for system integration (Pavitt, 2002), down to a variety of usually smaller, local specialized network suppliers. The flagship is at the heart of a network: it provides strategic and organizational leadership beyond the resources that, from an accounting perspective, lie directly under its management control (Rugman, 1997: 182). The strategy of the flagship company thus directly affects the growth, the strategic direction and network position of lower-end participants, like specialized suppliers and subcontractors. The latter, in turn, " have no reciprocal influence over the flagship strategy" (Rugman and D´Cruz, 2000, p.84). The flagship derives its strength from its control over critical resources and capabilities that facilitate innovation, and from its capacity to coordinate transactions and knowledge exchange between the different network nodes.

Flagships retain in-house activities in which they have a particular strategic advantage; they outsource those in which they do not. It is important to emphasize the diversity of such outsourcing patterns (Ernst,1997b). Some flagships focus on design, product development and marketing, outsourcing volume manufacturing and related support services. Other flagships outsource as well a variety of high-end, knowledge-intensive support services.

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role as intermediate supply chain coordinators. The same is true for printed circuit boards. Concentration of dispersion increases, the more we move toward more complex, capital-intensive precision components: memory devices and displays are sourced primarily from "centers of excellence" in Japan, Korea, Taiwan and Singapore; and hard disk drives from a Singapore-centered triangle of locations in Southeast Asia. Finally, dispersion becomes most concentrated for high-precision, design-intensive components that pose the most demanding requirements on the mix of capabilities that a firm and its cluster needs to master: microprocessors for instance are sourced from a few globally dispersed affiliates of Intel, two American suppliers, and one recent entrant from Taiwan (Via Technologies).

To move this model a bit closer to reality, we distinguish two types of global flagships: i) "Original equipment manufacturers" (OEM) that derive their market power from selling global brands, regardless of whether design and production is done in-house or outsourced; and ii) U.S.-based global "contract manufacturers" (CM) that establish their own GPN to provide integrated manufacturing and global supply chain services (often including design) to the OEM.

Asian suppliers

To determine whether a local company in Asia is integrated into a GPN, we have used a broad set of indicators that include: i) use of dedicated parts supplied by a foreign firm; or ii) contract manufacturing of parts or final products to the specifications of a foreign firm; or iii) contract manufacturing of parts or final products, based on own design; or iv) the provision of knowledge support services to foreign firm.

It is necessary to open the black box of "Asian suppliers". First, some of these suppliers have been around for quite a while. Since the 1960s, various groups of Asian suppliers have emerged, first in consumer electronics, then as contract chip assemblers (Korea's Anam as the most prominent example), and, more recently, in contract wafer fabrication ("silicon foundries"), and as ODM suppliers of computers and related equipment, IC design houses, suppliers of PDA and wireless devices. Second, Asian suppliers obviously differ considerably in their capabilities, network position and market power. Substantial differences also exist with regard to their capacity for component sourcing, design & development and engineering, the capacity to provide global support services, and the use of digital information systems.

Greatly simplifying, we distinguish two types of Asian suppliers: higher-tier and lower-tier suppliers. "Higher-tier" suppliers, like for instance Taiwan´s Acer group (Ernst, 2000c), play an intermediary role between global flagships and local suppliers. They deal directly with global flagships (both "brand leaders" and global US-based "contract manufacturers"), they possess valuable proprietary assets (including technology); and they have developed their own mini-GPNs (Chen, 2002). Building on their strengths in volume manufacturing and the provision of ODM services[7], these higher-tier suppliers are now under pressure to develop complementary skills and capabilities in new product introduction (NPI), process re-engineering), as well as in "embedded" software, SOC (system-on-chip) design, IP trade, system integration, and in the management of network resources, supply chains and customer relations. With the exception of hard-core R&D and strategic marketing that remain under the control of the global brand leader, Asian higher-tier suppliers must be able to shoulder all steps in the value chain. They must even take on the coordination functions necessary for global supply chain management.

"Lower-tier" Asian suppliers are the weakest link in the GPNs. Their main competitive advantages are low cost and speed, and flexibility of delivery. They are typically used as "price breakers" and "capacity buffers", and can be dropped at short notice. This second group of local suppliers rarely deals directly with the global flagships; they interact primarily with local higher-tier suppliers. Lower-tier suppliers normally lack proprietary assets; their financial resources are inadequate to invest in training and R&D; and they are highly vulnerable to abrupt changes in markets and technology, and to financial crises.

1.2.Industrial Upgrading[8]

An appropriate long-term development strategy for Asian electronics industries must focus on improvements in specialization, productivity, and linkages (as defined by Hirschman, 1958, chapter 6), all of which necessitate a braod base of skills and capabilities. All four elements are essential prerequisites for improving a country's capacity to raise long-term capital that is

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[7] An ODM service provider is defined

necessary for facility investment, R&D, and human resource development. The concept of industrial upgrading (IU) ties these four elements together in a cohesive framework to serve as a focusing device for unlocking new sources of economic growth[9]. Critical prerequisites for successful upgrading are a sufficiently large pool of specialized and re-trainable skills, a strong domestic knowledge base, forms of corporate governance that facilitate innovation, sophisticated information management, and strong international knowledge linkages.

Our definition emphasizes the importance of international linkages. We do not assume that IU ends at the national border, and that it occurs only if improved specialization generates pressures to create dense forward and backward linkages *within* the district or the national economy. A "closed economy" assumption is unrealistic, as globalization and information technology (IT) have drastically increased the international mobility of trade, investment, and even knowledge (Ernst, 2002c). This increases the scope for cross-border forward and backward linkages, in a similar manner that improved specialization generates pressures to create dense forward and backward linkages within the economy (Ernst, 2002 a).

Equally important, most countries are constrained by a narrow domestic knowledge base and limited linkages. Both constraints are particularly important for small developing economies. One of their primary features is a narrow and incomplete set of domestic linkages (e.g, Lall, 1997; Ernst, Ganiatsos, and Mytelka, 1998). The result is an "inverted production pyramid": a growing final product sector rests on a weak and much smaller domestic base of mostly inefficient support

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[8] Based on Ernst, 2002 d.

[9] By focusing on knowledge and innovation as major sources of economic growth, our approach is consistent with leading-edge economic thinking, such as *endogenous growth* theories (Romer, 1990; Grossman and Helpman, 1991); Lipsey`s *structuralist* growth theory (e.g., Lipsey, 2001); evolutionary economics (e.g., Penrose, 1959/1995; Richardson, 1960/1990; Nelson and Winter, 1982); and attempts to reunite economic growth and innovation theory and business history (e.g., Lazonick, 2000). A focus on knowledge and innovation also reflects a recent shift in policy debates within important international institutions, such as the OECD, the World Bank, and the European Commission.

industries. Rapid growth in the final products sector necessitates considerable imports of intermediates and production equipment. In addition, highly heterogeneous economic structures constrain agglomeration economies; weak and unstable economic institutions obstruct learning efficiency; and a high vulnerability to volatile global currency and financial markets constrain patient capital that is necessary for the development of a broad domestic knowledge base. As a result of this "vicious circle", very limited sharing and pooling of resources and knowledge occurs *within* the country, and often even within the export-oriented cluster. This implies that our model of IU needs to integrate international knowledge linkages. To compensate for their narrow domestic knowledge base and limited linkages, Asian developing economies have to rely on foreign sources of knowledge to catalyze domestic capability formation. International linkages need to prepare the way for an upgrading of East Asia's electronics industries.

We focus on two aspects of industrial upgrading found in the literature: "firm-level upgrading" from low-end to higher-end products and value chain stages, and "industry-level linkages" with support industries, universities and research institutes. Without the latter, "firm-level upgrading" will soon reach its limits.[10] We emphasize two additional features that distinguish our concept of IU. First, we include firm behavior as a key dimension, allowing for a co-evolution of industry structure and firm behavior in response to actions of key participants and also to the policy environment. And second, we use a broad definition of innovation that allows us

[10] The other three forms of IU are: (i) inter-industry upgrading proceeding from low value-added industries (e.g. light industries) to higher value-added industries (e.g. heavy and higher-tech industries); (ii) inter-factor upgrading proceeding from endowed assets (i.e., natural resources and unskilled labor) to created assets (physical capital, skilled labor, social capital); and (iii) upgrading of demand within a hierarchy of consumption, proceeding from necessities to conveniences to luxury goods. See Ozawa (2000) for discussion of upgrading taxonomies. Most research has focused on a combination of the first two forms of IU, based on a distinction between low-wage, low-skill "sun-set" industries and high-wage, high-skill "sunrise" industries. Such simple dichotomies however have failed to produce convincing results, for two reasons: First, there are low-wage, low-skill value stages in even the most high-tech industry, and high-wage, high-skill activities exist even in so-called traditional industries like textiles. And second, both the capability requirements and the boundaries of a particular "industry" keep changing over time, which makes an analytical focus on the industry level even more problematic.

to move beyond a narrow focus on R&D and patenting.[11] There is now a widespread consensus that a broad definition of "innovation efforts" is needed that includes engineering, technology purchases, expenditures on licensing and consulting services, and technology search, as well as the accumulation of tacit knowledge required to absorb imported technology (e.g., Nelson, 1990). That broader focus is necessary to capture the proliferation of knowledge-intensive professional services, made possible by ICT.

2. Networks of Networks: Outsourcing Based on Contract Manufacturing

The "New Economy" boom in the US has accelerated a long-standing trend toward vertical specialization in the electronics industry: outsourcing based on contract manufacturing became the "panacea of the '90s"(Lakenan et al ,2001: p3), a "New American Model of Industrial Organization" (Sturgeon, 2002). Two inter-related transformations need to be distinguished: supply contracts and M&A. Global brand leaders like Dell, the "original equipment manufacturers" (OEMs) increasingly subcontract manufacturing and related services to US-based global "contract manufacturers" (CMs), like Flextronics. Equally important however is that the very same CMs have acquired existing facilities of OEMs, as the latter are divesting internal manufacturing capacity, seeking to allocate capital to other activities that are expected to generate higher profit margins, such as sales and marketing, and product development.

2.1. Argument

[11] Most empirical work on IU has explored the expansion of R&D-intensive industries. For most developing countries, that narrow focus is of very limited value.The (usually) implicit notion is that potential rates of productivity growth are higher in "emergent", R&D-intensive industries (Globerman, 1997, pages 98 and 99). Hence, "… specializing in the "right" technological activities directly contributes to faster growth rates of real income". A related notion is that, for R&D-intensive industries, economic rents can be extracted, in part, from foreign consumers. A specialization in the "right" technological activities contributes to higher levels of national income by promoting more favourable international terms of trade.

Sturgeon and Lester, 2002 (in this volume) emphasize that the rise of U.S. contract manufacturers with global reach may pose a serious competitive threat to Asian suppliers. Their analysis highlights rising threshold requirements for supplier participation in GPNs. Complementing their analysis, we highlight the other side of the coin, and explore how Asian suppliers can exploit linkages with US-based contract manufacturers, that now complement the original linkages with OEMs, for their upgrading purposes. More specifically, we ask what new upgrading opportunities may open up for Asian suppliers, as outsourcing based on contract manufacturing has created increasingly complex, multi-tier "networks of networks" that juxtapose global ties among the two large global players (the OEMs and CMs), as well as intense regional ties with smaller firms (as argued, for instance, in Almeida and Kogut, 1997).

A focus on complex, multi-tier "networks of networks" distinguishes our analysis from Sturgeon's modular production network model (2002). That model focuses on two actors only: global OEMs and CMs, most of them of American origin. OEMs and CMs are perceived to interact in a virtuous circle where each of them can only win. In that model, nothing can stop continuous outsourcing through contract manufacturing: "turn-key suppliers and lead firms co-evolve in a recursive cycle of outsourcing and increasing supply-base capability and scale, which makes the prospects for additional outsourcing more attractive" (Sturgeon, 2002, p.6). If that scenario would materialize, Asian suppliers in the global electronics industry may face a considerable backlash. Specifically, Asian suppliers may be unable to compete against the vastly superior capabilities of US-based CMs in four areas: component sourcing; design, development and engineering (D&D&E); "global reach": the provision of support services across multiple locations in all major macro-regions; and "network coordination": improved network efficiencies through the use of sophisticated digital information systems.

Our analysis leads us to a less gloomy perspective. Asian suppliers already play an important role as global CMs. We highlight peculiar features of the US-style CM model that may indicate possible limitations of that model. We argue that the US model of contract manufacturing is just one possible approach, and that Asian electronics firms may have a role to play, based on their accumulated experience with contract manufacturing, before it was given that name.. Furthermore, there are ample opportunities to groom a variety of new specialized Asian suppliers, provided necessary changes are put in place in policies and support institutions.

To back-up this argument, we highlight three peculiar features of the US-style CM model: the critical role played by financial considerations (2.2); the as yet limited share of contract manufacturing in worldwide electronics hardware production (2.3); and the limited presence of American CMs in Asia relative to their presence in the Americas and Europe (2.4). In section 2.5., we will explore how the downturn in the global electronics industry has exposed serious limitations of these arrangements, forcing both OEMs and CMs to adjust and rationalize the organization of their networks. All of this has important implications for upgrading perspectives in Malaysia's electronics industry that we will discuss in section 5.

2.2. Drivers

Outsourcing through subcontracting has a long history in the electronics industry (Boswell, 1993). Yet, during the 1990s, outsourcing gained a new quality, spreading across borders: global brand leaders (OEM) have put up for sale a growing number of their overseas facilities, and in some cases whole chunks of their global production networks. OEM from North America like HP, Dell, Compaq, Motorola, Intel, IBM, Lucent, Nortel were first in pursuing such divestment strategies. But European OEM (e.g., Philips, Ericcson, Siemens) and, more recently, Japanese ones (e.g., NEC, Fujitsu, Sony) have followed suit. The main driver are financial considerations:

getting rid of low-margin manufacturing helps the OEMs to increase shareholder returns[12]. Other expected benefits include hedging against losses due to volatile markets and periodic excess capacity; scale economies: surface-mount-technology (SMT) requires large production runs, reflecting its growing capital and knowledge intensity; and an improved capacity to combine cost reduction, product differentiation and time-to-market.

2.3. Growth and Market Share

CMs have aggressively seized this opportunity: through acquisitions and capacity expansion they have developed, within a few years, their own GPNs that now complement the networks established by the OEMs. For instance, Flextronics has 62 plants worldwide, Solectron has factories in 70 countries, and the recently merged Sanmina/SCI has 100 factories around the world. This gave rise to an extremely rapid growth of the CM industry (figure 1). From 1996 to 2000, capital expenditures grew 11-fold (50% CAGR), and revenues increased by almost 400% (81% CAGR). The industry`s rapid growth was driven primarily by M&A (figure 2).

