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# Moving Beyond the Commodity Trap? Trade Adjustment and Industrial Upgrading in East Asia's Electronics Industry

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# INTRODUCTION

Much of the research on the Asian crisis highlights *endogenous* failures of international capital markets and domestic policy failures, especially for financial regulation (e.g., World Bank, 2000). While the primary source of the crisis lay in the financial sphere, there has been a tendency to neglect the contribution of underlying structural weaknesses in the real economy. The latter are the focus of this study.

A central proposition is that the "East Asian Miracle" was already under strain *before* the crisis: economic structures and institutions that were conducive for catching-up, can no longer guarantee sustained growth. In 1996, a dramatic export crash, leading to substantial current-account deficits, indicated that there was a serious problem. The crisis has further sharpened this dilemma: it has dramatically increased the need for industrial upgrading, while at the same time constricting the means required for its successful implementation. This precludes a return to the *status quo ante* - far-reaching changes are required in the different East Asian development models. *Industrial upgrading* needs to complement the current emphasis on financial and corporate restructuring. It constitutes the medium-term challenge that East Asia needs to master in order to establish new sources of growth. Defined as a shift to higher value-added products and production stages through increasing specialization and "industrial deepening" (Hirschmann-type forward and backward linkages[1]), industrial upgrading necessitates a strong domestic knowledge base.

We tell this story for the electronics industry, East Asia´s most prominent example of rapid catching-up. Electronic equipment and components dominate the region`s exports. When the crisis hit, it was widely expected that these industries would act as primary carriers of rapid trade adjustment. Yet, it was not before mid-1999 that adjustment gathered momentum. The study addresses three questions: i) What are the primary causes for the 1996 crash in East Asia`s electronics exports? ii) What explains the delay of post-crisis trade adjustment? And iii) are there realistic perspectives for a shift from a vicious to a virtuous circle of industrial upgrading?

As for possible explanations, most research has focused on disruptive changes in exchange rates. This is in line with international trade theory. Our research confirms that these changes matter. Yet, they only cover the tip of the iceberg. We also address explanatory variables related to firm behavior, country characteristics and industry dynamics that can help improve and fine-tune the generic propositions derived from trade theory. We argue that rapid catching-up has led to a narrow specialization in *commodity*-type products that are prone to periodic surplus capacities and price wars. We call this a "commodity trap". Without fundamental changes in the basic parameters of this development model, East Asian electronics industries will remain vulnerable to the vagaries of the industry-specific dynamics of change, as well as to the whims of volatile international capital and currency markets.

[1] The classical source is Hirschman (1958)

The bulk of our industry-level data is for Korea[2] simply because this country arguably is the most successful, and at the same time, the most controversial example of Asia`s rapid catching-up in this industry: i) It is the leading Asian electronics producer, in terms of its share of the global electronics market. ii) Korea´s unprecedented speed of entry into high-risk and very demanding precision component manufacturing, such as DRAM and advanced computer displays, may signal the limits of what is possible. And iii), while most countries in the region have used industrial policies and "guided credit", no other country has gone as far as Korea, creating an unbalanced industry structure, dominated by a handful of chaebol.

This points to considerable differences between Korea and other East Asian economies in the institutions, policies and firm behavior that have shaped the development of individual electronics industries[3]. There are however also important commonalties that justify cautious generalizations from the Korean data: export-led growth has focused on hardware rather than software, primarily for price-sensitive commodities; government policies played an important role in the early development of these industries; and efforts to develop domestic capabilities have been combined with international knowledge outsourcing through FDI and an integration into global production networks.

We first introduce the concept of "industrial upgrading" (IU) as a focusing device for identifying structural weaknesses in East Asia´s electronics industries and for assessing responses to the crisis. This concept demonstrates endogenous limits to IU: a vicious circle that links a narrow and sticky specialization with a narrow domestic knowledge base and limited Hirschman-type linkages. In part 2, we use this concept to explain possible causes for the pre-crisis crash in electronics exports, and present empirical evidence. In part 3, we ask what explains the delay in post-crisis trade adjustment. Based on the concept of "industrial upgrading", our analysis focuses on four explanations: a limited adjustment capacity of the region´s support industries and lower-tier suppliers; restricted access to input imports constrain capacity for export expansion, once inventories are exhausted; restrictions in export markets constrain demand for exports; and, most importantly, a sticky specialization on commodities magnifies

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[2] If not indicated otherwise, data on the Korean electronics industry are courtesy of the Electronics Industry Association of Korea (EIAK), the Korea Semiconductor Industry Association (KSIA),the Korea International Trade Association (KITA), the Korea Development Bank (KDB), the Korea Industrial Technology Association (KITA), the Korean Institute for Advanced Technology (KIAT), the Ministry of Commerce, Industry and Energy (MOCIE),and the Ministry of Information and Communications (MOIC). Additional data sources on East Asian electronics industries include the United Nations-COMTRADE trade data base, updated to include 1998; market and production figures from the Yearbook of World Electronics Data 1998/99 (Reed Electronics Research, 1998), and the 1998 Yearbook of the Information Technology Industry Council (1998), Washington, D.C.; and more disaggregated country-specific data on production, international trade, market shares and product prices, collected from various national industry associations and government agencies. An additional important source of information are interviews conducted over the last two decades in all major electronics producers in Developing Asia.

[3] For a related study that highlights peculiar features of the Taiwanese model in the computer industry, see Ernst, 2000 a.

deflationary pricing pressures. Finally, in part 4, we discuss perspectives for future industrial upgrading, highlighting the challenge of moving beyond the commodity trap.

## 1. INDUSTRIAL UPGRADING AS A FOCUSING DEVICE

### a. Challenge

The Asian crisis forces us to reconsider how globalization and technical change affect the sources of growth, and how this reshapes development options. The link between globalization and development has been critical for East Asia. This is true for international trade as well as for investment. Export-led industrialization has been a major engine of growth, providing access to markets, key tangible production inputs and knowledge (e.g., World Bank, 1993; Ernst, Ganiatsos, and Mytelka, 1998). In addition, inward FDI and participation in global production networks (GPN) have acted as powerful catalysts for learning and domestic capability formation; in some cases they have compensated for the latter`s initial weaknesses (e.g., Ernst, 2000e)

This region in fact had become a favorite choice for trade economists, growth economists and innovation economists to debate their conflicting theories of how to explain economic growth. Some observers even claimed that an *irreversible* shift of economic wealth and power had occurred to East Asia[4]. Then the financial crisis hit, threatening to devalue much of the region´s accumulated assets and capabilities. After almost two years of agonizing, the pendulum has swung back to cautious optimism. A return to export-led growth is assumed to be possible under two assumptions: i) Asian economies reform their financial sectors and corporate governance; and ii) they liberalize their trade and investment policies. Market-led recovery is assumed to be a foregone conclusion, once the region´s distorted market incentives have been reestablished. This is expected to induce FDI to play a much more active role as an engine of growth and modernization (e.g., UNCTAD, 1999).

Whether this proposition holds, is an empirical question. We need policy-oriented empirical research on how the Asian crisis has changed East Asia´s trade and upgrading options. This study demonstrates that there is no easy way to sustained recovery - neither market-led muddling through nor FDI will do the trick. Of course, nothing goes without a consolidation of the financial sector that reduces the vulnerability to volatile international capital. Equally obvious is the need for reforms of public as well as corporate governance that improve transparency, reducing the likelihood of moral hazards. There is also no doubt that this needs to be combined with cost-cutting and a reduction of surplus capacity in key sectors like electronics. But, and this is a big BUT, very different approaches are possible to financial and governance reforms and to corporate restructuring. Much depends on how one defines the long-term development model.

### b. Defining Industrial Upgrading

[4] Witness the statement of a former chief economist of a leading brokerage firm: "I don´t think the Good Lord himself could stop this trend, short of nuking Southeast Asia." (Albert Wojniloner, CS First Boston, quoted in Greider, 1997, chapter 3, p.42)

An appropriate long-term development strategy must focus on improvements in *specialization*, *productivity*, and *Hirschman-type linkages,* all of which necessitate *local* knowledge creation. All four elements are essential prerequisites for improving a country´s capacity to raise patient capital that is necessary for facility investment, R&D, human resource development and welfare expenditures. This is what industrial upgrading (IU) is all about. This concept has recently gained acceptance among economists who are interested in identifying new sources of growth, both in industrialized and in developing countries. As a focusing device for unlocking new sources of growth, this concept attempts to model the link between innovation, specialization and Hirschmann-type linkages ("industrial deepening"), and possible consequences for economic growth through induced improvements in productivity. This requires a development model that focuses on knowledge and innovation as major sources of economic growth[5].

How to operationalize the concept of IU? Drawing on Chenery (1960), Chenery and Syrquin (1975), Ernst, 1998 a, and Ozawa (2000: 2-3), one can construct a *taxonomy* that distinguishes five forms:

- *inter-industry* upgrading within a hierarchy of industries that proceeds from low value-added industries (e.g., light industries) to higher-value added industries (heavy and higher-tech industries);
- *inter-factorial* upgrading within a hierarchy of factors of production that proceeds from "endowed assets" or "natural capital" ( natural resources and unskilled labor) to "created assets", i.e. "physical capital", "human capital" (specialized skills), and "social capital" ( a region`s support services);
- upgrading of *demand* within a hierarchy of consumption, that proceeds from "necessities" to "conveniencies", to "luxury goods";
- upgrading along *functional* activities within a hierarchy of *value-chain* stages, that proceeds from sales & distribution to final assembly and testing, to component manufacturing, engineering, product development, and system integration; and
- *industrial deepening* within a hierarchy of Hirschman-type forward and backward linkages, that proceeds from tangible, commodity-type production inputs to intangibles, i.e. a variety of knowledge-intensive support services.

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

[5] This is in line with the leading-edge in economic theorizing, such as *endogenous growth* theories (Romer, 1990; Grossman and Helpman, 1991; Aghion and Howitt, 1992, and Helpman, 1998); Lipsey`s *structuralist* growth theory (Lipsey, 1997 and Lipsey, Bekar and Carlaw, 1998 a and b); 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 (e.g., OECD, 1999).

and the boundaries of a particular "industry" keep changing over time, which makes an analytical focus on the industry level even more problematic.

While all four forms of IU matter, we emphasize the last two aspects: *firm-level* upgrading from low-end to higher-end value chain stages, and *industrial deepening* that provides the social capital that is the lifeblood for the individual upgrading firm. We need to emphasize four additional features that distinguish our concept of IU. *First*, we use a *broad* definition of innovation that allows us to move beyond a narrow focus on R&D and patenting[6] . There is now a widespread consensus that a broad definition of "innovation efforts" is needed that includes engineering, technology purchases, expenditures on licensing and consultancy, and technology search, as well as the accumulation of tacit knowledge required to absorb imported technology (e.g., Nelson, 1990; and Mowery, 1998).

*Second*, we use industrial upgrading as a *context-specific* concept - its characteristics differ across industrial sectors and countries. This is important, as information technology and globalization have substantially extended the geographic dispersion of economic transactions, involving diverse economic structures and institutions (Ernst, 1997b). Equally important are changes over time. Evolutionary economics has highlighted the importance of history, nationality and industry-specific features for peculiar trajectories of industrial dynamics. Nothing is predetermined about the outcome of these processes (Schumpeter, 1912/1961 and 1928; Richardson 1960/1990). There is no guarantee against crises and malignant growth, hence the possibility of truncated upgrading. There are many reasons why a firm can get stuck with obsolete features that once were useful, but now have become barriers to a further upgrading (e.g., Christensen, 1997). The same is true for an industry or an economy.

Third, the concept is extended to include *firm behavior* as a key variable, and focuses on the *co-evolution of industry structure and firm behavior.* There is a growing consensus that industry structure is insufficient to explain the dynamics of innovation, and that firm behavior (organization and strategy) has an important bearing on the strength as well as the kinds of innovation activity (Teece, 1998: 134). It is also necessary to move beyond the *internalist* bias that characterizes much of the literature on industrial organization and the theory of the firm[7]. We need to consider the sources of

[6] Most empirical work on IU has focused on the expansion of R&D-intensive industries. 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.

[7] Two versions of the internalist bias can be distinguished. Teece (1998: 148) highlights a focus on internal hierarchical control: "Economists, as well as many organization theorists, have traditionally thought of firms as islands of hierarchical control embedded in a market structure and interacting with each other through the price mechanism." A second version of the internalist bias relates to innovation: capability-based theories of the firm have focused primarily on the internal accumulation of knowledge and skills which underpins its productive activity (Coombs and Metcalfe, 1998).

innovation and growth in a broader frame of reference that "includes the firm itself, its relationship with other organizations, and also government policy." (Stopford, 1998: 296)

Fourth, and finally, we do not share the assumption 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 economy. This assumption is problematic, to the degree that globalization and IT increase the scope for cross-border forward and backward linkages (Ernst, 2000e).

### c. Stylized Model

Let us briefly sketch a stylized model of IU. The model is designed to explain how *specialization* affects *market structure* and *upgrading potential*. Specialization is the *explanatory* variable, while market structure and upgrading are the *dependent* variables. The model can also highlight the dynamics of IU, and specify conditions, which make it possible to move from a *vicious* to a *virtuous* circle. **(Table 1)**

*Specialization* is an important indicator of the degree of *industrial upgrading* that a country has achieved. Industrial economists (e.g., Nilsson, 1996) distinguish specialization patterns that reflect differences in the product composition (homogeneous versus differentiated products), and in the types of production process (mass production versus flexible production). This distinction is based on two criteria: the complexity of technology (complexity), and peculiar characteristics of demand (uncertainty). For commodities, complexity and uncertainty are low: these products are easy to replicate, changes in demand and technology are predictable, and only limited interaction is required with customers. The reverse is true for differentiated products. Similar distinctions can be made for process specialization.

It is argued that different market structures will result from these different product compositions and production processes that account for a different upgrading potential. Market structure is defined by entry barriers, mode of competition and value generation[8]. Finally upgrading potential covers technological learning requirements and Hirschman-type linkages. For instance, for differentiated products, firms can charge premium prices, while for homogeneous products, price competition is the over-riding concern. Differentiated products are associated with high entry barriers and significant value generation, while both are low for homogeneous products.