Fig.1 The Growth of the CM Industry, 1996-2000

Figure 2 M&A in the CM Industry, 1997-2000

It is important however to emphasize the still limited share of US contract manufacturers in worldwide electronics hardware production. In 2001, this share was estimated to be around 13.7% (up from 13.0% in 2000); for 2002, this share is projected to increase to 16.3% (email from Eric Miscoll, CEO, Technology Forecasters, Inc, April 15, 2002).

[12] In response to pressures from institutional investors and financial analysts, OEM were eager to "slash their balance

2.4. Late Move to East Asia

The presence of American CMs in East Asia pales relative to their presence in the Americas (US, Canada, Mexico, Brazil) and Europe (including Eastern Europe and Israel). The move to East Asia came relatively late. During the 1990s, American CMs spent most of their money on acquiring global flagship facilities in the Americas and Europe. During the "New Economy" boom in the US, speed-to-market due to close proximity was much more important than cost considerations. With the slow-down in the electronics industry, cost reduction now again has become a central concern. Arguably, this may create new incentives for CMs to expand their East Asian networks.

Let us look at a few illustrative examples (see table 1). Flextronics, which has its headquarters in Singapore, has the strongest presence in Asia: 12 facilities in 6 nations, i.e. Singapore, Malaysia, Thailand, China, Taiwan, and India. Yet, this compares with a total of 62 plants worldwide, of which 18 are in the Americas, and 27 in Europe (including two in Israel)[13].

Table 1: Contract Manufacturing Clusters in East Asia, 01/2002

Solectron, the long-time industry leader[14], has factories in 70 countries, but only four of these countries are in Asia. Solectron began to increase its presence in Asia only since 2001. This is primarily in response to the company's projections that, by 2005, 60% of its turnover would come from Asia (including Japan), up from about 30% in 2001. Traditionally focused on Penang

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sheets by placing the low-margin operations with hungry contract manufacturers" ((Lakenan et al, 2001: p4).

[13] Reflecting the growing importance of the Asia-Pacific market, Flextronics decided in December 2001 to make Malaysia its manufacturing and logistics hub for its operations in the Asia-Pacific region (most likely, excluding China, given that Flextronics has five facilities there).

[14] During the 2001 recession, its leadership position is being challenged by Flextronics and by the merger of Sanmina and SCI.

(since 1991), Solectron has added during 1996 facilities in Johor/Malaysia and Suzhou/Jiansu Province in China. During 2000, Solectron acquired two Sony factories, one in Japan and one in Taiwan, as well as NEC's Ibaraki production facilities for servers, workstations and system file products[15]. The latter acquisition provides Solectron with 500 highly skilled Japanese employees who are well trained in build-to-order manufacturing, and final test and fulfillment services.

The presence in Asia is even more limited for the remaining three major global CM players. The recently merged Sanmina/SCI has 100 factories around the world. This compares with seven facilities in Asia (Singapore, Malaysia, China, Taiwan and Thailand), but this number pales relative to the long list of locations in the Americas and Europe. Celestica, a spin-off from IBM Canada in 1994, has 36 plants around the world, acquired through acquisitions. Until mid-2001, it had four plants in Asia: one in Malaysia's Kulim Hi-Tech park (part of the northern cluster), two in China, and one in Thailand. Since then, Celestica has substantially expanded its Asian presence, to meet the growing outsourcing demands of Japanese OEMs[16].

Finally, Jabil Circuit, the smallest of the global CM players, has 21 facilities worldwide. As with the other CM leaders, Jabil's presence in Asia (three facilities), lags behind its presence in the Americas (11) and Europe (7). Its involvement in Asia started in 1995, with its factory in Penang. In 1998, it established its Asian regional headquarters in Hong Kong, and a large low-cost manufacturing plant in China´s Gunagzhou Province, in the YiXing Industrial Estate in Panyu[17].

2.5. Limitations to the US-Style CM Model

[15] For acquisitions of smaller Southeast Asian contract manufacturers by major global CM players, see section 6.4 below.

[16] The starting-point was an $ 890 million acquisition of Omni, one of Singapore's leading contract manufacturers that added facilities in Singapore, Malaysia, Indonesia and Thailand. And in January 2002, Celestica acquired two optical and broadband equipment factories in Japan from NEC, as part of a five-year $ 2.5bn supply agreement.

[17] Jabil has recently expanded its long-established operations in Penang through the acquisition of Xircom, a wholly-owned subsidiary of Intel that supplies PC and network cards (New Straits Times, August 23, 2001).

The downturn in the global electronics industry has exposed serious limitations to the US model of contract manufacturing, forcing both OEMs and CMs to adjust and rationalize the organization of their networks. That model was based on the assumption of uninterrupted demand growth. In reality however, demand and supply only rarely match. This simple truth was all but forgotten during the heydays of the "New Economy".

Industry observers highlight seven important limitations[18]: First, global contract manufacturing is a highly volatile industry. While powerful forces push for outsourcing, this process is by no means irreversible. Major OEMs retain substantial internal manufacturing operations; they are continuously evaluating the merits of manufacturing products or providing services internally versus the advantages of outsourcing. Second, global CMs are now in a much weaker bargaining position than OEMs, whose number has been reduced by the current downturn and who are now much more demanding. In principle, important long-term customer contracts permit quarterly or other periodic adjustment to pricing based on decreases or increases in component prices. In reality however CMs "typically bear the risk of component price increases that occur between any such re-pricings or, if such re-pricing is not permitted, during the balance of the term of the particular customer contract (Jabil, 10K report 2001, p.49).

A third important limitation of the US CM model represents trade-offs between specialization advantages and rapid inorganic growth through M&A. In economic theory, vertical specialization is supposed to increase efficiency, i.e. to reduce the wastage of scarce resources. It is not clear whether the recent rapid growth of CM has produced this result. The excessive growth and diversification that we have seen during the "New Economy" boom may well truncate the specialization and efficiency advantages of the CM model. The leading CMs have aggressively used M&A to pursue in parallel four objectives that do not easily match: rapid growth; a broadening of the portfolio of services that they can provide; a diversification into new product markets (especially telecom equipment); as well as an expansion of their own production networks, establishing a global presence at record speed. Yet, this forced pace of global expansion may well create an increasingly cumbersome organization that could undermine the supposedly primary advantage of the CM model: a capacity for rapid scaling-up and scaling-down, in line with the requirements of the OEMs.

Fourth, the rapid expansion of GPNs is subject to extreme risks and uncertainty. This reflects the much greater volatility of international operations compared to domestic ones. Managing GPNs thus requires major efforts, in terms of management time and resources, which of course conflicts with the need to keep overheads at very low levels.

Take as an example Jabil's assessment of the risks involved in its international operations: In its 10K report for 2001 (p.50), the company emphasizes the following risks: "difficulties in staffing and managing foreign operations; political and economic instability; unexpected changes in regulatory requirements and laws; longer customer payment cycles and difficulty collecting accounts, receivable export duties, import controls and trade barriers (including quotas); government restrictions on the transfer of funds to us from our operations outside the United States; burdens of complying with a wide variety of foreign laws and labor practices; fluctuations in currency exchange rates, which could affect local payroll, utility and other expenses; inability to utilize net operating losses incurred by our foreign operations to reduce our US income taxes; …(and, especially in lower-cost locations) …" currency volatility, negative growth, high inflation,

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[18] This section is based on: a recent study by Booz-Allen & Hamilton (Lakenan et al, 2001); email coorespondence with the study's lead author, Bill Lakenan; recent 10K reports of the leading US global CMs; and author's interviews at affiliates of global CMs in Malaysia.

limited availability of foreign exchange”. The latter risks are particularly prominent in Asia, outside of Japan.

Fifth, rapid growth, based on the use of stock as a currency for mergers and acquisitions (M&A) is extremely risky, and contains the seed of future problems. It stretches the already limited financial resources of CMs, which typically have to cope with very low margins. The downturn of the global electronics industry has further increased these financial pressures on leading US-based CMs[19]. This of course raises the question whether this will lead to off-balance sheet financing techniques to hide accumulated debt.

Sixth, in contrast to the original expectation that outsourcing based on contract manufacturing may improve inventory and capacity planning, global brand leaders in the electronics industry, that rely heavily on outsourcing, have experienced very serious periodic mismatches between supply and demand. When a product unexpectedly becomes a hit, outsourcing provides these OEMs only with a limited capacity for scaling-up. During a recession, on the other hand, OEMs cannot abruptly reduce orders that they had previously placed with CMs[20].

Lastly, there seems to be a conflict of interests between OEMs, who are looking for flexibility, and CMs, who are looking for predictability and scale. For instance, OEMs focus on early market penetration and rapid growth of market share to sustain comfortable margins. OEMs thus need flexibility in outsourcing arrangements that allows them to divert resources at short

[19] Ironically, these pressures are particularly severe for those CMs, like Solectron, that have aggressively diversified beyond the PC sector into telecommunications and networking equipment, the high-growth sectors of the “New Economy” boom.

[20] Take Cisco. During the peak of the “New Economy” boom, from 1999 to 2000, demand for its products grew by 50%. Reliance on CMs produced severe component shortages and a massive backlog in customer orders. When demand fell abruptly, starting from the fall of 2000, Cisco found itself saddled with excess capacity of $ 2.25bn that it had put in place to meet expected demand growth. Excess capacity of this magnitude is deadly in time-sensitive industries like electronics.

notice to a given product as it becomes a hit. This sharply contrasts with the situation of CMs: with razor-thin margins, they need to focus ruthlessly on cost cutting. CMs need predictability: “they want to make commitments in advance to reap benefits like big-lot purchases and decreased overtime.” (Lakenan et al , 2001, p.10).

These conflicting interests complicate the coordination of CM-based outsourcing arrangements. They also require substantial fundamental changes in the organization of both OEMs and CMs, as well as an alignment of incentives through contract terms and agreements. Effective outsourcing requires that both flagships and CMs acknowledge their conflicting interests. Further, with complexity comes uncertainty. In industries with rapidly shifting technologies and markets, OEMs have no way to predict with any accuracy the specifications of what they will need, in terms of capacity, design features and configuration, and in terms of the specific mix of performance requirements. In the electronics industry, all of these variables can change quite drastically and at short notice.

Table 2 Changes in CM-based Outsourcing Arrangements

Such high uncertainty has important implications for the reorganization of CM-based outsourcing arrangements (table 2). Flexibility now becomes the key to success. Proceeding by conjecture (“stochastically”) takes over from a deterministic approach. Flagships need adjustable networks to ”satisfy a range of possible demand profiles with a portfolio of customizable capacity.” They “need access to - and the ability to turn off - big chunks of production more quickly than ever contemplated in order to capture profitability.”(Lakenan et al, 2001, pages 11, 12). This has important implications for East Asia’s upgrading perspectives. As we will see in section 5., the transition to stochastic and fluid-outsourcing arrangements will substantially increase the required capabilities that local network suppliers in East Asia will have to master. We will show however that this also opens up new upgrading possibilities, provided necessary changes in policies and support institutions are put in place.

3. Coordination and Contents: Information Systems and Services

A second important transformation of GPNs results from the increasing use of digital information systems to manage these networks (*coordination*), and to build "global information service networks" (GISN) that complement networks centered on manufacturing (*contents*).

3.1. Digital Information Systems and Knowledge Diffusion

Digital information systems (DIS) - electronic systems that integrate software and hardware to enable communication and collaborative work - are increasingly used to manage GPNs. While still at an early stage of "trial-and-error", these systems appear to enhance gradually the scope for knowledge sharing among multiple network participants at distant locations. Equally important, they will reduce (but not eliminate) the problems of rapid coordination of product design and manufacture over long distance[21]. This new mobility of knowledge arguably may provide new opportunities for Asian suppliers to upgrade their capabilities, provided appropriate policies and support institutions are in place.

DIS provide new opportunities for improving communication routines within GPN: new combinations become feasible between old and new forms of communication. The most commonly used technologies today facilitate *asynchronous* interaction, such as e-mail or non-real time database sharing. But as data transfer capacity ("bandwidth") increases, this is creating new

[21] I am grateful to Keith Pavitt for this suggestion.

opportunities for using technologies that facilitate *synchronous* interaction. This involves video-conferencing and real-time data exchange for financial control, engineering, and R&D.

The digitization of knowledge implies that it can be delivered as a service and built around open standards. This has fostered the specialization of knowledge creation, giving rise to a process of modularization, very much like earlier modularization processes in hardware manufacturing. Under the heading of "e-business", a new generation of networking software provides a greater variety of tools for representing knowledge, including low-cost audio-visual representations. Those programs also provide flexible information systems that support not only information exchange among dispersed network nodes, but also the sharing, utilization, and creation of knowledge among multiple network participants at remote locations. New forms of remote control are emerging for manufacturing processes, quality, supply chains, and customer relations.

DIS, and especially the open-ended structure of the Internet substantially broadens the scope for outsourcing. It has allowed OEMs to shift from *partial* outsourcing, covering the nuts and bolts of manufacturing, to *systemic* outsourcing that includes knowledge-intensive support services. This has intensified the competition among the providers of CM services: competition now focuses on the capacity to provide integrated manufacturing, design and supply chain management services wherever required.

In turn, this has intensified the competition among specialized clusters in the electronics industry. For lower-cost outsourcing, OEMs and CMs can now choose between alternative locations in Asia, Latin America, the former Soviet bloc, and the European periphery. For higher-end outsourcing, they can choose between specialized clusters in Nordic countries, the US, France and Germany, as well as in Singapore, Taiwan, Korea, Shanghai, Israel, Ireland, and Hungary.

3.2. Global Information Service Networks[22]

Global information services networks (GISNs) complement the existing production networks (GPN) with their primary focus on manufacturing. GISNs cover a variety of knowledge support services, such as software engineering and development, IT applications development, business process outsourcing, maintenance and support of information systems, as well as skill transfer and training. While much of this service outsourcing involves low-cost “sweatshop” activities[23], it also provides considerable opportunities for Asian network suppliers to upgrade their capabilities.

a. Market pull

The growth of these service networks in Asia’s electronics industry is due to a combination of market pull and government policies. With the drastic slow-down in major IT markets, especially in the US, the center of activity has shifted to Asia. During 2001, the region`s information services market outpaced other regions significantly, with a growth rate double the world average, and nearly three times that of North America (Gartner Dataquest data, quoted in CMPnet.Asia, December 4, 2001). The main drivers of demand are attempts by both global flagships and local suppliers to improve the efficiency and security of existing GPNs. Asian lead markets are Singapore; Korea; Taiwan; major export platform clusters in Malaysia and elsewhere in Southeast Asia; China´s electronics clusters, especially in the South, and Shanghai; as well as India`s software clusters.

b. Government policies

[22] Based on phone interviews, company websites and the following sources: various issues, during 2001, of CMPnet.asia and Asia Computer Weekly.com; Aberdeen Group, 2001.

[23] A typical recent example is a call center set up by General Electric in the city of Dalian (Liaoning Province). Staffed by Chinese people fluent in Japanese, the center handles inquiries from GE Consumer Credit`s Japanese customers (The Nikkei Weekly, November 12, 2001).

A second important driver of GISN are support policies and incentives to foster the establishment of higher-level software and service development centres, especially in Singapore, China, Korea, Taiwan and Malaysia. Singapore, for instance, has amended its highly successful policy to develop local manufacturing support industries (especially for the electronics industry) with a policy to promote local information service suppliers. While the former policy is called "Local Industry Upgrading Programme" (LIUP), the new service-oriented programme is called "Infocomm Local Industry Upgrading Programme" (iLIUP). A typical example are the iLIUP partnership agreements that link Software AG, the German vendor of XML (=extensible markup languge) software, with specialized Singaporean solution providers[24] to develop customized XML-based business solutions for foreign affiliates and Asian companies. To make this network work, Software AG has brought in a global supplier of training programs for XML and related technologies, called Genovate Solutions. The latter company is responsible for establishing and running an XML Academy in Singapore that serves the Asia-Pacific region, training enterprises and individuals on XML, SAP, Java, Oracle, Linux, Web Logic and other enterprise software programs.

Of particular interest are policies, pursued in China, to develop software and information service capabilities. A core element of these policies is the development of ten major software bases. Three important examples include the Yangtze River Software Belt, the Qilu Software Park in Jinan/Shandong Province, and Shanghai`s Pudong Software Park. Most of these projects are quite ambitious. For instance, the Jiangsu Software Park, the center of the Yangtze River Software Belt takes up 120,000 sq.m. and contains 165 software companies that focus on applications in telecommunications, network security, and e-business. This Park is expected to become a major

[24] These Singaporean solution suppliers focus on enterprise resource planning (ERP), system management, network

export platform for software, way beyond the current software export revenues of Jiangsu province of Yuan 2.3bn (about 277 $), one tenth of China`s total software exports.

The Qilu Software Park in Jinan/Shandong Province is expected to develop into China´s largest software park. The park covers a vast area of 6.5 sq.km, and sales revenues (mostly exports) are expected to reach $ 1.2bn in 2005, up from sales revenues of $ 233million in 2000. A very different approach has been chosen for Shanghai`s Pudong Software Park. Space constraints (only 9000 sq.m. are available for this park) and the high price of land have led to a very selective focus on the dominant global flagships in the information industry. The dominant flagship there is IBM, which is responsible for roughly one third ($ 300 million) of total current investment in the Pudong Park by foreign corporations. The Park's specialization is shaped by two important recent developments. First, Shanghai is rapidly developing into a regional R&D and engineering center for leading global network flagships (so far around 40), especially in the electronics industry. Second, Shanghai is about to become one of Asia's most important clusters for the design and manufacturing of semiconductors. The Pudong Microelectronic Industrial Belt aims to build around 10 chip production lines by 2005, with a projected production value of yuan 100 billion (ca. $ 12.05 billion). Proximity to this cluster implies that much of the Pudong Software Park' activities are geared to circuit design and related activities.

Another example of joint cross-border software development is a new research center, established by Ericcson, the Swedish telecommunications equipment producer, in China´s Southern Software park in Zhuhai, China. That center serves as a focal point for interaction with Ericcson`s local partners, enabling them to co-develop and test 2G, 2.5G, and 3G applications for the Chinese market. The center is jointly run with Zhongshan University of Guangzhou province

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security, network knowledge management and a variety of Internet-based application services.

that provides top-notch graduates to pursue joint research projects with Ericcson related to wireless IP data network compression and encryption technology, multimedia services, mobile electronics business, bluetooth technology, embedded software, and 3G systems.

c. Skill development and training

Skill development and training are an essential element of these GISN. This may open up new opportunities for industrial upgrading. Often training and service provision are closely intertwined. A first example is the development of Asian networks for wireless Java applications. This is based on the joint initiative of two global flagships: Sun Microsystems, the developer of the Java operating system, and Nokia, the leading supplier of mobile handsets. This initiative brings together the individual GISNs, established by both flagships: the Sun Developer network and the Forum Nokia. The Asia-Pacific Sun-Nokia Wireless Java Developers networks have a twofold purpose: to develop the Asian market for wireless Java applications, and, at the same time, to create an Asian low-cost base of developers of such systems. A key component of these networks is the Developer Training Program that is based on tools, knowledge and resources provided by the two network flagships. While programs and Java tools will be available at no charge to Asian developers, they will be charged for hardware, training and technical support. The objective is to "train up to 30,000 (Asian) developers to develop wireless Java applications … and to bring to market 1000 Java content providers by end-2002" (AMPnet.asia, November 29, 2001). For Nokia, the objective is to create an Asian consumer market for over 50 million mobile terminals supporting the Java platform.

A second example of emerging GISNs involves the skill transfer and the outsourcing of support services for storage area networks (SAN), a technology where Asian markets are expected to play an important role. With the exception of Singapore, Asia economies are latecomers in the use of digital information systems (DIS). Asian companies and government agencies thus have the opportunity to base their storage infrastructure on the new SAN model that is more flexible and cheaper than traditional direct-attached storage models. In response, all major providers of infrastructure for SAN are rushing to establish GISNs that, in addition to providing training for potential users, seek to develop a robust supply base for software development and SAN-related support services. An example is the emerging network of Brocade Communications Systems that has nodes in Hong Kong, Seoul, Singapore, Sydney, Tokyo and Beijing. An essential element of Brocade`s network are partnerships with leading Asian universities, like Beijing`s Tsinghua University, to establish joint technology labs and scholarship programs.

3Com Asia-Pacific, the network equipment and software supplier provides a third example of GISN that are centered on IT-enabled training (so-called “e-training”). Its 3Com University network provides online training and certification programmes in simplified Chinese, as well as web-based support services to customers and suppliers in 11 major cities in China. 3Com also has established similar networks in Japan and Korea, and plans to expand into other Asian countries. An important motivation is the need to create new markets for 3Com’s products and software. Equally important however appears to be that 3Com needs to have access to lower-cost local supply bases for service modules.

Our last example concerns Sybase, a global vendor of database technology and e-business applications. The company has strong links with Korea and China. In Korea, its has partnered with Samsung to create new e-business software designed to facilitate the management of Asian suppliers` multiple linkages with GPNs. In China, Sybase has developed strong links with leading telecommunications carriers, supplying data base management software to support the billing systems for these carriers[25]. Sybase's entry into the e-training market is motivated by two concerns: to develop the Chinese market for data base management software, and to reduce the growing IT skills deficit in this country. An equally important objective is the development of a robust low-cost human resource base that Sybase can tap into at a later stage. A major component of this training network is a joint venture between Sybase and the Beijing University of Aeronautics and Astronautics (BUAA) to offer IT training courses online that are customized to the requirements of specific industries. Topics covered include database technology, e-business applications, Java development, and mobile and wireless applications.

4. China: A Shift in Network Location

A third important transformation within East Asia is the emergence of China as a priority investment target for the leading global electronics flagships (whether from the US, Japan or Europe), their global suppliers from Korea and Taiwan, and, more recently, the leading U.S. contract manufacturers. As a result, China poses a serious challenge for mid-size countries (like Malaysia) with a focus on volume manufacturing. But the new challenge from China could also be a "blessing in disguise", catalyzing for serious IU efforts. Furthermore, China's huge potential market for electronic products and services provides new trade and investment opportunities for Asian firms. Equally important, Asian electronics firms may consider to tap into China's huge pool of low-cost engineers and scientists.

4.1. China Fever- What is Real?

There is of course a tendency to exaggerate the China factor. From Southeast Asia to Korea and Taiwan, from Mexico and Brazil to Germany and Spain, a perceived threat from China

[25] Sybase`s main partners include China Unicom, Shandong Telecom, Zhejiang Telecom, Heilongjiang Telecom,

rather than internal, homemade problems are at the center of public debates. Widespread claims that China in a short while will be an economic superpower and a major player in the electronics industry, should be treated with a grain of skepticism (e.g. Dahlman and Aubert, 2001). The same goes for the perceived diversion of FDI away from Southeast Asia to China. During 2001, four of ASEAN's ten economies (Indonesia, Malaysia, the Philippines, and Thailand) are estimated to have received more than five times the net FDI from the US than China (U.S. Department of Commerce data, quoted in" Asian Economic Survey - A Special report, Asian Wall Street Journal, October 29, 2001). Most of the reported $ 40 bn FDI inflows come from Hong Kong and Taiwan, and a substantial part is "round-tripping" domestic investment disguised as FDI (Credit Suisse First Boston data, quoted in the Financial Times, August 14, 2001).

4.2. China´s New Role in the Electronics Industry

Despite these caveats, there is no doubt that in the electronics industry, the center of gravity of FDI is beginning to move toward China, transforming the geography of GPNs within the region. China is no longer only a cheap labor location. China's new attractiveness results from a combination of five developments: a booming market for IT products and services, when the rest of the world is in recession; China's unlimited supply of low-cost IT skills; abundant land and a rapidly improving infrastructure; a massive rush of capital flows into China; and, catching this opportunity, support policies pursued by the central government, as well as regional and local authorities to rely on FDI as an accelerator of industrial upgrading[26].

The move toward China is particularly pronounced in three sectors: electronic components (especially semiconductors), computers, and telecommunications. For US FDI in semiconductors, China has become the second most important recipient, after Singapore, overtaking Malaysia,

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Shananxi Mobile, and Sichuan Mobile (CMPnet.Asia, October 24, 2001).

which was the main recipient in 1996. Even the new incentives provided by the Malaysia's IMP2 did not prevent this move toward China. A similar trend can be discerned for FDI by Japanese electronics firms: China has moved into first place ahead of Malaysia, which was its biggest recipient during the early 1990s (Malaysia Ministry of Finance data, quoted in Takeuchi, 2001).

Taiwanese computer companies that supply leading US computer OEM have played an important pioneering role in integrating China into GPNs. Since the early 1990s, they have continuously moved production from Taiwan to China. The result is that roughly 40% of China's electronics exports today are shipped from Taiwanese factories in China (courtesy of Market Intelligence Center, Institute for Information industry, Taipei, December 2001). Taiwanese suppliers now need to serve a large share, around 33.2%, of their export orders from overseas production lines in China.

From the US, OEMs like Motorola, Intel, AMD, HP, Compaq, Microsoft, Cisco, and Sun Microsystems have all initiated significant new investment projects in China. Motorola for instance considers China to be of critical importance. "Our main driver of growth is China", according to the company`s newly appointed Asia pacific president (Asia Wall Street Journal, November 20, 2001). At present, Motorola has 12 affiliates in the Asia-Pacific region. While the company´s involvement started out with Korea, later followed by Taiwan and Singapore, China has gained substantially in importance since the early 1990s. Currently, six of Motorola`s Asian affiliates are based in China, with two in Singapore, including the regional headquarters, and one each in Korea, Taiwan, India and Thailand. Motorola counts on continuous rapid growth of the China market to reduce the negative impact of the current recession. In 2000, China accounted for 12% of Motorola`s global sales, generating $ 4.5 billion of revenue.

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[26] Section 5.3 provides a discussion of such policies for the semicondutor industry.

But China is also expected to play an important role for Motorola's long-term strategy. By providing access to the world`s largest pool of relatively lower-cost IT skills, the company expects to enhance its innovation capabilities. For instance, out of the 13,000 people that Motorola currently employs in China, 1,000, i.e. almost 8% are active in R&D. Reflecting China´s growing importance, Motorola has held its annual board meeting for 2001 in China, its first board meeting outside the US. During that meeting, Motorola`s chairman also met China´s president, and announced that the company planned to double its China investment from $ 5 bn in 2001 to $ 10bn in 2005.

China also has attracted major new investments from leading European electronics flagships, like Philips, Nokia, Siemens, Alcatel and Ericsson. Philips for instance has moved its entire cell phone manufacturing operations to its Shenzhen joint venture with Beijing-based China Electronics Corp. And Nokia has committed itself to establish a large integrated cluster, the Xingwang (International Industrial Park) in Beijing which incorporates Nokia´s own mobile phone plant and that brings together 15 of its long-standing and trusted international component suppliers. This Nokia-centered cluster involves an initial investment of about $ 1.2 billion and is expected to create 15,000 jobs, with a projected annual sales volume of $ 6 billion.

In addition, all leading Japanese electronics flagships are considering major new investments in China, as they struggle under a depressed domestic economy and high manufacturing costs. Toshiba is building a plant for computer hardware and components in Nanjing, while Mitsubishi Electric, Matsushita and NEC all are expanding their phone production in China. Finally, a large surge in China investments is also reported by the Korean electronics chaebol that are all gripped by a severe "China fever".

4.3. Semiconductors[27]

Since 2000, the semiconductor (SC) industry provides a telling example of the speed of China's integration into GPNs. In terms of policies and support institutions, China's experience in the SC industry also provides a useful reference point for our case study of Malaysia.

Until 1999, investment in China´s SC industry lacked woefully behind similar investments in Korea and Taiwan. The turning point came in 2000. During that year, the Chinese government apparently made a strategic decision to rely on FDI to accelerate the development of this industry. The underlying expectation is that FDI can generate a critical mass, establishing new global dynamic clusters for SC manufacturing, primarily in Shanghai and Beijing. The hope is that, if this strategy succeeds to engage leading US flagships (both SC manufacturers and equipment producers), this may provide enough pressure within the US to dismantle the remaining US technology export restrictions. This may be an unrealistic expectation however, in light of the current resurgence of defense and security concerns in the US[28].

China's new pragmatic policies toward FDI have induced global flagships to announce several large investment projects worth around $ 7 billion. During 2000, China's SC output grew by 42%. Exports during 2000 grew by almost 35% in unit terms, and 30% in value terms, to $ 2.1 billion. The role of GPNs has been critical: Foreign-invested enterprises dominate China's SC exports, with a share of about 94%, with state-owned enterprises only responsible for a meager 5.3%.

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[27] If not stated otherwise, the following is based on Simon, 2001, and phone interviews with leading US semiconductor vendors.

[28] By late December 2001, the US administration was in fact considering imposing new controls on the export of high-performance US-made computers, out of fear that these technologies "could help adversaries in intelligence-gathering or the design of advanced weaponry." Such policies would reverse a campaign pledge by President Bush, who then argued that such export control policies were "arbitrary and irrational". They also fly in the face of the findings of a major Pentagon study, published in late 1999 which concluded that "it is no longer feasible to control high performance computer hardware." Financial Times, December 30, 2001.