The purpose of this exercise becomes clear when we look at the last row of our matrix: While homogenous products have only a limited upgrading potential, in terms of technological learning requirements and linkages, the opposite is true for differentiated

[8] Lazonick (1991) argues that, although it is used all the time, "rent" is generally the wrong word analytically. In economics, rent is the return on a resource that is inherently in scarce supply (e.g., the rent that can be charged on a house in a prime location in a major city), irrespective of the quality and the cost of the house. What matters for our purposes are Schumpeter`s "entrepreneurial profits" which derive from the ability of the producers to generate value through higher quality, lower cost products, i.e. innovation (Schumpeter, 1961, 153-4).

products. Similar distinctions can be made for production processes: flexible production is linked to premium pricing and significant value generation, giving rise to a substantial upgrading potential. The downside of course are the substantially higher upfront preparatory efforts that are necessary for successful entry. It is important to emphasize that causality works both ways: Not only does a narrow specialization on commodities fail to provide sufficient pressure to broaden the domestic knowledge base and to develop forward and backward linkages. The reverse is also true: necessary improvements in specialization are constrained by a narrow domestic knowledge base and limited linkages.

East Asia´s electronics industry contains all three ingredients of our stylized model. Its defining characteristic is a *sticky product specialization*: catching-up has focused on rapid capacity and international market share expansion for homogeneous, mass-produced products such as TV sets, monitors, DRAM and PCs ("commodities"). Very little upgrading has occurred into higher-end and rapidly growing market segments for *differentiated* products and services that require flexible production (such design-intensive ICs and computer products, software and Internet services).

A second important characteristic are *limited* and *achievable technological learning* requirements[9]. A focus on mass-produced commodities (like DRAM) requires a narrow set of capabilities: a capacity to absorb and upgrade imported foreign technology and to develop operational capabilities in production, investment and minor adaptations. The main objective has been to accumulate superior *production capabilities* and to become a *quick, lower-cost follower* for established product & system designs and component technology, through reverse engineering & subcontracting (especially OEM).

A third important structural weakness is a lack of "industrial deepening", especially for materials and production equipment., that gives rise to a persistently high dependence on input imports. The result is an *inverted production pyramid*: a huge and rapidly growing final product sector rests on a weak and much smaller domestic base of support industries. Rapid growth in the final products sector necessitates considerable imports of intermediates and production equipment.

In East Asia, this approach initially has been a major strength, as it established a *virtuous circle* between quick learning and late market entry. A focus on commodities, combined with limited linkages and learning requirements was necessary to overcome initial latecomer disadvantages. This was the only realistic entry possibility - it guaranteed access to rapidly growing and relatively open markets. It also helped to keep manageable the scope and depth of technological learning. However, once catching-up has reached a certain level, a shift has apparently occurred to a *vicious circle*. A narrow specialization on commodities reduces the scope for value generation, giving rise to what

[9] One needs to distinguish the increasing sophistication of the institutional arrangements for technological learning, especially for international technology sourcing, and the relatively mundane contents of the knowledge thus generated. In line with the theory of the path dependency of innovation, it is hardly surprising to find that most of this knowledge has been confined to operational production capabilities of a fairly conventional mass production type, which after all has been the region´s original advantage.

we call a "commodity price trap": commodities like DRAM are prone to *deflationary* pricing pressures, which result from periodic over-capacity and price wars. A heavy specialization in commodities also fails to provide sufficient pressure for industrial upgrading, i..e. an improvement of the domestic knowledge base, and a deepening of linkages. In turn, a narrow domestic knowledge base constrains necessary improvements in specialization. It also erodes export competitiveness, and it constrains secondary import substitution, perpetuating a heavy dependence on input imports[10]. The flip side of rapid catching-up focused on commodities has been a *narrow* domestic knowledge base which now has become a major barrier to a continuous industrial upgrading. This may well lead to "immiserising growth" - an increase in economic activity which results in lower per capita incomes

In part 2, we use this concept to identify fundamental structural weaknesses of East Asia`s electronics industries that explain the pre-crisis export crash in electronics. It will also guide our assessment of post-crisis trade adjustment and upgrading options (parts 3 and 4).

## 2. CAUSES FOR PRE-CRISIS CRASH IN ELECTRONICS EXPORTS

### 2.1. Achievements

East Asia has been highly successful in establishing itself as a major production base and export platform in the electronics industry. Compressed into a short period of time, there has been an extraordinarily rapid capacity and international market share expansion: the region´s production of electronics equipment and components has increased tenfold since 1973, compared to a quadrupling of production in Japan. Four Asian countries (Korea, Taiwan, Singapore and Malaysia) today belong to the group of the top ten world electronics producers.

Unsurprisingly, the region´s strength is well-established for consumer electronics: in volume terms, it contributes almost 50% of world production, up from 34% in 1993. This massive expansion of production capacity results from the relocation of Japanese consumer electronics production, first to Southeast Asia (primarily Malaysia and Thailand) and later to China (Ernst, 1997a). It also reflects the emergence of Korea as the second largest supplier. The really intriguing achievements however can be found in high-precision components and industrial electronics, such as computer memories (especially DRAM), motherboards, computer data storage and imaging products[11], and advanced displays (like TFT-liquid crystal displays). Less well-known but of equal

[10] In part 3 we will see how this mechanism has delayed the widely expected rapid trade adjustment to the crisis.

[11] Data storage products include hard disk drives (HDD), tape drives, CD-ROM drives, disk media and their related components and subassemblies. Imaging output products include printers, facsimile machines and photocopiers, as well as multifunctional products with combined printing, facsimile and copier functions plus ink-jet color copiers and printers.

importance are achievements in other areas: contract manufacturing[12], especially for complex printed circuit board assembly; add-on and multimedia cards; embedded controllers; and a variety of specialized electric components (motors and compressors) both for computer and consumer products.

These are impressive and widely documented achievements (e.g., Hobday, 1995; Ernst and O`Connor, 1989 and 1992). Yet already since the late 1980s it became clear that the more successful catching-up, the more it would run into fundamental limitations (e.g., Kim, 1997a; Ernst and O`Connor, 1992; Ernst, 1994a). After reviewing empirical evidence, we identify possible explanations.

### 2.2. Weakening of Export-Led Growth

The financial and currency crisis did not occur in a vacuum: it was predated by a dramatic *export crash* which, in turn, caused growth to slow dramatically. The magnitude of East Asia´s export fall was unprecedented in recent history. The region´s export growth reached a peak in the first quarter of 1995. By the first quarter of 1996, it fell to zero in the East Asia-5 countries (World Bank, 1998b, chapter 2) and to negative rates for other East Asian countries, including China and the NIEs. This decline has been especially prominent in the electronics industry (**Table 2**).