During 2001, China has emerged as the main growth market for SC production equipment manufacturers. This of course reflects the worldwide downturn of new investment in SC manufacturing capacity. Leading equipment makers are all scrambling to expand their sales in the thus far largely untapped China market[29]. Table 3 presents information on major investment projects by global flagships; Taiwanese contract manufacturers ("silicon foundries"), as well as domestic firms.

Table 3: Major Investment Projects in China`s Semiconductor Industry, since January 2000

The prospective boost in FDI has given rise to highly optimistic projections. In-Stat Group, a SC industry-consulting firm, argues that China has the potential to become the third-largest SC producer after the US and Japan by 2003, and the second-largest SC market after the US by 2005. The Chinese government certainly leaves no doubt that it has very ambitious objectives. By 2005, it hopes to increase SC sales revenues to $9.7 billion, or 2% of the global market. By then, domestic production is expected to meet about 30% of China's demand. By 2010, China expects to be where Korea is now, i.e. producing roughly 5% of the global SC market.

If these projections would materialize, this obviously would pose a major threat for existing SC industries in Asia. This threat would be most immediate for Malaysia, with its heavy reliance on SC assembly. However, important threats may also emerge for semiconductor manufacturing in Korea, Taiwan, and Singapore, as well as in Japan. But it is unlikely that these countries will simply sit still and let shifting comparative advantage run its course. In fact, all major competitors in the global SC industry are currently pursuing aggressive policies to upgrade

[29] Applied Materials, the world`s leading SC production equipment vendor, for instance expects to increase its sales in

their product composition and capabilities, giving rise to a major transformation of this industry (e.g., Macher, Mowery, Simcoe, 2002).

In addition, it will not be easy for China to realize its ambitious upgrading objectives. One reason is the still relatively low level of development of China`s semiconductor industry. An important indicator of is the fundamental mismatch between China's exports and imports of SCs. In value terms, China imports over 70% of all SC devices that it needs. This is slightly better than the ratio found in Korea´s semiconductor industry during the early 1990s (Ernst, 1994b and 1998). Most Chinese exports are lower-end devices involving fairly mature and basic process and manufacturing techniques. Imports, on the other hand, are much more sophisticated. Between 1995 and 2000, China´s SC imports grew at a compound annual rate of almost 92%, while exports over the same period rose by less than 60%.

A further fundamental constraint to a rapid upgrading of China's SC industry are the massive investments in production equipment, facilities, infrastructure, R&D, and education and training. The projected expansion of international market share requires an upgrading in the product mix as well as in process and design capabilities. Out of China`s 25 wafer fab lines in early 2001, only one used 8-inch wafers, while 21 lines used outdated 5-inch wafers (6 lines) and even 4-inch wafers (15 lines)[30].

Table 4 provides a widely used proxy, developed by the U.S. Semiconductor Industry Association (SIA), for the investment costs of wafer fabrication. It is important to emphasize that these estimates assume that sophisticated infrastructure and support industries exist within the relevant clusters, or at least in close proximity. This is by no means the case in China. For

China from $ 100 million in 2000 to $ 1 billion by 2005 (Far Eastern Economic Review, Cover Story, November 1, 2001).

[30] China Electronics News, March 27, 2001. The 8inch line is a JV with Japan`s NEC, the Shanghai Hua Hong NEC Electronics Co.

instance, 90% of the materials used in the production of 8inch wafer fab lines must be imported. And domestic manufacturers of SC production equipment meet less than 10% of domestic requirements. In other words, China`s weak SC infrastructure and support industry base clearly implies that the effective investment costs for upgrading its SC industry may be substantially higher than indicated by the SIA figures.

Table 4 The Cost of Upgrading: Investment Costs of Wafer Fabrication

In short, there are clear indications in the semiconductor industry of a shift in network location away from the traditional export platform sites in Southeast Asia to China. Yet, this process may not be as quick and smooth as many observers appear to believe. This may provide enough breathing space for those countries that are most heavily exposed to the threat from China.

5. Implications for Malaysia's Upgrading Perspectives in the Electronics Industry

Let us now return to our initial question: In light of the afore-mentioned three transformations of GPNs in East Asia's electronics industry, what can we say about Malaysia's upgrading perspectives? Do these transformations provide new opportunities for relieving domestic upgrading constraints? And what policies and support institutions could help to successfully implement upgrading strategies?

We first highlight achievements and structural weaknesses of the Malaysian electronics industry that define and constrain its upgrading perspectives (5.1 and 5.2). We then assess current policies that try to link cluster development and global network integration (5.3), discuss adjustments in linkages with global brand leaders (OEMs) (5.4), and ask to what degree linkages with contract manufacturers (CMs) can broaden these opportunities (5.5). We conclude, by exploring new opportunities for diversifying Malaysia's international linkages that could enhance the upgrading prospects of its electronics firms, focusing on carriers of knowledge exchange that play an important complementary role to formal GPNs (5.6).

5.1. Achievements

A progressive integration into GPNs has been a primary driver of Malaysia´s success in the electronics industry. This integration started in the early 1970s with offshore chip assembly, primarily by US semiconductor firms. The next stage, since the early 1980s, was centered on Japanese electronics makers that moved their export platform production for consumer electronics to Malaysia and other Southeast Asian locations. Since the late 1980s, Malaysia was integrated into the production networks of American producers of computer-related equipment, as well as those established by their Taiwanese subcontractors. The most recent stage involves the production of communication and networking equipment, and the acquisition of existing flagship affiliates by global contract manufacturers (CM).

The Malaysian government, through its Industrial Master Plan (1986-1995), tried to reap as many benefits as possible from this fortuitous tailwind of foreign direct investment (FDI)(Ministry of International Trade and Industry, 1986[31]). The guiding principle has been "outward industrialization", subordinated to the needs of global network flagships. The results have been impressive, in terms of production, exports, employment and investment (**table 5**)

Table 5: Electronics Industry: Performance Compared to Objectives of Industrial Master Plan

[31] Ministry of International Trade and Industry, 1986, Industrial Master Plan 1986-95, Kuala Lumpur.

Within a relatively short period, Malaysia experienced a substantial capacity and international market share expansion for electronics products. A heavy reliance on electronics exports has acted as a powerful engine of growth. While there were periodic disruptions, like the downturn in 1985/86, and in particular the Asian financial crisis in 1997/98, the overall balance is remarkably positive. During the last decade, from 1990 to 2000, Malaysia`s electronics industry registered a CAAGR of 23.5%. During the same period, exports grew at an annual average of 25.2%, while employment grew almost 11% annually (figures courtesy of Ministry of International Trade and Industry, Kuala Lumpur, June 2001).

Global electronics brand leaders, and more recently, their contract manufacturers, played an important role. The electronics industry is the major recipient of FDI, absorbing more than one third of total manufacturing FDI between 1996-98 (MIDA, 1999). Around 100 large foreign affiliates effectively dominate this industry. Their share in manufactured exports (most of it electronics), has increased sharply from 39.8% in 1985 to 68.3% in 1992 (Takeuchi, 1997: p.9). The 18 members of the Malaysian-American Electronic Industry (MAEI) association accounted for more than 14 % of Malaysia`s electronics exports during 2001 (Business Times, Kuala Lumpur, October 3, 2001).

5.2. Weaknesses

Yet, despite these achievements, a shift in strategy is now overdue. Since the summer of 2000, the downturn in the global electronics industry has brutally exposed six structural weaknesses of Malaysia`s electronics industry that define and constrain its upgrading perspectives: an asymmetric industry structure; a heavy import dependence, due to weak domestic support industries and limited Hirschman-type linkages; a heavy reliance on exports, especially to the US market; a highly concentrated product composition, centered on low-end assembly operations; a declining capacity to generate employment; and a serious mismatch between the demand and supply for skills. While "outward industrialization" policies have provided Malaysia with substantial initial advantages in terms of export and capacity growth, these policies failed to develop sufficient sectoral breadth and depth.

a. Asymmetric industry structure

Malaysia's integration into GPN gave rise to the development of an asymmetric industry structure: multiple layers of electronics firms are distinguished by asymmetric control over resources and decision-making. At the end of 2000, roughly 900 electronics companies were registered in Malaysia employing more than 400,000 workers. While Malaysian firms dominate in numbers, Malaysia`s electronics industry continues to be shaped by strategic decisions of global flagships (both OEMs and major American CMs). In hierarchical order, four types of firms can be distinguished: at the top of the industry pyramid are global OEMs and CMs; followed by suppliers and contract manufacturers from Taiwan, Japan, Singapore, and Korea; higher-tier local suppliers; and, at the bottom, lower-tier local suppliers.

In contrast to countries like Taiwan, South Korea and Singapore, Malaysia has failed to develop a broad and multi-tier base of support industries. There are of course a few widely quoted success cases, almost all of them located in Penang, such as BCM, Globetronics, Unico, LKT, and Eng Teknologi, that have successfully positioned themselves as higher-tier local suppliers for leading OEMs (Rasiah, 2002; Best, 2001). As we will see later, these companies are currently moving to upgrade their capabilities to cope with the new opportunities and challenges that result from the transformations of GPNs.

However, the majority of the local suppliers possesses few proprietary advantages, and clearly qualifies as "lower-tier" suppliers. They lack sufficient financial resources to invest in training (and re-training), and to invest in digital information systems and leading-edge equipment. This is so, despite various promotion policies, focused on the smaller suppliers, introduced by the government. Possible explanations may include the proximity to Singapore and its sophisticated local supplier base, which may discourage flagships from using Malaysian suppliers; and negative side effects of Malaysia's "New Economic Policy".

This asymmetric industry structure has given rise to a lack of efficient domestic linkages and an inverted production pyramid -- a huge and rapidly growing final product sector that rests on a weak and much smaller domestic base of support industries.

b. Import dependence

The result is persistently high import dependence: rapid growth in the final products sector necessitates considerable imports of intermediates and production equipment. Between 1986 and 1992, imports of Malaysia's electronics industry increased at a rate of more than 24%, far exceeding the goal of 7.6% envisioned under the IMP. By the late 1980s, the Malaysian electronics industry had to import almost 43% of the intermediate goods that were required for the production of one unit of final output, far more than Korea (37%) and Japan (8.2%) (Takeuchi, 1997:7). This of course was a reflection of the initial strategy to position Malaysia as a low labor cost assembly site. By the late 1980s, however, the government acknowledged that this strategy was no longer sustainable, as new lower labor cost locations emerged within Southeast Asia, as well as in China, and Mexico.

Yet, Malaysia´s dependence on imports of electronics components, and especially semiconductors kept increasing during the 1990s, both as a share of electronics imports, and as a share of total merchandise imports (**table 6**). This suggests a fundamental mismatch of the country´s electronics exports and imports, with negative terms-of-trade implications: while imports involve high value-added core components, especially microprocessors and other ICs, Malaysia's component exports overwhelmingly consist of low-value added final assemblies.

Table 6 Dependence on Input Imports

c. Export dependence

Malaysia`s electronics industry remains heavily dependent on exports: in 2000, electronics manufacturing made up about 60% of Malaysia`s total export value, of which 35-40% were exports from Penang. Malaysia is one of the eight countries that are most dependent on exports to the US, six of these being from East Asia: its exports to the US (most of them electronics products) account for 24% of its GDP in 1999. This implies an extreme vulnerability of Malaysia's electronics industry to a recession in major export markets, especially the US. During 2001, when the U.S. electronics market was in free fall, Malaysia's electronics production and exports dramatically declined, the former by more than 25%, and exports by almost 19%.

d. Concentrated product composition

A highly concentrated product composition adds further to the country`s vulnerability. The share of electronics in merchandise exports has increased from 47.6% (1993) to almost 58% in 1998. And components account for 46% of all electronics exports, of which semiconductors alone account for more than one-third. **(table 7).** Industrial electronics (including computer-related products and telecom equipment) account for slightly more than 30%, and consumer electronics for about 15%.

Table 7 Developing Asia's Trade Specialization Profiles: RCA and Leading Exports Products

In historical terms, this constitutes an important improvement. Back in 1986, 84% of Malaysia`s electronics exports were components (most of them assembled chips), with 14% consisting of CE, and a measly 2% for industrial electronics. Unfortunately, this impressive change has not been sufficient to reduce the country´s vulnerability to abrupt changes in the world market. An important reason for this vulnerability is that SC exports generate very little local value-added, as Malaysia only performs assembly and testing. A heavy dependence on assembly-type operations for a handful of products can be crippling, as those operations can be easily replicated in countries with low education levels.

The government has tried to address this issue, by promoting investment in two new silicon foundries, Silterra (in Kulim High-Tech Park), and 1st Silicon, in Sarawak. To justify the heavy investment outlays, an attempt has been made to use these fabrication plants as catalysts for the development of circuit design houses. It is too early to assess the success of these investments. Bad timing has been an important constraint - these facilities became operational during the downturn. However, there are also positive signs. As the provision of silicon foundry services is becoming a commodity (Form 20-F report of United Microlectronics Corp. to the U.S. Securities and Exchange Commission, December 31, 2001, section on "risk factors"), there are now new entry possibilities for low-cost foundries in Malaysia and China, while the industry leaders (IBM

Microelectronics; and Taiwan's TSMC and UMC) move up the ladder to combining design capabilities with advanced fabrication technology (300 mm wafers) (Depeyrot, 2002)

e. Declining capacity for employment generation

A capacity for job creation in Asia's thriving electronics sector has been a hallmark of the region's successful export-oriented industrialization. Since the 1997 financial crisis, however, the sector's capacity for employment generation has declined. Take Seagate, the leading US. disk drive manufacturer. Since the mid-1980s, the company was among the largest employers in Southeast Asia - topping the list in Penang and Singapore. That golden age of employment generation has long gone. Table 8 documents the company's massive destruction of manufacturing jobs in Asia.

Table 8 Seagate: Shrinking Asian Manufacturing Employment

In Malaysia's electronics industry, an estimated 150,000 to 165,000 jobs have been lost since the financial crisis (**table 9)**. During 2001, the most recent year for which data are available, almost 19,000 workers have been laid off. Malaysian labor market experts talk of a declining employment-generating capacity of the electronics industry: while after earlier downturns, a substantial share of laid-off workers has been re-hired, this no longer seems to be the case.

Table 9: Job Losses in Malaysia`s Electronics Industry, 1998 - 2001

The latest unemployment report, prepared for the Penang State Government, conveys some distressing findings (Too and Leng, 2002). With job losses of more than 16,000 during 2001, most of them in sectors related to the electronics industry, retrenchment has been pretty dramatic, and it hits primarily low-skilled, female production workers[32]. Particularly disturbing is an unusually high proportion of the retrenched workers (62%) that could not be located, indicating a massive return of Malay females (in the 25-29 age range) to their villages. This shows that export-led electronics manufacturing is unlikely to act again as an engine of employment growth.

f. Mismatch between the demand and supply for skills

Finally, an increasingly important weakness in Malaysia's electronics industry is a serious mismatch between the demand and supply for skills. Despite the recession, job vacancies have increased to nearly 90,000 nationwide (September 2001), with the biggest job openings in the "managerial and professional" categories in the electronics industry. Data collected in Penang show that a growing deficit of specialized IT skills is an important qualitative constraint to Malaysia's upgrading perspectives in the electronics industry (DCT, 2002). This is especially true for engineers with degrees in electronics, mechanical engineering, quality control, testing and chemistry. There are also important bottlenecks for mechanics, and tool-and-die-makers, and IT professionals, especially system analysts. All of this indicates weak incentives for firms to invest in long-term assets, such as specialized skills.

This human resource bottleneck also has an important qualitative dimension. As Too and Leng (2002) document, having the right degrees in EEE, IT, and management does not guarantee entry into the labor market. They also find that the majority of unemployed graduates have not held a job of any kind since graduation. This reflects the perception of electronics firms that local university graduates have book knowledge, but are ill-equipped to deal with real world problems on the shop floor, and that they lack basic skills in communication, negotiation and presentation.

[32] Production workers with limited skills account for three-quarters of the total retrenched workers, while female workers account for almost two-thirds of total job losses.

This has led to the emergence of a bifurcated labor market, where the winners pick all the stakes: there is intense competition for those engineers and managers who either graduated from overseas universities or who worked for a foreign firm. Obviously, upgrading efforts will remain truncated, as long as this skills mismatch will not be reduced.

5.3. A Shift in Strategy (I): Clusters and Global Network Integration

Two policy initiatives are important for assessing Malaysia's upgrading perspectives in the electronics industry: the Second Industrial Master Plan (IMP2)[33] and the Multimedia Super Corridor (MSC) concept (Multimedia Development Corporation, 2002). Both represent attempts to overcome some of the afore-mentioned structural weaknesses of this sector. Both point in the right direction, but have had only limited success. In what follows, we will explore whether the transformations of GPNs that we have documented in this chapter, provide new opportunities for relieving domestic upgrading constraints.

In section 5.3 to 5.5, we focus on attempts to link cluster formation with global network integration that were initiated by IMP2. Finally, in section 5.6, we will address related attempts to strengthen innovative capabilities in Malaysia that were initiated by the MSC concept, and ask what new opportunities have emerged for diversifying international knowledge linkages.

a) The Second Industrial Master Plan (IMP2)

The IMP2 document signals a fundamental change in Malaysia's industrialization strategy, away from assembly-based "outward industrialization" to value chain-based manufacturing, from sector-based to cluster-based development, and from performance targets to productivity-driven growth. The strategy is defined by two key concepts: "manufacturing ++" and "cluster-based

[33] Ministry of International Trade and Industry, 1996, Second Industrial Master Plan, Kuala Lumpur, Malaysia.

development". In line with Porter (1990), "manufacturing ++" highlights activities at both ends of the value chain, i.e. R&D and engineering, and in-bound logistics on the one hand, and outbound-logistics and sales & marketing, on the other hand. It is argued that a move into knowledge-intensive support services like product development, process engineering, supply chain management, and some select areas of R&D will enhance local value-added and productivity. "Cluster-based development" implies that, based on existing strengths especially in components and semiconductors, developing a dense web of domestic linkages will enhance value -added and deepen domestic capabilities.

On paper, these two concepts represent the cutting-edge in current policy debates on regional and technology policy (e.g., OECD, 1999 and Best, 2001). It is important however to emphasize that, within Malaysia, there are four different "electronics clusters"[34] that differ quite substantially in their upgrading objectives and capabilities: i) in the North, the Penang Island and the Kulim HiTech park in the neighboring state of Kedah; ii) in the Center, Selangor and Negeri Sembilan; iii) the southern part around Johor, with close linkages with Singapore; and iv) the more recent MSC around Kuala Lumpur. Of these, the combined Penang/Kedah cluster has arguably been the most successful one, with good chances for further upgrading.

IMP2 highlights four specific objectives: i) foster the growth of "leading local companies (Malaysian brands); ii) reduce dependence on input imports; iii) strengthen agglomeration economies by developing "Integrated Manufacturing Centers" (IMC) for global network flagships; and iv) develop cross-border clusters. Of these, the first two objectives are problematic, while the last two indicate a move in the right direction.

[34] The designation of a particular location as a "cluster" raises of course tricky questions that are beyond the scope of this chapter. For instance, which of these "clusters" are just a collection of firms drawn to this location purely based on incentives given to local firms? And are there non-policy rationales for the observed level of agglomeration in the electronics industry in Malaysia?

The first objective represents an outdated concept of IU that assumes a fixed sequencing pattern from low-end, assembly-type subcontracting to “original brand name” (OBM) manufacturing (for a typical example, see Hobday, 1995). We now know that the transition to OBM is extremely difficult - even Taiwan´s Acer group has had only limited success (Ernst, 2000a and 2000c). The limited achievements of the “Proton City cluster” in automobiles also indicate that this objective may be unrealistic. As for the second objective, much depends on whether the country succeeds in finding the right balance between reaping the benefits of foreign input imports (as described in Rodrik, 1999) and the development of local backward and forward linkages[35].

b) Integrated Manufacturing Centers

The third objective contains some promising elements. Take recent developments in the Penang cluster. For instance, rather than just giving in to requests for improved incentives by foreign companies, the state government pursues a more selective approach: incentives are explicitly linked with the promotion of “integrated manufacturing centres” (IMC).The goal is to induce global flagships to move to Penang an “entire chain of operations for a particular product” (Asia Computer Weekly Online, October 22, 2001: 4). It is expected that this should enable the Penang cluster to upgrade from mere assembly and testing to knowledge support services, like sales and marketing, adaptive process engineering and tooling, financial planning, and, eventually parts of R&D like design and development (D&D)[36]. Table 10 provides examples.

Table 10 Penang - “Integrated Manufacturing Centre”

[35] Hirschman (1956) in fact emphasizes the need to combine both effects.
[36] Already since the late 1980s, Japanese flagships, like Matsushita etc. relocated D&D activities to places like Taiwan and Malaysia (e.g., Ernst, 2000b; and Ernst and Ravenhill, 1999).

An equally important development is attempts by the Penang state government to develop a “photonics industry cluster”. “Photonics” is the technology of harnessing light for digital applications, covering CD-ROMs, fibre-optic communications, lasers, sensing and measuring devices, and liquid crystal displays (LCDs). Penang has developed volume-manufacturing capabilities in all of these areas. Major global players in this sector, such as Osram, Agilent, Finisar and Solectron, are already active in Penang. In August 2001, the Penang Photonics Consortium (PPC) was established. Its main objective is to bundle existing activities into a dynamic cluster that could provide a broad range of contract manufacturing services in optical components. One of the main local players is Chahaya Optronics, a company that has received funding from the US based hard disk manufacturer, Komag Inc, and leading venture capital firms.

The current downturn in the global telecommunications industry has drastically reduced the pace of these efforts. Firms are currently struggling to survive. But, in principle, the idea is sound, and the challenge now is to be prepared, once demand for optical components will grow again. A defining characteristic of Penang’s photonics cluster development are attempts to leverage multiple and diverse sources of knowledge and capital, both foreign and domestic, to create a critical mass for local clustering. For instance, the Penang Development Corporation (PDC) has organized two working meetings with engineers and managers from Taiwan’s Photonics Industry and Technology Development Association (PIDA), with a twofold objective: to learn from Taiwan’s experience, and to develop joint projects. Equally important are linkages, developed by the Penang Photonics Consortium (PPC), with US and Taiwanese venture capital firms. Finally, a concerted effort is under way, in cooperation with the Penang Skills Development Centre (PSDC), and several local universities, emphasizing photonics in their core curriculum. While

5.4. Upgrading Linkages with OEMs

The fourth objective of the IMP2 however is of greatest interest. Extending existing clusters beyond national borders originally was driven by two concerns: to ease the severe shortage of IT skills by establishing joint “Growth Triangles” with neighboring countries that would attract low-cost engineers from all over Asia. Yet, competition between Asian countries for scarce IT skills has drastically intensified, frustrating progress along these lines. It is time now to redefine the meaning of cross-border clusters, and to ask how Malaysia’s existing electronics clusters could reap greater benefits from participation in GPNs.

We have seen that, as part of the concept of IMC, Malaysia was able to induce some OEMs to contribute to the development of specialized clusters. Such policies, which build upon earlier successful policies in Taiwan (Ernst, 2000a) and Singapore (Wong Poh Kam, 2000), can play an important catalytic role and need to continue.

Yet, to a large degree, the outcome of these policies depends on sector-specific developments that are beyond the control of a mid-sized country like Malaysia. Accumulated agglomeration economies matter of course, in terms of human resources, infrastructure and support industries (e.g., Best, 2001; Ernst, Guerrieri, Iammarino, and Pietrobelli, 2001). They also need to be continuously improved. Beyond that, the availability of incentives may tip the balance in favor of a particular location, but only if all the other conditions are in place. Otherwise, incentives are a waste of money.

A brief comparison of the cases mentioned in table 9 illustrates this point. The decisions by Komag and Quantum reflects the relentless pressure within the hard disk drive industry to move volume manufacturing and support services to locations in close proximity to Singapore, the dominant global cluster for these activities (Ernst, 1997b and McKendrick et al, 2001).

a) Footloose nature of FDI

An especially serious concern is that much of Malaysia's inward FDI remains highly "footloose" and prone to sudden relocation decisions to lower-cost locations. Equally important is that global flagships that are forced to downsize to retain shareholder value in a recession are inclined to cut first employment in export platform locations, reflecting their flexible labor market regulations[37]. Table 11 provides examples for both cases.

Table 11 Malaysia: Footloose FDI

Of particular interest is the recent decision by Dell to relocate its desktop production for the Japanese market from Penang to Xiamen/China, and to assign Xiamen to be the exclusive supply base China for Dell´s complete product line. While Dell's two plants in Penang remain the BTO shipment hub for the rest of Asia-Pacific (with the exception of desktops), this constitutes a major blow for Malaysia. While immediate job losses are only 60 (out of a total of 2000), this move to China indicates that more such redeployments may be in the offing. Dell gives three reasons for its decision to redeploy to China: good and low-cost Chinese engineers, cheap land, and the limited number of flight connections between Malaysia and Japan. This indicates how unpredictable and fragile Malaysia's upgrading perspectives are.

b) Upgrading opportunities

But linkages to OEMs also provide important new upgrading opportunities. We highlight two examples: "embedded" software", and RosettaNet.

"Embedded software"

[37] Thus far, contract manufacturers have been reporting only limited retrenchments. It remains to be seen to what degree the new limitations of CM-based outsourcing, discussed in section 3, may force contract manufacturers to lay off workers and to close factories in Asia.

For Malaysia, important upgrading opportunities reside in "embedded software", a no-frills program used in a broad array of electronic systems that does only the specific task it is meant to perform. The program takes very specific inputs from its usage environment, processes these and produces very specific outputs. Typical applications are car electronics, avionics, intelligent consumer products, communication and tracking devices, industrial automation and medical equipment. In Malaysia, examples include the joint software development projects of Intel and Motorola.

These projects are in line with a general industry trend. There is a worldwide shortage of the specific skills required for "embedded software" development. It requires very distinctive skill sets that are closer to hardware design than mainstream software development. Essential prerequisites are an experience in manufacturing and hardware design, and state-of-the-art equipment and quality control. Places like Penang, with their accumulated experience in manufacturing and product design (even if it involves only product customization) apparently have some advantages relative to traditional software outsourcing locations in India, where there has been less exposure to hardware design.

RosettaNet

Another interesting example is the RM 5 million grant allocated in the 2002 budget to promote the adoption of Rosetta Net e-business standards (interview with participants of PSDC seminar "Jump Start your e-Business with RosettaNet/XML", July 11, 2002). RosettaNet is a global consortium of over 400 of the world's leading OEMs and CMs for electronic components, semiconductors, computers and telecommunications equipment, working to create, implement and promote open e-business process standards. Malaysia is the fifth country in Asia to join RosettaNet, after Japan, Korea, Singapore, and Taiwan.

Two tools are available to implement the RosettaNet initiative: incentives and participation in standard definition. Out of the RM 5 million grant, roughly ten percent has been spent to set up the local operations of RosettaNet, with the Penang Development centre (PDC) responsible for providing the backbone infrastructure. The remaining RM 4.5 million will be given out to eligible companies with no more than RM 100,000 per company. The grant will be administered by the Small and Medium Industry Development Corporation (SMIDEC).

The idea is to involve major global network flagships that are already on the RosettaNet, such as Cisco, Dell, Quantum, Siemens, Solectron, Intel, AMD, Hitachi, Agilent, and Motorola. These flagships could then be used to pressure and cajole their local suppliers to upgrade their IT infrastructure so that these local suppliers become eligible for the above grants. Another criterion for the grant is financial strength, i.e. the eligible company must finance out of its own funds another 50% of the project cost. It is however an open question, how the substantial constraints can be overcome that prevent smaller lower-tier suppliers to adopt the RosettaNet standards.

Participation in the definition of the RosettaNet standards is probably the more immediately relevant tool. Six Malaysian electronics engineers, on loan to RosettaNet for two years, will work for six months at the California-based RosettaNet headquarters alongside American engineers to define XML-based specifications for the global electronics industry. The companies that provide these Malaysian engineers include global flagships (Intel and Microsoft), leading local suppliers (BCM Electronics, Globetronics Multimedia Technology), and two employees of MIMOS (= Malaysian Institute of Microelectronics Systems), a web developer and a public key infrastructure developer. Obviously, these six Malaysian engineers will play an important role as multipliers and upgrading catalysts, once they return from their US mission. They will also act as gatekeepers for these more knowledge-intensive linkages with global flagships.

5.5. Developing Multiple Linkages with Contract Manufacturers

To what degree can linkages with contract manufacturers (CM) broaden Malaysia's IU opportunities? Within Asia, two regions have experienced the greatest concentration of CM clusters: first Malaysia and Singapore (with a few additional sites in Thailand); and then, during the latter part of the nineties, China (see table 5). As for Malaysia and its neighboring countries, four important developments affect IU opportunities: the arrival of major US CMs; the acquisition of second-tier Asian contract manufacturers by major US CMs; the mutation of component suppliers from Japan and Taiwan into contract manufacturers; and upgrading efforts of Malaysian higher-tier suppliers.

a. Arrival of major US CMs

All the main US CMs are now present in the Northern Penang/Kulim Hi-Tech cluster, or in the southern Johor/Singapor cluster. Solectron is present in Penang, Johor and Singapore; Flextronics in Singapore and Johor; Sanmina/SCI in Penang, and Singapore; Celestica in Kedah`s Kulin Hi-tech Park; and Jabil Circuit in Penang. There are also a few important investments elsewhere in the region, such as Malaysia`s Kuching/Sarawak (Sanmina/SCI), Thailand (Flextronics, Sanmina/SCI and Celestica), and Indonesia (Celestica).