Without exception, all major Asian electronics producers have experienced a substantial export crash in 1996. Korea displays the most dramatic decline: after extremely rapid growth in 1994 (+ 24%) and 1995 (+35.5%), its 1996 exports fell by more than 3% (in US dollar terms). **Table 3** documents the devastating decline in Korea´s semiconductor exports. **(Table 3)**

There has also been a decline in the growth of electronics production well before the crisis hit: after showing two-digit growth since the early 1990s, growth for the region (excluding China) fell off to 10.6% (in 1996). Take for instance Singapore (**table 4**): growth of its electronics industry fell from an average annual growth rate of 15.7% between 1990 and 1995, to 8.9% in 1996 and 3.1% in 1997. This compares with a long-term average annual growth, between 1960 and 1995, of 26.1%. **(Table 4)**

### 2.3. Endogenous Barriers

East Asia´s problems did not occur in a vacuum: they reflect a substantially more hostile international environment. In 1996, the fall in world export growth from its cyclical peak in 1995 was the largest in the past 15 years - from about 20% to about 4% in US dollars in just one year (World Bank, 1998b). The sharp depreciation of the yen in 1995 compounded the negative impact of the slowdown in world exports on many East

[12]Contract manufacturers are precision engineering firms that traditionally have focused on PCBA (= printed circuit board assembly); recently, however they have expanded into the final assembly of PCs (="complete-box-build-and-ship").

Asian countries[13]. Furthermore, some East Asian countries experienced an appreciation of the real effective exchange rate, partly caused by the renminbi 1994 devaluation, which may have hurt their exports. Hence, exchange rates matter.

Equally important however are structural weaknesses that reflect peculiar features of East Asia´s successful catching-up strategies. Based on the conceptual framework, described in part 1, let us review empirical evidence on *endogenous* barriers to IU. These impediments reflect fundamental characteristics of successful catching-up strategies: export-driven growth, combined with state-led industrial development have created a narrow domestic knowledge base, sticky specialization and limited linkages. Korea has pushed this strategy to the extreme (Kim Linsu, 2000; Ernst, 1994a): a handful of multi-sector, family-owned business groups (the *chaebol*) were given privileged access to large amounts of patient debt capital. This has shaped key features of the chaebol's strategy in terms of product specialization, type of production, size of commitment and entry strategy, vertical integration, competition focus and technology management. Upon deciding to enter a sector, the chaebol normally move in on a massive scale and in a highly integrated manner: firm growth has occurred through "octopus-like" diversification into many different and unrelated industries rather than through an accumulation of knowledge through industrial upgrading. However, such unrelated diversification has been restricted to commodity-type products[14].

The resultant narrow domestic knowledge base has made it difficult to move up the ladder of specialization. It has also constrained industrial deepening, perpetuating a heavy dependence on input imports. In short, Korea's successful entry into the electronics industry was based on a forced march to develop a "mass production" capacity that could serve high-growth export markets for "homogeneous products". Very little upgrading occurred into higher-end and rapidly growing market segments for "differentiated" products and services. We demonstrate how a narrow domestic knowledge base that was sufficient for the purposes of rapid catching-up (2.4.), has given rise to sticky product specialization (2.5.), and to a high dependence on input imports (2.6.).

### 2.4. Narrow Domestic Knowledge Base

Catching-up required a limited set of capabilities: a capacity to absorb and upgrade imported foreign technology and to develop operational capabilities in production, investment and minor adaptations. The challenges today are different, and in any event, after the crisis, the country simply does not have the foreign exchange required to buy in foreign technology.[15] Korea thus needs to broaden its knowledge base to compete in product design, market development, the design of key components and the

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[13] This is especially so for Korea whose export structure is similar to Japan´s: in 1996, Japan´s imports from Korea fell by 8.5%. Throughout the period 1990 to 1997, Korea´s real export growth mirrors changes in the yen-dollar exchange rate, rising with an appreciation of the yen, and falling with its depreciation (World Bank, 1998b, figure 2.2., p.21)

[14] This implies that unrelated product differentiation may well coincide with sticky specialization (see 2.5.)

[15] According to the Ministry of Trade, Industry and Energy (MOTIE), Korean firms´ annual royalty payments more than doubled between 1990 and 1996, from $ 1.1 billion to $ 2.3 billion.

provision of high-end, knowledge-intensive support services. Korea´s knowledge base remains constrained, however, by three main weaknesses: an insufficient critical mass of R&D and patenting; gross inefficiencies of corporate technology management; and equally important inefficiencies of its public innovation system.

**i) An insufficient critical mass of R&D and patenting**

Korea has consistently ranked first among East Asian economies in terms of resources devoted to R&D. In 1996, for instance, Korean R&D expenditures represented 2.79% of GDP, far ahead of the 1.86% achieved by second-placed Taiwan (figures are courtesy of Korean Development Institute). Korea also led the region in terms of the number of R&D personnel per 1000 inhabitants. Nevertheless, there is evidence of an insufficient critical mass of R&D and patenting. Such a constraint matters especially in a highly knowledge-intensive and volatile industry like electronics.

Until around the mid-1980s, Korean electronics firms had little motivation to invest in R&D[16]. Since that time, however, Korea has seen its comparative labor cost advantages erode, while product life cycles have shortened and competition has intensified in the electronics industry (Ernst, 1997b and 2000c). This forced the Korean electronics firms to develop their own R&D capacity. Take Samsung Electronics, the industry pace setter: its R&D expenditures, as a share of total sales, increased from 2.1% in 1980 to 6.2% in 1994 (Kim, 1997a, p.141). Overall, Korea´s private R&D spending, as a ratio of total sales, increased from 0.36% in 1976 to 2.5% in 1995. While this is an impressive achievement, it is still less than half of the current R&D/sales ratios of U.S. and Japanese manufacturing companies. And Korea´s per capita R&D expenditures of $176.2 (in 1993) lag well behind those of Japan ($762.9 in 1992) and the US ($540.9) (Lall, 1997, table 8). In order to reach a "critical mass" for industrial upgrading, R&D investments in Korea still have to grow much further[17]. The extremely tight budgetary constraints imposed by the crisis, however, imply that Korean firms have to withdraw, at least temporarily, from this R&D investment race.

As for patents, Samsung registered a total of 2310 patents in the US between 1980 and 1996, with most of these being registered over the last few years. In terms of "patent intensity"[18] Korea still badly trails major OECD countries: with a patent intensity of 10 only a fraction of that reported for Germany (around 180), Japan (170), the US (140), and the UK and France (slightly below 100)[19] This gap is likely to increase, as the crisis has dried up funds available for this "patent portfolio race".

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[16] Explanation for limited R&D expenditures up to that point are provided in Ernst, (1994a, chapter 4).
[17] The most vivid illustration is that, in comparison to GM's R&D budget, Korea's total R&D expenditures amount to only 54% (Kim 1997b).
[18] The European Patent Office measures "patent intensity" as the share of a country´s patent applications per 1 million inhabitants.
[19] The measure of patent intensity for OECD countries, Triad patents, refers to high quality patents, i.e. world market-oriented patents registered in at least two overseas markets within the Triad region. In other words, the gap between G7 countries and Korea is even higher than shown by a mere quantitative comparison.

### ii) Inefficiencies of corporate knowledge management

Patent figures indicate that while Korea spends more than twice as much on R&D than Taiwan, the number of U.S. patents granted to Koreans in 1992 was only 538 compared to 1252 patents to Taiwanese (Kim Linsu, 1997b, p.15).[20] Serious problems have been detected with regard to the effectiveness of the chaebol's knowledge management (e.g., Bloom, 1992; Kim Sun G., 1995; Kim Youngsoo, 2000). While external technology sourcing strategies are highly sophisticated, the organization of innovation *within* these firms follows an outdated centralized R&D model, in contrast to the progressive decentralization of R&D, which is typical today for Japanese, U.S. and European firms.[21] The persistence of hierarchical patterns of firm organization in Korea has important negative implications for the organization of R&D: Korean engineers and technicians are more inclined to work on their own and are much less willing to contribute to a team than their Japanese counterparts (Oki, 1993). Organizing R&D in a centralized manner produces rigid procedures concerning information management and decision-making, delaying product design cycles and speed-to-market. In addition, centralized R&D organizations are ill equipped to coordinate the complex requirements of innovation. Feedback loops across the value chain thus remain weak and unreliable, and design, marketing and manufacturing often proceed in an asynchronous way.

A bias for centralized R&D organizations also has quite negative implications beyond the boundaries of the firm. It is probably one of the main reasons for the still very weak domestic linkages among the different actors involved in the process of technology generation and diffusion. This applies in particular to linkages between the large electronics manufacturing companies and their suppliers of parts and components[22]. Most of these links are either with foreign companies or are internalized by the leading chaebol (Wong, 1991; Bloom, 1992).

### iii) Inefficiencies in the public innovation system[23]

Important inefficiencies also exist in Korea´s public innovation system. While the government´s share of R&D has declined to less than 20%, it remains significant, and a

[20] Note however that, by 1996, Korean companies registered 1,567 patents in the US, which is the seventh largest number of US patents registered by foreign companies (figures are courtesy of Korean Development Institute).

[21] Successful innovation requires continual and numerous interactions and feedbacks among a great variety of economic actors and across all stages of the value chain (OECD, 1992, chapters 1-3).

[22] A rich body of theoretical and empirical literature shows that both end product manufacturers and component suppliers can reap substantial benefits from vertical production networks . Such networks make possible a shift to a new division of labor in R&D: they enable manufacturing firms to concentrate on system design and final assembly and thus to restrict their R&D primarily to product design and process innovations for final assembly. Suppliers, in turn, can focus their limited resources on product and process innovations for parts and components and thus can aspire to accumulate specialized technological capabilities. For case studies, see Ernst, 1994b, 1997a and 1997b.

[23] The following is based on discussions with Dr. Lee Won-Young from the Science & Technology Policy Institute (STEPI), Seoul, Korea.

serious lack of coordination among R&D programs of different ministries has wasted scarce resources. Before the crisis, each ministry had autonomy over its own program without regard to those of other ministries. Meanwhile, private sector R&D retains a very narrow focus: geared largely to development rather than research, especially process re-engineering and product customization, it actually tends to block opportunities for the kinds of research needed for industrial upgrading. Those chaebol that have funds for research thus neglect it in favor of development activities. This reflects a fundamental *mismatch* in the *allocation* of R&D funds and recruitment. Nearly 80% of the government´s civilian R&D funds go to government research institutes (GRIs)[24] Yet, due to the recent deterioriation of salaries and social status in GRIs, there is now a heavy brain drain from GRIs to universities. Korean universities which employ 76% of the PhD holders, however lack the research facilities and funds to conduct serious research: receiving less than 11% of the government civilian R&D funds, Korean universities are in a much weaker position than even in Japan, where universities are also quite feeble in terms of R&D.

A further important weakness of the Korean education system is its heavy focus on the training of mid-level managers, engineers and technicians. This was an important prerequisite of success during the catching-up phase. Yet, as the focus shifts to research, product design and market development, the educational system is poorly equipped to cope with these new requirements.[25]

### 2.5. Sticky Specialization: Focus on Commodities

How resistant has Korea´s electronics industry been to an upgrading of its product mix? Almost without exception, the chaebol have targeted those segments of the electronics industry that require huge investment outlays and sophisticated mass production techniques for fairly homogeneous products ("commodities") like microwave ovens, TV sets, VCRs, computer monitors, picture tubes and computer memories, especially DRAMs. Overwhelmingly, the focus has been on consumer electronics and components, with only limited inroads into industrial electronics. Burdened with unimpressive "me too" products, the chaebol have all failed to establish themselves as credible competitors in the more design-intensive sectors of the computer industry.

RCA analysis confirms a highly concentrated product specialization (see table 5). Trade data for 1996, the year before the crisis, show electronics accounting for almost 29% of Korea´s merchandise exports. Moreover, product specialization is heavily concentrated *within* electronics. Three products dominate with a very high RCA: semiconductors (SC) with 3.6, components (Comp) with 2.7, and consumer electronics (CE), with 2.0. And, almost 61% of Korea´s electronics exports consist of components, with semiconductors (SC) alone accounting for 40%.

[24] This is much higher than even in France and Japan - two countries where the government traditionally has played a strong role in the national innovation system.
[25] The focus is on classical material rather than more recent debates. Too much focus is placed on conformity and memorization, too little on creativity (Kim Linsu, 1997a). Despite recent improvements (Kim Linsu, 2000), higher education remains a glaring bottleneck.

A particularly disturbing feature of Korea´s specialization pattern is that it combines high investment thresholds and highly volatile income streams: in their choice of sectors, the chaebol exposed themselves to considerable risk resulting from highly volatile markets. Typical examples are DRAM and advanced displays that are prone to periodic boom-and-bust cycles and hence do not generate a steady flow of profits. For companies with a high debt-equity ratio, this is obviously not an optimal choice**. (Table 14)**

Sticky specialization also characterizes Korea´s semiconductor industry the crown jewell of its electronics industry. The three leading Korean semiconductor producers are all heavily dependent on computer memories: Before the crisis, 80% of Samsung's semiconductor revenues came from memories (most of them DRAMs), and in the case of Goldstar and Hyundai, this share was even higher, i.e., 87% and 90%[26]. This type of specialization clearly handicaps profitability. DRAMs are the "bleeding-edge" of the semiconductor industry: they are prone to periodic surplus capacity and price wars. During 1998, excess capacity for DRAMs was estimated to be around 40%. This resulted in a 60% price fall, after already sharp price declines over the previous two years. Current price levels are below the manufacturing costs of even the most efficient DRAM manufacturer (NEC).

The narrow focus on memory products has very negative implications for the overall structure of the electronics industry. Korea keeps exporting more than 90% of its total semiconductor output, while at the same time importing more than 87% of its domestic demand. Such an extreme imbalance between supply and demand makes it very difficult to broaden and deepen forward and backward linkages within the electronics industry and to place it onto a more viable basis.