Table 12 Contract Manufacturing - Geographic Dispersion of Capabilities, 2001

The arrival of major global CM players thus far has created only limited upgrading opportunities for countries like Malaysia. Against our initial expectations, a website search for the above five global CM players conducted in December 2001 does not provide evidence that operations in Asia have significantly moved beyond manufacturing (table 12). Compared to a few years ago, the main progress has been an increasing sophistication in assembly technologies, especially multi-tier SMT, used for PCBA. Most of the above sites now also routinely provide support services related to manufacturing, with the exception of asset and logistics management. Typically, this also includes electrical and mechanical design services, global test services, printed circuit board layout services and detailed process engineering ("advanced manufacturing technology research" in CM industry parlance). The purpose of these services is to provide manufacturing solutions that enable a quick ramping-up of volume manufacturing.

A few locations, primarily in Singapore and Penang, are now also involved in new product introduction (NPI). These two locations are witnessing the development of original design for manufacturing (known as ODM) capabilities, but still on a very limited scale. Overwhelmingly, global CM players keep design (and especially circuit, advanced optical and systems design) concentrated in the US and Europe. One would of course expect such a disparity in design and product development, due to their high knowledge-intensity. This however is now changing, as Taiwanese contract manufacturers are now providing such ODM services (**Wu, 2002**). Industry observers expect that leading Taiwanese design firms will soon provide ODM services also from their overseas network sites in China, as well as in Singapore and Penang.

A comparison with locations in China, Hong Kong and Taiwan also demonstrates an important weakness of CM locations in Southeast Asia. Very few final or system assembly activities are located in the Malaysia/Singapore clusters. Overwhelmingly, they are located in the

US and Europe, in close proximity to the traditionally dominant markets. But over the last few years, and especially in response to the recession in the US and Europe, leading CM have started to establish final assembly locations and BTO shipment hubs in China, Hong Kong and Taiwan. The obvious motivation is to be as close as possible to the potentially huge China market.

In short, the inflow of substantial CM investments thus far has produced some limited opportunities for Malaysia to move beyond its traditional focus on volume manufacturing. But these opportunities have not yet reached a critical level that would be sufficient for a major push into more knowledge-intensive activities.

b. The acquisition of second-tier Asian contract manufacturers

A second important development in Malaysia´s CM cluster is that leading US contract manufacturers have recently rushed to acquire second-tier Asian contract manufacturers, primarily in Singapore, but also in Malaysia and elsewhere in the region. These acquisitions reflect the concentration in the global CM industry that has rapidly increased over the last few years, driven by M&A (see figure 2 above). The turn to recession has further accelerated these concentration trends.

Important recent examples include: Solectron which acquired the Singaporean contract manufacturers Natsteel Electronics and Singapore Shinei Sangyo (the latter an affiliate of a Japanese component supplier); Flextronics which acquired second-tier Singaporean CM JIT Holdings and Li Xin Industries; and Celestica which, through its acquisition of Singapore's Contract manufacturer Omni (October 2001), has acquired facilities in Singapore, Malaysia, Thailand and Indonesia, with almost 9000 employees.

To the degree that these acquisitions will result in plant closures and lay-offs, the may constrain IU opportunities. However, there could also be positive effects, if these acquisitions insert new capital, customers and management approaches.

c. Component suppliers from Japan and Taiwan

A third important development in fact predates the arrival of American contract manufacturers that has absorbed most public attention. Part and component suppliers from Japan and Taiwan, whose arrival in Malaysia goes back to the second part of the 1980s, have both acted as catalysts for the development of Malaysia's local support industries (e.g., Takeuchi, 1993, and Ernst, 1997b). Japanese component manufacturers have been concentrated primarily in the consumer electronics sector. Some of them, however, have also branched out into the computer sector. An interesting example is Kobe Precision (Malaysia), a company that, in Oct 2000, has been acquired by one of the leading Malaysian contract manufacturers, Eng Technologi Holdings Bhd (ETHB) (Business Times, Kuala Lumpur, Oct 27, 2000).

Taiwanese firms have played an important role in Malaysia´s computer industry. Prominent examples are Acer Peripherals and Iventech. The involvement of both companies in Malaysia started during the late 1980s. Over time, the Malaysian affiliates of these and other Taiwanese firms have upgraded from simple volume manufacturing, according to designs owned by the global flagships, to sophisticated contract manufacturers for leading computer network flagships. In addition to manufacturing, these Taiwanese affiliates now provide from their Malaysian sites product and component design, supply chain management services, and other knowledge-intensive support services. A handful of large Taiwanese contract manufacturers, led by firms like Acer, USI, Kinpo Electronics, Delta Networks, and Iventech, have pioneered the use of original design for manufacturing (known as ODM) capabilities in Asia (report by Technology

Forecasters, Inc., Alameda, CA, quoted in: EMS Insight, supplement on Circuits Assembly, September 2000). This apparently has forced major US-based CM players to follow suit. For Malaysian firms that interact with affiliates of these Taiwanese contract manufacturers, the move to ODM capabilities may provide IU opportunities. This example illustrates that FDI policies and incentives should not target only the world industry leaders. Wherever possible, these policies should try to bring in second-tier actors that are willing to bring along more knowledge-intensive activities.

d) Upgrading Efforts of Malaysian Higher-tier Suppliers

Our analysis of the US model of global contract manufacturing and its limitations indicates that there might be significant entry opportunities for higher-tier Asian suppliers to compete as low-cost niche contract manufacturers. Recent interviews in Penang (July 2002) indicate that leading higher-tier local suppliers all understand that they need move up *within* the hierarchy of contract manufacturing arrangements, from low-end box build, and consignment arrangements, to ODM provision, and total solutions provider. They are however facing major problems in sustaining and expanding their upgrading efforts. They all face the demanding challenge of pursuing *simultaneously* the following upgrading strategies, each of which requires major investments: establish a credible position as low-cost niche contract manufacturers (CMs); develop global presence, through overseas FDI; diversification and market segmentation; develop knowledge-intensive support services; and invest in design and R&D.

Take LC1, one of the most successful local companies. The company attempts to build on existing strengths in contract manufacturing and the provision of ODM services, to become a lower-cost "total solution provider" for carefully chosen niche markets. To do this with low overheads requires strong capabilities in six highly interdependent functions: manufacturing, quality, materials, procurement, engineering and human resources. It is important to emphasize the systemic nature of the required capabilities.

The implementation of these upgrading options requires the development of a broad and diverse set of capabilities. Take manufacturing services. The move from PCBA and box build to test necessitates the development not only of testing capabilities (which are scarce), but also of system engineering and maintenance capabilities. Furthermore, developing design & engineering capabilities requires substantial funds for R&D. Or take after-ship services. A seemingly mundane activity like repair requires the training of technicians in failure analysis, while end-life program management requires capable supply chain managers. As for the upgrading of procurement and outbound logistics, substantial funds are required for the gradual upgrading of the necessary information systems.

In short, the successful upgrading into an Asian niche market contract manufacturer requires substantial investments in training, equipment and facilities, and, most importantly, R&D. LC1 identifies the following seven challenges that result from the above strategy. First and foremost, substantial improvements are required for supply chain management and in the efficient use of the company's assets. These are the most fundamental requirements for staying in this business. Yet, their implementation requires substantial resources and management attention. Challenges 3 to 5 constitute the medium-term challenge: the company needs to develop a strong portfolio of designs (so-called intellectual properties, or IPs); it needs to capture new global niche market opportunities; and it needs to develop a global presence. Finally, the last two challenges highlight critical changes in industry organization, i.e. the move towards flexible domestic supplier networks that can complement LC1's own capabilities; and the overriding importance of human resource development, as a constant process of re-skilling and re-learning.

5.6. A Shift in Strategy (II): International Knowledge Sourcing

a. Searching for new sources of productivity growth

Despite impressive achievements, Malaysia's knowledge base in the electronics industry remains too weak to sustain industrial upgrading into more knowledge-intensive activities. There is a heavy reliance on technological capabilities developed within affiliates of global flagships, and their eventual spillovers into local firms. This traditional transfer pattern however does not seem to work any longer. In Penang for instance, a disturbing slow-down in TFP growth has been observed since 1995 (State Government of Penang, 2001). Between 1995 and 1997, TFP declined by -0.5 for all manufacturing, compared to an increase of 8.9% between 1990 to 1995. In the electronics industry, TFP growth fell to 2% (from 14.1% during the earlier period), hardly sufficient for an industry that is supposed to be the engine of upgrading.

As for TFP growth for all of Malaysia, most estimates put it around 1 to 2 % p.a. (until 2000). This is way below the minimum TFP growth projected by the government of 3.2% (for the period 2001 to 2010), which is necessary, if Malaysia wants to achieve the projected growth rate of 7.5%. Compared with historical growth patterns of productivity in industrialized countries, one is forced to argue that this slow-down in productivity growth comes much too early. For Malaysia, such a massive slow-down in TFP growth is certainly premature, in light of the thus far still limited progress in its specialization by product and production stage.

In short, while FDI by major global electronics OEMs used to play a catalytic role in boosting Malaysia's productivity growth before 1995, they may no longer play that role. Except for China, and possibly India, OEMs are unlikely to increase their inward FDI in Asia. As argued before, these changes are structural rather than cyclical, and they are here to stay. Hence, Malaysia needs to develop a set of alternative international linkages that could play a complementary role as external sources of productivity growth.

b. The MSC concept

A widely known attempt to address this issue is the government's initiative to establish a $40 billion Multimedia Super Corridor (MSC) that was supposed to leapfrog the country into fully developed nation status by the year 2020 (Multimedia Development Corporation, 2002). In 1996, the government had hired McKinsey, the global consulting firm, to draft a blueprint for a 15-kilometer-by-50-kilometer strip intended to be Malaysia`s answer to Silicon Valley. An unprecedented set of incentives, enshrined in the Bill of Guarantees, were offered to companies involved in the creation, distribution, integration or application of multimedia products and services within the MSC.

According to the Multimedia Development Corporation (2002), these incentives include commitments "to provide a world-class physical and information infrastructure; to allow unrestricted employment of local and foreign knowledge workers; to ensure freedom of ownership by exempting companies with MSC Status from local ownership requirements; to give the freedom to source capital globally for MSC infrastructure, and the right to borrow funds globally; to provide competitive financial incentives, including Pioneer Status (100 percent tax exemption) for up to ten years, or an investment tax allowance for up to five years, and no duties on the importation of multimedia equipment; to become a regional leader in Intellectual Property Protection and Cyberlaws; to ensure no censorship on the Internet; to provide globally competitive telecommunications tariffs; to tender key infrastructure contracts to leading companies willing to use the MSC as their regional hub; and to provide a high-powered implementation agency to act as an effective one-stop super shop."

It is hard to find a more aggressive list of incentives. $3.7 bn have been spent thus far, but results are disappointing. A leaked confidential report by the very same company that designed the project (McKinsey) concluded in February 2001 that the Multimedia Super Corridor " had not attracted much interest from global investors, nor made an impact on the domestic economy." (Prystay, 2001)[38]. In the meantime, the debate has moved on to explore what one can learn from this failure (author's interviews with members of the National Information Technology Council, July 4, 2002, in Kuala Lumpur). Three conclusions seem to emerge: First, initiating the MSC was a step in the right direction. However, it is now time to expand its geographic coverage and to extend MSC status to other emerging electronics clusters in Malaysia. The Penang State Government in particular has been actively lobbying for such an extension, arguing that this was necessary to attract specialized skills from overseas on a contract basis to overcome its critical shortages.

Second, lavish tax incentives and massive investment in infrastructure are insufficient to bring about the development of dynamic clusters. Especially for the IT sector, infrastructure is a highly perishable "public good": the infrastructure for the MSC was perhaps state-of-the -art when it was established a few years ago, but it becomes obsolete very rapidly. Third, arguably the most important ingredient of successful cluster formation is missing: specialized skills and innovative capabilities. As emphasized throughout this study, the key to success is incessant efforts on a massive scale to continuously upgrade existing skills and capabilities. The lack of depth and horizontal mobility in Malaysia's labor market increases the risk of individual investment in specialized skills. Therefore the importing of scarce skills should be given greater emphasis. While this seems to be obvious, this simple fact is frequently forgotten. In the case of Malaysia,

[38] Some 500 companies, including 45 international ones, are located in the corridor. But the McKinsey report

the gap between the supply and the demand of specialized IT personnel has continuously increased, especially for engineers[39]. In short, as long as this critical human resources bottleneck is not overcome, there is little hope that the MSC concept can act as a "breeding ground for technological innovations, new businesses and companies through the cooperation between the industrial and academic circles" (Takeuchi, 1997, quoting from official background documents).

The following major priority areas for reducing the skills mismatch in the Malaysian electronics industry were identified during recent interviews with government agencies and leading companies (June/July 2002)[40]: 1. A massive re-skilling and re-training requirements for production workers, 2. Graduates, especially for EEE, IT, circuit design who are able to combine hardware, software, and application knowledge; 3. Experienced managers, especially for strategic marketing, upgrading management, and management of international linkages; 4. Entrepreneurs that combine street-wise commercial and financial instincts with analytic capacity for strategic decision-making 5. Experienced and industry-savvy administrators who are willing to stick out their necks and to do more than just follow the rules (this of course requires some incentive alignment); 6. Incentive alignments for university professors and academics that encourage close interaction with private sector (company internships and sabbaticals); 7. dense interactions with expatriate nationals who are based in the US, Australia and Europe, or elsewhere in Asia; and 8. a capacity to bring in at short notice specialized experts from overseas who can help bridge existing

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described the level of investment of those international electronics firms as "not very significant." (Prystay, 2001).

[39] On this indicator, Malaysia is continuously ranked at the bottom in the annual World Competitiveness Report, lagging substantially behind Korea, Singapore, Taiwan and India.

[40] In Kuala Lumpur, I am especially indebted to discussions with Dato Prof. Dr. Zawai Ismail, director, Commerce Asset Ventures, who has set up brainstorming sessions with relevant government agencies and venture capital firms. In Penang, I am especially indebted to discussions with Tan Sri Dr. Koh Tsu Koon, Chief Minister of Penang, Dato Dr. Toh Kin Woon, Penang State Executive Councillor, Mr. Boonler Somchit, Executive Director of the Penang Skills Development Centre (PSDC), Dr.Ganesh Rasagam, CEO, DCT Consultancy Services, and Dr. Anna Ong, Senior Analyst, Socio-Economic and Environmental Research Institute (SERI).

knowledge gaps and who can catalyze necessary changes in organization and procedures required to develop these capabilities locally.

c. Diversifying international linkages

In light of the transformations of GPNs that we have documented in this chapter, Malaysia should exploit new opportunities for diversifying international linkages. Three complementary international linkages deserve particular attention: i) with foreign universities and research institutes, moving beyond the exclusive ranks of the "Ivy League"; ii) with information service and consulting firms, especially smaller, second-tier firms; and iii) with informal global peer group networks that now play an increasingly important role as carriers of knowledge.

d. Foreign universities and research institutes

We have seen that current transformations in the organization of GPNs, accelerated by the use of digital information systems, have substantially increased the mobility of knowledge. The digitalization of knowledge implies that it can be delivered as a service and built around open standards. This has fostered the specialization of knowledge creation, giving rise to a process of modularization, very much like earlier modularization processes in hardware manufacturing.

These developments may well create new opportunities for more aggressive forms of IU that no longer need to stay away from original knowledge creation. But, at this stage, this is largely uncharted territory, as these developments are very new, and there is practically no research. Nevertheless, it is time for a country like Malaysia to strengthen linkages with overseas universities that can help to upgrade research, development and design capabilities in Malaysian universities and public labs. The starting point is to correct the current policies. The focus thus far has been on a handful of global elite institutions that bring in their standard, routine IT and business courses at very high cost. Instead, collaboration should focus specific niche areas, in line with Malaysia's needs. Possible examples include certain areas of chip design, packaging technology, and photonics. Realistically, the search should move beyond the exclusive ranks of the "Ivy League" universities: there is ample choice of smaller, less well-known universities and research institutes that are more willing to develop innovative courses that are customized to the specific needs and capabilities of Malaysia's electronics clusters. This may include institutions in countries like Taiwan (e.g., ITRI; ERSO, III, etc); Korea (e.g., ETRI; KAIST; ICU and other specialized research institutes), India (e.g. its well-regarded Indian Institutes of Technology, and the Indian Institutes of Information Technology).

e. International consulting firms

Equally important is a reconsideration of linkages with consulting firms. For information technology, these firms now play a critical role in diffusing both codified and tacit knowledge. The problem however is that this market is overwhelmingly dominated by a handful of giant corporations like IBM and consultancies like Accenture that grew out of global accounting firms. These firms thrive on the economies of scale of knowledge sharing (called "network economies" by information economists). As flagships of global information service networks, these firms provide a standard product wherever they go. Customization is possible only within the limits of these standard solution packages. This approach to customization is extremely costly: customers are charged for the time required for adjusting the standard IT package and for effective implementation, and these costs are inflated by massive delays. The result is that new systems often come in late, over budget and unable to solve problems they were meant to address. This has created a demand for smaller, specialized niche players that do not start from standard solution packages and that offer clients fixed-price projects. There is now a wide choice available of smaller, less well known but proven information service and consulting firms. This may include also firms from some of the afore-mentioned Asian countries that have already some experience with knowledge-intensive information services.

f. Informal peer group networks

Malaysia also needs to tap into an increasingly important carrier of international knowledge diffusion: “transnational technical communities” (Saxenian, 2002) of technically skilled immigrants with business experience and connections in the US, Europe and Japan that play an important and complementary role to network flagships in global production networks. Such informal global peer group networks have created new opportunities for IU in formerly peripheral, economies around the world. By linking their home countries with the world´s centers of information and communication technology (encompassing Silicon Valley and other centers of excellence in less well known places like Helsinki, Kista/Stockholm, Grenoble, Munich, Tsukuba, Tel Aviv, etc), these informal social networks transform what used to be a one-way “brain drain” into a two-way process of “brain circulation”. These networks generate invaluable knowledge on global market and technology trends in a way that addresses the needs of domestic firms much better than linkages with global flagships, or for that matter with global consulting firms. They also provide entrepreneurs and venture capitalists that can function in both worlds. This has created alternative and robust mechanisms of knowledge exchange across geographic borders and firm boundaries. Examples include Israel, Taiwan, South Korea, India, China, as well as Mexico and Brazil.

In Malaysia, the Penang cluster has obviously benefited from students who have studied engineering and management overseas, whether in Australia, Japan, the UK and the US, and who have returned with business experience and connections. Predominantly, these connections have been with global flagships like Intel and Motorola in semiconductors, or Matsuhita and other

Japanese flagships in consumer electronics. Overwhelmingly, the technology, skills, and knowledge generated by these immigrant engineers has focused on manufacturing-related activities. It is time now for Malaysia to adjust this “brain circulation” to encompass new areas like knowledge-intensive support services, circuit design and chip packaging.

CONCLUSIONS

Based on operational definitions of key characteristics of global production networks (GPN) and industrial upgrading (IU), this chapter has explored how East Asia, and especially Malaysia, could build on recent transformations in the structure, coordination, contents and location of GPNs to promote a continuous upgrading of the electronics industry. We highlight the new opportunities and competitive challenges that result from these transformations, review major constraints to IU, and assess policy responses.

The growing mobility of knowledge has created greater opportunities for using network participation as a catalyst for further IU. But realizing this potential has also become more difficult for mid-sized countries like Malaysia. The best choice arguably is to move forward in incremental steps, and to build on existing strengths in assembly and volume manufacturing, by adding knowledge-intensive support services. Of critical importance is the absorptive capacity of the local suppliers, i.e. their resources, capabilities and motivations. The absorptive capacity is shaped by pressures exerted by network flagships and by the existing incentives. To stay on the GPNs, local suppliers must constantly upgrade their absorptive capacity by investing in their skills and knowledge base.

Equally important are attempts to strengthen the country’s innovative capabilities through selective international knowledge sourcing. Transformations in GPNs are gradually reducing the barriers for effective knowledge diffusion. As an immediate policy instrument, it is advisable to import missing critical skills from overseas. This could help to catalyze necessary reforms in the domestic innovation system. The timing may be good, as massive retrenchments in the US and European electronics industries, and a more hostile attitude toward foreign researchers, especially from the Middle East, but also from Asia, may induce foreign researchers to work in Malaysia.

Adequate incentives are required to generate sufficient investments in the development of skills and capabilities (as illustrated for instance by the Nordic countries in Europe, and by Taiwan, and Singapore). Policies towards both OEMs and CMs need to move beyond "incentive tournaments". Infrastructure development is critical, but needs to move beyond a widespread "hardware" bias. As illustrated in this paper, successful IU within GPNs requires support policies for local firms through local supplier development, (co-funded) skill development, standards setting, and the provision of investment and innovation finance through a variety of sources, including venture capital, and IPOs.

Of particular importance for East Asia are new opportunities to tap into international flows of human capital and knowledge through informal peer group networks of technically skilled immigrants with business experience and connections in the US, Europe and Japan. These international social networks can play an important and complementary role as carriers of knowledge and capital to OEMs, CMs and global consulting firms. While Malaysia has developed some of the most ambitious sets of policies and incentives, the country still has a long way to go to exploit these new opportunities.

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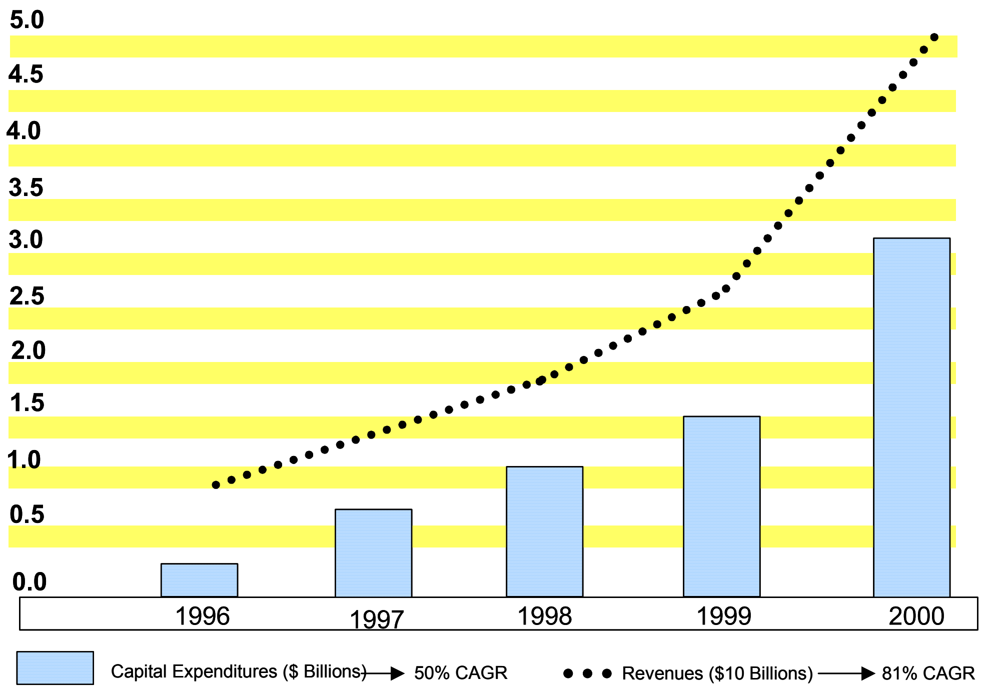
APPENDIX

Figure 1. The Growth of the CM Industry, 1996-2000*



*CM industry includes Solectron, Flextronics, SCI Systems, Jabil Circuit, ACT Mfg., Celestica, Plexus, and Sanmina.
Source: Hoover's

Figure 2. M & A in the CM Industry, 1997-2000

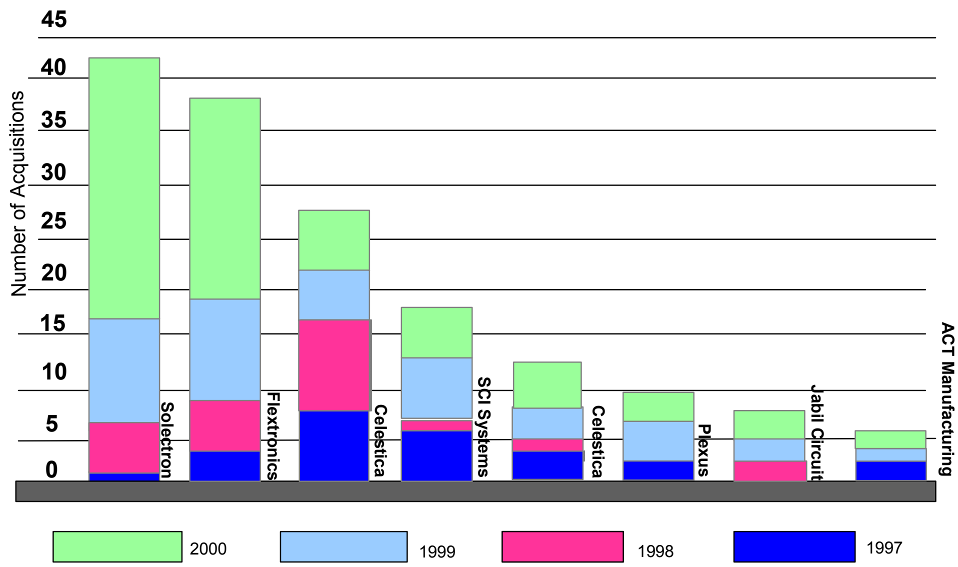


Table 1. Contract Manufacturing Clusters in East Asia, 01/2002

Company	Southeast Asia*	Greater China**	Other countries
Flextronics	Singapore/HQ Malaysia • Johore • Johor Baru • Melaka Thailand • Samutprakarn	Taiwan • Taipei China • Beijing • Changzhou/ Jiangsu • Doumen/Zhuhai • Shanghai/ Wai Gao FTZ • Xixiang/ Baoan Shenzhen	India • Bangalore
Solectron	Singapore Malaysia • Penang • Johor (1991)	China • Suzhou/ Jiangsu Taiwan • Taipei	Japan • Tokyo • Kanagawa
Sanmina/SCI	Singapore Malaysia • Penang • Kuching/ Sarawak • Sana-Jaya FTZ Thailand	Taiwan • Taipei China • Shenzhen • Qingdao • Kushan/Jiangsu	
Celestica	Singapore Malaysia • Kulin High Tech Park Thailand Indonesia	Hong Kong China • Dongguan/ Guangdong	
Jabil	Malaysia • Penang	Hong Kong: Asia HQ China • Kanton/ Guangdong • Shenzhen/ Guangdong Panyu/ Guangdong	

* = Singapore, Malaysia, Thailand, Philippines, Indonesia, Vietnam
** = China, Hong Kong, Taiwan

Table 2. Changes in Outsourcing Arrangements

Activity	Traditional Approach	Emerging Changes
Capacity planning	**Deterministic** • capacity, service levels & performance requirements are fixed at contract closure	**Stochastic** • proceeding by conjecture • reserve capacity that covers baseload • up-scaling if product becomes a hit
Production planning	**Precise commitment** • product mix & linkages are determined at contract closure	**Rolling commitment** • aggregate capacity is reserved for contract period • OEM reserves right to decide how to use that capacity just before actual production starts • CMs must provide flexible production systems that allow alternative uses
Product design	**Frozen** • minimal changes in configuration	**Flexible** • allow for variations in availability of parts & components • ditto for capacity • faster turnover: extend successful lines with derivates
Network governance	**Strategy shapes structure** • develop network organization in line with given strategy • control every aspect of value chain	**Iterative learning** • start outsourcing arrangement, without seeking perfect solution at the beginning • correct as you go along • speed of iterative adjustment is key to profitability
Performance expectations	**Focused** • unit cost reduction over a small range of production volumes • limited scalability • local, not global optimum	**Systemic** • combine unit cost reduction with extended scalability • flexible use of reserved capacity • focus on high-margin products & services • "90% of the global optimum – fast"

Table 3a: Major Investment Projects in China's Semiconductor Industry, since January 2000

Global Flagships (100% affiliates)

	Location	Activities	Investment ($ bn)	Capacity/Technology
Intel	Waigaoqiao Free Trade Zone, Shanghai	expansion of chip assembly & test	0.302	• Intel`s new 845 chipsets used with Pentium 4 processors
AMD	Suzhou/Jiangsu Province	assembly & test	0.108	
Motorola	Tianjin	integrated wafer fab, assembly & test	1.9	
Fairchild	China-Singapore Suzhou Industrial Park/Jiangsu Province	• assembly & test for wide range of logic, discrete and analogue devices • plans to outsource > 50% to local suppliers	• 0.010 (2002) • total: 0.200 • plans to use latest in IT to enhance cost efficiency and time-to-market	• 120,000sqft (2002) • total: 800,000 sqft.
Philips	Dongguan/ Guangdong Province	assembly & test		