In short, Korea's competitive position in semiconductors remains highly fragile, despite impressive achievements. Its wafer fabrication capabilities are excellent or good for a limited number of products, i.e., DRAMs, SRAMs and ROMs. Other than that, very little has been achieved, and glaring deficits continue to exist, especially for circuit design. It is probably fair to say that Korea's semiconductor industry represents a modern version of the classical "mono-product export enclave", characterized by a minimum of linkages with the domestic economy. There is, however, one important difference: the cost of entering the semiconductor industry is horrendously high, and certainly exceeds that of entering the plantation industry. And even higher is the cost of continuously upgrading the industry, and of maintaining the competitiveness of its exports. Moreover, while Korea's entry into semiconductors has been a major achievement, it should not be interpreted as a move beyond mass production. The very high entry barriers typical for DRAM are due less to their R&D intensity than to their capital-intensity, very high economies of scale and the extremely volatile nature of demand for these devices[27].

[26] In the case of the largest Japanese semiconductor producer, NEC, for example, only 35% of its semiconductor revenues were generated by MOS (metal oxide on silicon) memories.

[27] The minimum efficient scale for producing these devices is now roughly $2 billion of annual sales. This implies that only firms that have reached the critical threshold of 5% of world production can compete

Competitiveness in DRAMs centers on the capacity to invest in huge mega-plants churning out a limited variety of standard products and on the capacity to improve as quickly as possible yields and productivity.

Guaranteed access to "patient capital" and ample opportunities for internal "cross-subsidization" place the chaebol among the few firms worldwide that could cope with the demanding financial requirements for entering the DRAM business. The chaebol also were able to accumulate increasingly sophisticated production and investment capabilities, both in typical mass production industries like cars and consumer durables and in resource-intensive process industries like the steel industry. Yet Korea's entry strategy into semiconductors did not fundamentally differ from its earlier entry into shipbuilding, steel, or the production of picture tubes for TV sets and monitors. Success in DRAMs was based not on strength in research and technology development but rather on the capacity to raise incredibly large funds for high-risk investments into huge mass-production lines for standard products[28].

In other words, as long as East Asia´s electronics industries continue to rely on commodity-type products like TV sets, monitors or DRAMs, such sticky specialization provides limited possibilities for IU. For such commodities, competition is of a fairly conventional nature, with size, economies of scale and first mover advantages being of primary importance rather than R&D or knowledge-intensive support services.

### 2.6. Heavy Dependence on Input Imports

A lack of “industrial deepening”, i.e. weak forward and backward linkages, constitutes the third important structural weakness of East Asia´s electronics industry. This has given rise to a persistently high dependence on input imports, especially for key components and production equipment. While import content ratios are not available[29], it is possible to construct proxy indicators. **Table 5** documents the critical role played by electronic components, and especially semiconductors (SC) both for electronics imports and merchandise imports. It is important to emphasize that these shares are highest for the region´s four leading electronics producers (Korea, Taiwan, Singapore and Malaysia). On the positive side, this of course reflects the more sophisticated product mix of these four industry leaders, with industrial electronics outweighing consumer products. It raises however also an important question: Why is it that rapid capacity and international market share expansion for final products has not been matched by a progressive reduction in input imports? **(Table 5)**

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successfully. For a detailed analysis of entry barriers in different sectors of the electronics industry, see Ernst and O'Connor (1992).

[28] High risks in this case do not result from technological uncertainty but from the extremely volatile nature of demand and from the periodic emergence of huge surplus capacities. For an early model of the volatility of demand and recurrent periodic surplus capacities in semiconductors, see Ernst (1983, chapter I).

[29] Import content ratios differ from product to product, and even for a given product, they differ from company to company. This obviously poses severe methodological problems for the collection of such data. An important objective for future research is to conduct a questionnaire survey to collect a representative set of product-specific import content ratios and to document how these ratios have developed over time.

Let us take again a closer look at Korean data. In 1996, the year before the crisis, components accounted for more than 55% of electronics imports. After the crisis, this share has risen quite drastically to almost 72 % (1998)[30]. Semiconductors constitute by far the most important single product group, with 37% in 1996. After the crisis, its share in Korea´s electronics imports has increased to almost 55%. This translates in substantial foreign exchange costs: In US-dollar terms, electronic components account for 10.0% of Korea´s merchandise imports in 1996 (SC alone for roughly 7%), a share which has increased to almost 17% in 1998 (ca 13% for SC).

The tenacity of Korea´s import dependence in electronics becomes clear when we look at semiconductors, the most sophisticated sector of its electronics industry. That sector is based on an extremely weak foundation, in terms of the materials and production equipment required. Korea's current annual consumption of semiconductors materials is approximately $600 million, with 70% of total consumption being imported (40% from Japan and 20% from the United States). As for production equipment, 90% has to be imported, with 50% originating from Japan[31]. It will be extremely difficult to reduce this dependence. Only joint production with leading overseas manufacturers may help.

### Latecomer trajectory of input imports

A persistant dependence on input imports reflects the combined impact of a narrow domestic knowledge base and sticky specialization that we have analyzed before. This impact is magnified however by peculiar features of the electronics industry: short product cycles, combined with rapid and often disruptive technological change (Christensen, 1997; Ernst, 2000c) imply that a latecomer cannot count on a continuous decline of capital goods imports. Such imports, on the contrary, are likely to increase periodically, with each shift to a new product generation, with each extension of the product mix, and with each substantial change in technology. The same is true for the imports of those key components that are essential for the cost and performance features of a particular product.

Consider a simple model of the *latecomer trajectory of input imports* in the electronics industry. Input imports cover both key components and machinery. Suppose country K decides to establish local production for a certain key component C required for a particular product Pt. And suppose further that K has sufficiently strong companies that can cope with the substantial entry barriers that characterize the production of Ct - an assumption which surely cannot be taken for granted. Even then, catching-up requires a certain period of time. As a latecomer, country K may thus end up in a paradoxical situation: Once it has finally succeeded in producing a substantial part of Ct required for Pt, the industry may already have moved on to the next product generation(s) Pt1 or Pt2, which require substantially more sophisticated key components Ct1 or Ct2. This does not imply that catching-up efforts have been in vain: learning and capability formation has

[30] Industrial electronics accounts for another 24%, according to EIAK.
[31] Korea´s heavy dependence on component imports from Japan has been the root cause for its exploding electronics trade deficit with Japan (Ernst and Guerrieri, 1998)

taken place, and the country K can build on this. What it implies however is that country K will remain dependent on input imports for Ct1 and Ct2, till it has finally caught up to their more sophisticated requirements. At that stage, K´s import dependence is likely to shift to Ct3 or Ctn, etc.

A high dependence on input imports thus constitutes the Achilles` heel of East Asia´s export-led catching-up in electronics. This explains why capacity and international market share expansion may well produce significant trade deficits and why exchange rates may come under downward pressure, even if economic growth rates rise. As long as this structure is preserved, this will constrain the scope for trade adjustment and industrial upgrading.

## 3. DELAYED POST-CRISIS TRADE ADJUSTMENT: POSSIBLE EXPLANATIONS

### 3.1. A Puzzle

We now turn to the second question of this study. When the crisis hit, there was a widespread expectation that "… trade adjustment in East Asia…will be rapid and sizable, lifting aggregate growth in these economies even as the domestic non-tradable sectors continue to suffer a decline (as in Mexico)" (World Bank, 1998a, p.5)[32]. Much hope has been pinned on the electronics industry to come through with rapid growth through expanding exports. These expectations were based on three assumptions: i) the severity of the region´s currency depreciations has lowered the cost of much of its electronics supply base relative to its competitors, hence improving its export competitiveness[33]. Ii) The electronics industry´s proven track record as an engine of export-led growth shows that it can be quickly started and accelerated in response to changes in the market[34]. And iii) the historically fast growth of demand for Asia´s electronics products will continue unabated.