Table 3b: Major Investment Projects in China's Semiconductor Industry, since January 2000

Contract manufacturers, primarily from Taiwan

	Location	Activities	Investment ($ bn)	Capacity/Technology
SMIC (= Semiconductor Mfg. Int'l. Corp.)	Shanghai	silicon foundry		480,000 8-inch wafers at 0.25 micron
Shanghai Grace Semiconductor Mfg. Corp.	Shanghai (JV between Formosa Plastics & Chinese group headed by the son of PRC president	silicon foundry	1.6	
TSMC	considering investment in silicon foundry			
UMC	ditto			
ASE (Advanced Semiconductor Engineering Inc)	Hangzhou/ Zhejiang province	IC assembly & test	0.0028	
USI Electronics (Universal Scientific Industrial Co Ltd.), a subsidiary of ASE	Shenzhen	PC motherboards (Pentium 4) • for IBM, via USI Co Ltd. Taiwan	• Operating revenues for 2001: $ 100 million	• Capacity expansion from 6 to 10 lines • monthly production capacity increasing to 400,000 units
Siliconware Precision Ind Co	Shanghai (possible JV with Shanghai Huahang Group Co. Ltd.	IC assembly & test		

Table 3c: Major Investment Projects in China's Semiconductor Industry, since January 2000

Chinese Companies

	Location	Activities	Investment ($ bn)	Capacity/Technology
Shanghai Hongli Semiconductor Mfg. Co.	Shanghai	production of 8inch & 12 inch wafers		
Sast Group	Shenzhen	2 wafer fab lines	1.2	40,000 wafers per month
Beijing Xunchuang IC Co.	Beijing (JV that involves Chinese companies and Kingston, plus Taiwanese investment fund (Asia Pacific Technology development Corp.) **??**	assembly & test	0.200	
China Great Wall Computer Schenzhen	• Pudong "Silicon Harbor"/ Shanghai • JV with Kingston Technology, a US. (or Taiwan-based**?**) memory module vendor which owns 80%	assembly & test		50,000 sq.ft.
Beijing Huaxia Semiconductor Mfg. Co, Ltd		wafer fab		8-inch, o.25 micron

Table 4 The Cost of Upgrading: Investment Costs of Wafer Fabrication

Process technology	Minimum investment requirements*
6-inch wafers (0.5 - 1.2 microns)	$ 200 million
8-inch wafers (0.35 - 0.5 microns)	$ 1.2 billion
12-inch wafers (< 0.35 microns)	$2.5 billion

* = estimates, courtesy of US-Semiconductor Industry Association (SIA)

Table 5

Electronics Industry: Performance Compared to Objectives of the Industrial Master Plan

	IMP Goals	Performance
Production	11.0	30.5
Exports	10.9	32.6
Employment	5.5	21.l7
Investment value	6,298	25,985

Note: Figures for production, exports and employment are average rates of growth between 1986-1992. Those for investment are the cumulative total of investment approved between 1986-1995.
Source: Ministry of International Trade and Industry, 1996, Second Industrial Master Plan 1996-2005

Table 6 Heavy Dependence on Input Imports

		In Electronics Imports (%)						In Merchandise Imports (%)					
		1993	1994	1995	1996	1997	1998	1993	1994	1995	1996	1997	1998
Korea	Components	57.0	53.2	54.1	55.3	60.2	71.6	9.5	9.5	9.7	10.0	12.0	16.6
	o/w Semiconductors	34.8	34.0	35.7	36.8	43.0	54.7	5.8	6.0	6.4	6.7	8.6	12.7
Taiwan	Components	66.3	67.5	70.0	65.3			13.7	14.8	16.9	16.7		
	o/w Semiconductors	41.2	43.9	46.5	43.1			8.5	9.7	11.2	11.0		
Singapore	Components	48.0	52.9	56.9	55.4	53.4	56.4	18.6	23.2	26.0	24.3	23.8	26.5
	o/w Semiconductors	25.0	30.5	35.6	33.9	33.6	37.3	9.7	13.4	16.2	14.9	15.0	17.5
Malaysia	Components	76.5	78.7	78.1	76.7	72.8	78.5	25.3	28.3	28.8	29.6	28.3	36.7
	o/w Semiconductors	42.9	45.9	49.7	49.6	49.2	56.5	14.2	16.5	18.3	19.1	19.1	26.4
Thailand	Components	55.1	55.9	59.1	60.0	58.7		9.6	11.6	12.4	12.6	14.1	
	o/w Semiconductors	26.4	26.8	28.7	30.2	29.9		4.6	5.6	6.0	6.4	7.2	
Philippines	Components	37.8	40.3	43.7	54.7	34.9		5.8	6.6	7.7	20.7	9.4	
	o/w Semiconductors	28.0	28.8	30.3	46.6	27.0		4.3	4.7	5.4	17.7	7.3	
Indonesia	Components	46.4	48.6	46.3	37.5	33.8	33.9	4.4	3.5	3.3	3.2	3.0	2.0
	o/w Semiconductors	4.5	4.0	3.8	2.9	2.1	2.4	0.4	0.3	0.3	0.2	0.2	0.1
Hong Kong	Components	38.0	38.1	39.7	39.6	40.5	40.1	9.8	10.4	11.6	11.6	12.5	12.8
	o/w Semiconductors	18.8	18.7	20.7	20.2	20.3	19.6	4.8	5.1	6.0	5.9	6.3	6.2
China	Components	40.9	43.1	44.3	49.6	55.0	53.1	5.3	6.3	6.9	7.4	9.2	11.4
	o/w Semiconductors	11.0	12.5	14.7	17.7	21.4	22.3	1.4	1.8	2.3	2.6	3.6	4.8

Source: UN Trade Data Base Comtrade

Table 7. Asian Trade Specialization Profiles: RCA and Leading Export Products

Country	Product	RCA '93	RCA '94	RCA '95	RCA '96	RCA '97	RCA '98	Share in Electronics exports (%) '93	'94	'95	'96	'97	'98
Korea	EDP	0.9	0.8	0.8	0.9	0.9	0.7	14.4	11.9	12.2	14.5	15.5	13.9
	Storage	0.2	0.3	0.4	0.7	1.3	1.1	0.5	0.8	1.0	1.8	4.1	4.1
	COMP	2.4	2.7	2.8	2.7	2.8	2.7	50.1	56.2	62.4	60.8	62.3	63.4
	SC	3.3	3.8	4.1	3.6	4.0	3.8	30.4	37.2	45.7	40.3	42.9	45.3
	Cons. Electronics	2.3	2.4	2.0	2.0	1.7	1.5	22.5	20.5	16.1	15.6	12.8	12.7
	Telecom	0.9	0.9	0.8	0.8	0.6	0.5	3.0	2.7	2.4	2.4	2.1	1.9
	Memo: Share of Electronics in Merchandise exports (%)	28.0	29.7	30.9	28.8	29.2	28.3						
Taiwan	EDP	2.5	2.7	3.0	3.4			39.4	39.0	41.6	45.0	44.62	45.29
	Storage	0.3	0.3	0.5	0.6			0.8	0.6	1.0	1.3	2.10	1.97
	COMP	1.9	2.0	2.1	2.2			37.2	39.3	41.6	40.2	41.93	40.86
	SC	1.6	1.8	2.0	2.2			13.7	16.8	20.4	19.6	22.05	21.77
	Cons. Electronics	1.4	1.5	1.2	1.1			12.9	12.0	8.5	6.8	6.42	5.98
	Telecom	1.7	1.7	1.6	1.6			4.9	4.8	4.1	4.0	3.59	4.20
	Memo: Share of Electronics in Merchandise exports (%)	29.5	31.0	34.3	35.8								
Singapore	EDP	4.6	5.1	5.1	5.4	5.5	5.2	40.7	38.6	39.4	42.8	44.1	44.6
	Storage	12.9	13.4	12.8	15.3	12.4	11.4	17.6	15.7	16.0	18.8	19.3	19.8
	COMP	2.7	3.4	3.4	3.6	3.7	3.7	29.4	35.4	38.5	38.0	38.9	40.7
	SC	3.2	4.0	4.2	4.5	4.8	5.0	15.7	19.4	23.8	23.9	25.0	27.4
	Cons. Electronics	3.1	3.2	2.9	2.9	2.3	1.7	15.9	13.7	11.6	10.4	8.7	6.8
	Telecom	1.1	1.2	1.1	0.8	0.7	0.6	1.9	1.9	1.6	1.3	1.1	1.1
	Memo: Share of Electronics in Merchandise exports (%)	53.0	58.8	60.7	60.7	60.6	61.4						
Malaysia	EDP	1.4	1.8	2.0	2.3	2.9	3.0	13.8	15.6	17.1	20.5	25.3	27.4
	Storage	0.0	0.1	0.8	0.2	3.7	4.1	0.0	0.2	1.1	0.3	6.3	7.6
	COMP	3.7	3.7	3.6	3.8	3.9	3.9	44.6	42.6	43.9	44.6	45.1	45.7
	SC	5.6	5.2	4.7	4.9	5.3	5.2	30.5	28.3	29.8	29.3	30.1	30.7
	Cons. Electronics	4.2	5.0	5.1	5.0	4.1	3.5	24.2	24.2	22.6	20.1	16.5	15.1
	Telecom	2.1	2.4	2.0	2.0	1.7	1.5	3.8	4.0	3.2	3.3	3.1	2.8
	Memo: Share of Electronics in Merchandise exports (%)	47.6	52.5	54.9	54.7	55.8	57.5						
Thailand	EDP	1.4	1.8	1.9	2.4	2.5		32.2	34.0	36.8	41.4	40.9	
	Storage	2.8	5.4	4.6	4.5	2.0		9.8	15.5	14.0	11.9	6.2	
	COMP	1.4	1.5	1.5	1.6	1.6		38.4	38.8	39.9	36.5	35.8	
	SC	1.7	1.6	1.4	1.6	1.7		20.8	19.3	19.5	18.8	18.3	
	Cons. Electronics	1.3	1.6	1.4	1.5	1.7		16.7	16.4	13.3	12.0	13.1	
	Telecom	1.2	1.1	1.0	1.2	1.2		5.2	3.9	3.7	4.1	3.9	
	Memo: Share of Electronics in Merchandise exports (%)	20.8	24.0	24.9	28.4	29.6							

Source: UN Trade Data Base Comtrade

Table 8 Seagate: Shrinking Asian Manufacturing Employment

Locations	**Peak year**	**2002**	**Job Losses**
Malaysia	24,000 (1987)	5,500	- 18,500
Thailand	40,000 (1998)	18,000	- 22,000
Singapore	20,000 (1998)	9,000	- 11,000
Total	84,000	32,500	- 51,500

Source: company reports & 10Ks

Table 9: Job Losses in Malaysia`s Electronics Industry

1998	1999	2000	2001 (Jan to August)
83,900	37,400	25,600	18,900

Source: Government figures, quoted in: Hamid, H., 2001, "Lay-Offs Unlikely to be as Severe as Three Years Ago", Business Times, Kuala Lumpur, October 3

Table 10 Penang - "Integrated Manufacturing Centre"

Year	Company (Product)	Remarks
1999	Komag (world largest supplier of thin-film disks)	Relocates entire US operations to Penang, except R&D, and sales& marketing
2000	Dell Computer (PCs, servers & storage products)	• Establishes Penang as BTO (built-to-order) hub for the Asia-Pacific region • Decision reversed 1 year later, when much of these activities are moved to Xiamen/China
20001	Quantum (hard disk drives)	Plans to move to Penang entire manufacturing line for digital linear tape
2001	Intel	• For embedded 8bit processors, Penang covers all value stages, including design of chip & motherboard • Plans to locate 2 new designs centers in Penang
2001	Motorola	M's software centers in Penang and MSC receive ACI level 5 certification (= highest level of software certification)

Table 11. Malaysia: Footloose FDI

Year	Company (product)	Remarks
1998	Read-Rite (hard disk drives)	• Penang facility closed and relocated to Thailand and Philippines • job loss: 4,000
2000	Seagate (hard disk drives)	• share-holder driven downsizing • closing facility in Ipoh → job loss: 2,000
2001	Seagate (hard disk drives)	• closing one of its plants in Prai→ job loss: 4,000
2001 April	Motorola	• lays off 10% of its 4000 employees in its plant in Sungei Way, Selangor • job loss: 400
2001	Intel	• Reduces worldwide workforce by 5 % • Expected job loss in Malaysia: 500 • massive expansion in China
2001	AMD	• job loss in Penang plant: 1,300 (52% of worldwide job cuts) • massive expansion in China
2001 August	Dell	• relocates desktop production for Japan market from Penang toXiamen/China • Xiamen becomes exclusive supply base China for Dell´s complete product line • With exception of desktops, Penang remains hub for the rest of Asia-Pacific • Main reason: limited flight connections between Malaysia and Japan
2001	Lucent	• closes its regional technology center in Malaysia → jobs loss: 150 • cuts workforce at manufacturing plant by 50%

Table 12 Contract Manufacturing: Geographic Dispersion of Capabilities, 2001

CAPABILITIES	Americas	Europe	Asia
Manufacturing & Distribution			
Supply-base & logistics management	•	•	•
PCB assembly	•	•	•
Flexible circuit assembly	•	•	•
Complex systems assembly	•	•	•
Build-to-stock systems assembly	•	•	•
Build-to-order systems assembly	•	•	X Penang (2002)
Configure-to-order systems assembly	•	•	a
Channel assembly	•	•	a
Systems integration & reconfiguration	•	•	a
Testing	•	•	•
Environment stress screening	•	•	•
Custom packaging	•	•	•
Logistics & distribution management	•	•	•
Support Services			
Repair – systems & PCBs	•	•	•
Product refurbishment/remanufacturing	•	•	•
Asset and logistics management	•	•	
Product upgrades	•	•	•
Sustaining engineering	•	•	•
End-of-life manufacturing	•	•	•
Warranty processing	•	•	•
Technology			
Interconnection & Packaging consulting	•	•	•
Process development	•	•	•
Reliability & failure analysis	•	•	•
Manufacturing technology roadmap	•	•	•
Test technology roadmap	•	•	•
Design			
ASIC design	•		b
Circuit design	•	•	b
RF & wireless design	•		b
Mechanical design	•	•	b
Systems design	•	•	b
Test process design	•	•	b
Design validation	•	•	b
Product Development			
New Product Introduction (NPI) management	•	•	•
Component engineering	•	•	•
Design-for-manufacturability	•	•	•
Design-for-testability	•	•	•
PCB layout	•	•	•
Test development	•	•	•
Quick-turn prototyping	•	•	•
Quick-turn testing	•	•	•

a = will change: focus on China
b= will change: Taiwanese ODM companies