At first sight, these assumptions sound plausible. Not before the middle of 1999 however has export-led recovery taken place. Trade data show that, while exports were more resilient than production, pricing losses outweighed net volume gains (3.2.). What explains this delay of post-crisis trade adjustment? Based on the concept of "industrial upgrading", our analysis focuses on four specific explanations: a limited adjustment capacity of the region´s support industries and lower-tier suppliers (3.3.); restricted access to input imports constrain capacity for export expansion, once inventories are exhausted (3.4.); restrictions in export markets constrain demand for exports (3.5.); and,

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[32] "Given their deep exchange rate depreciations, EA5 (= Korea, Malaysia, Indonesia, Thailand and the Philippines) exports are expected to rebound by 18% in 1998 and 12 percent in 1999. Sharply lower GDP growth and real exchange rate depreciations are simultaneously expected to cut EA5 import growth to a negative 2 percent in 1998 and to 6 percent in 1999." (World Bank, 1998a, p.6)

[33] The crisis has in fact imposed a massive devaluation: since July 1997, the countries worst affected have seen the value of their currencies fall by between 35% and 70% against the US dollar. (Real effective exchange rates, courtesy of Morgan Guarantee Trust Company, Economic Research, at: www.jpmorgan.com)

[34] For case studies, see various contributions in Ernst, Ganiatsos and Mytelka, 1998

most importantly, a sticky specialization on commodities magnifies deflationary pricing pressures (3.6.).

### 3.2. Export Tournaments and Falling Revenues

In response to the crisis, there has been a significant decline in the growth of electronics exports, measured in U.S.-dollars, for major East Asian producer countries (**Table 2)**. The Philippines apparently is the only country in East Asia where the growth of electronics exports increased after the crisis, from 29% in 1997 to 32% in 1998[35].

Four important developments need to be emphasized: First, a dramatic fall occurred in electronics production, reflecting a free fall in domestic consumption, and, equally important, depressed facility investment due to high interest rates and financial retrenchment. Second, in response to the decline in domestic demand, Asian electronics producers rushed to expand exports, by slashing export prices. Third, this was made possible by the existence of substantial excess capacity and inventory stocks left over from the 1996 export crash. And, fourth, the downward pressure on export prices was substantially magnified, due to the global downturn that has hit most sectors of the region`s electronics industry since 1996. This explosive combination of developments has produced two noteworthy features of export performance: (i) a divergent performance of exports and production; and (ii) price declines compensate for net volume gains.

#### i) Divergent performance of exports and production

The region´s electronics exports have remained more resilient than production. Take Korea (**Table 6)**: its electronics exports experienced a substantially lower decline than production (-6.7% versus -21.4%), leading to an increase in export orientation (from 70% in 1997 to 83.2% in 1998). **(Table 6)**

The greater resilience relative to production holds for all major product groups. CE stands out with a mind-boggling fall of production of more than 36% (with AV equipment production tumbling by a sharp 46%), yet its exports fell by less than one half that rate (18%). The drastic fall in domestic production reflects a crash in domestic sales of more than 52%. However, it also reflects the expansion of overseas production networks by Korean CE vendors that exerts pressure to reduce domestic production (Ernst and Guerrieri, 1998; Kim Young Soo, 2000). The latter development is obviously not directly linked to the crisis: internationalization of production dates back to the early 1990s. CE is the most internationalized of all sectors of Korea´s electronics industry. Overseas production today accounts for a substantial share of total production for major Korean CE products: 58% for audio equipment, 55% for VCR and 44% for TV sets. Internationalization of production of course also partially explains the large fall in CE

[35] There are three possible explanations for this divergent export behavior: i) a massive inflow of Japanese FDI, since 1994, into the production of hard disk drives, ii) a wave of FDI by taiwanese producers of computer-related products and components, again since 1994; and iii) the limited reliability of data generated by the National Statistical Office, Philippines.

exports (-18%), which is three times larger than the industry average[36]. Over the last few years, Korean CE producers have substantially expanded their global production networks, hence reducing the importance of direct exports .

The divergence in the performance between production and exports is greatest for industrial electronics (-20.4% versus - 4.8%). This reflects important product-specific differences. While telecommunications equipment (especially mobile phones, pagers and related equipment) experienced both rising production (+ 41.2%) and exports (+ almost 22%), PCs and the rest of this sector were in a dramatic decline. Again, this indicates how difficult it is to separate out crisis-induced effects from long-term effects that result from a combination of country-specific features (as formalized in sections 1. and 2.) and industry-specific developments.

A similar story can be told for semiconductors (SC), Korea´s leading export product, which remained relatively resilient to the crisis: its 13.8% decline in production pales relative to the 21.4% decline for overall electronics. Semiconductors also display the lowest decline in exports (-2.4%). Such resilience is most evident for DRAM devices, Korea`s dominant export item. Despite the sizable contraction in global DRAM sales, the three Korean players held their ground more successfully than their five Japanese counter-parts: during 1998, the former registered an overall 15.7 % decrease in DRAM sales compared to the combined 35.1% fall for the latter (data are courtesy of IDC, March 1999)[37]. As a result, the combined share of Korean DRAM producers in the world market increased to 40.9 % in 1998, outperforming Japan`s 36.3% share.

Scale and speed describe two important reasons why Korea`s DRAM producers were less damaged by the downturn of the SC industry than their Japanese counterparts. This reflects the country´s accumulated competitive advantage. Scale economies are of critical importance, especially during price wars, as they enable a firm to slash prices. Due to their sticky specialization in DRAM, Korean producers are now leaders in volume production and outperform the erstwhile Japanese industry leaders. This implies that Korea´s large-scale facility investments during the pervious DRAM boom have facilitated trade adjustment. Furthermore, these investments enabled Korean producers to speed up their time to market, and to launch new 64Mb DRAM products earlier than their competitors. It is however unlikely that without the crisis-induced devaluation of the Won, Korean DRAM producers would have been able to sustain as well their market position. In other words, the surprising resilience of Korea´s DRAM exports during 1998 does not provide evidence for successful upgrading: Korea has not yet managed to develop a viable source of competitive advantage in this industry that could survive the unavoidable erosion of its current exchange rate advantage.

### ii) Price declines compensate for net volume gains

[36] Korea´s largest CE export item is AV equipment which, during 1998, registered by far the largest decline (-30.3%).

[37] Korea´s resilience can also be seen from data on its SC exports to the US: relative to a 12.7% decline of total US SC imports, such imports from Korea declined by "only" 11.2% (The Korea Herald, July 14, 1999).

The second important feature of the region´s export performance during 1998 is that net volume gains have been offset by substantial pricing losses. Let us look at Korean data (**Table 7)**

Due to this decline in unit prices, hard currency export revenues have risen little, despite substantial volume increases. EIAK data for 1998 show for instance that exports of general electronic parts & components increased by 32.4%, when measured in Won. However, when denominated in US-dollars, they fell by 9.3%. Negative price effects were also significant for the following product groups: HDD exports increased by almost 69% in won terms, yet US-$ denominated export revenues increased at a much lower rate of 35.9%. Or take mobile phones, one of the fastest growing Korean electronics export category: an almost 120% volume increase translates into a 68% rise in US-$ denominated export revenues.

In other words, as net volume gains have been more than compensated by pricing losses, electronics exports have failed to act as an engine of growth. The rest of this section tries to explain this puzzle.

### 3.3. Limited Adjustment Capacity of Lower-Tier Suppliers

A stylised *taxonomy* of East Asia´s electronics firms and market segments highlights a strictly *hierarchical* industry structure: global brand-name multinationals, the *flagships* of the industry´s global production networks (GPN) [38] dominate and shape the development of all the other layers of East Asia`s electronics industry. Such an unbalanced industry structure imposes fundamental constraints on the region`s adjustment capacity. The "rapid trade adjustment" proposition fails to address such constraints that reflect the link between industry structure, firm size and firm behavior. Clearly, some firms are " more equal than others", to paraphrase George Orwell, in terms of their capacity to ride out the crisis. We will see that global network flagships have little difficulties to adjust, and that it is local firms, primarily lower-tier suppliers to GPN, that are negatively affected.

Five *layers* can be distinguished[39]:

- On top, the industry is dominated by "global network flagships" which control *global brands and architectural design standards* for computer, communications and consumer applications (Ernst, 2000c)[40].

[38] The concept of a *global production network* (GPN) captures the spread of the value chain across firm boundaries and national borders. It may, or may not, involve ownership of equity stakes. For details, see e.g., Ernst, 1994b, 1997a, 1997b, 2000a, 2000c, 2000d, 2000e and 2000f. For empirical case studies on diverse GPN, see Ernst and Ravenhill, 1999, and various chapters in Borrus, Ernst and Haggard (eds.), 2000.

[39] Over-lappings occur for large multi-divisional and multi-product flagships, reflecting the coexistence of diverse strategies.

- A second layer consists of large firms (mostly foreign MNCs) that dominate the production of key sub-assemblies and components like hard disk drives (HDD), picture tubes or displays, and semiconductors (especially DRAM)[41].
- A third layer consists of a small group of local "original-brand-manufacturers" (OBM), such as Samsung, LG, and Hyundai in Korea, Acer in Taiwan and Creative Technology in Singapore.
- A fourth layer comprises "contract manufacturers" which can be foreign firms like Solectron, Flextronics and SCI, or Asian firms like for instance Venture Manufacturing from Singapore, and many others[42].
- Finally, a fifth group of firms consists of many small-and-medium-sized suppliers of a great variety of components and support activities, located all over the region. This includes for instance plastic molding, metal stamping, tool and die making, precision parts and components, electroplating and finishing, mold making, jigs and fixtures, casting and industrial automation equipment. Many of these suppliers are small, local companies or affiliates of small Japanese suppliers. Both have very limited capital resources.

This stylised taxonomy can help to distinguish different response patterns to the crisis, especially with regard to trade adjustment. The taxonomy highlights some fundamental differences in terms of size-related economies of scale and scope, financial clout, technological capabilities and market access. The firms in the top layer obviously have much greater opportunities to cope with the impact of the crisis than firms on the respective lower layers. As we will see, this is especially true for their capacity to ramp up quickly export production and to generate rising hard currency revenues. For instance, the business perspectives of the key component suppliers are shaped by the requirements of the first group of companies, i.e. the global brand name companies. However, these second-layer flagships have clearly more options than local firms in their response to the crisis.

Apart from size-related factors, there is an additional important dividing line: leading network flagships also benefit from the spread of GPN throughout the region. Most of the components and subassemblies that are used in their export platform affiliates are sourced from neighboring countries in the region. Take Singapore, a major agglomeration of flagship affiliates in the electronics industry: Singapore's import of electronics products from ASEAN as a share of total imports has increased substantially from 14.2% in 1980 to 25.8% in 1990 and 33.3% in 1996 (Wong, 2000). This share is

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[40] Main actors include a handful of global flagships like Microsoft, Intel, Cisco, Compaq, HP, Dell, IBM, Sony, Fujitsu, Toshiba, Ericcson, Motorola, Siemens, Philips, Matsushita, Sharp and Canon.

[41] For DRAM for instance, this includes Japanese and American flagships (like NEC, Toshiba, Hitachi, and Micron Technology); Asian companies that have established their own GPN, such as Samsung Electronics, LG, and Hyundai (from Korea), Acer Semiconductor Manufacturing (ASMI), Nanya Plastic and others (from Taiwan); as well as alliances between multinationals and state-owned enterprises, such Singapore`s Chartered Semiconductor Manufacturing, Tech-Semiconductor and Tri-Tech.

[42] While traditionally these firms have focused primarily on printed circuit board assembly, they have recently expanded into the final assembly and shipment of PCs and digital consumer and communication devices (="complete-box-build-and-ship").

even higher for semiconductors (48.4%) and for storage units (63%)[43]. Singapore-based flagship affiliates are thus well-placed to benefit from the heavy devaluation of local currencies, and are likely to expand their net exports to the US and Europe. The situation is very different however for firms placed on layers 3 to 5: especially local lower-tier suppliers may find it difficult to reap similar benefits.

It is the fifth layer of East Asia´s electronics industry that is clearly most vulnerable to the impact of the financial crisis: especially small domestic local suppliers are exposed to restrictions on trade finance and to price rises for input imports; they are also least capable of hedging against foreign exchange losses. At the same time, most of these small players can only survive, if they are able to upgrade their capabilities and/or if they are able to regionalize their production activities. This requires substantial investments when access to funds has dried up.

### 3.4. Restricted Access to Input Imports

A second important cause for the delay in trade adjustment is that the crisis has restricted the region`s access to input imports. This has constrained the capacity of Asian electronics firms for export expansion, once inventories are exhausted. Three aspects need to be addressed: i) Trade data show a drastic decline in critical input imports during 1998; ii) the unequal incidence of devaluation-induced price increases for input imports; and iii) restricted access to trade finance, especially for smaller Asian exporters.

#### i) A decline in critical input imports

The crisis has reduced the region´s access to critical input imports. Take Korea: during 1998, its electronics imports have drastically declined (- 24.2%). Korea´s electronics imports overwhelmingly consist of "input imports" (components account for 72%, and industrial electronics account for another 24%). A decline in input imports restricts the country´s access to critical machinery and key components that are necessary for new investment. For instance, Korea´s imports of capital goods fell 36.1% in 1998, because the weak Won made imports that much more expensive. The fall has been even more dramatic for industrial electronics, with a registered decline of almost 50%. And imports of telecommunications equipment, which are critical for upgrading the country`s internet infrastructure, have fallen by a whopping 39.2%.

This is of great importance for trade adjustment - once inventories are exhausted, capacity limitations may constrain export expansion. Even more important however are possible constraints for future industrial upgrading (see part 4). In principle, this could lead to increasing secondary import substitution. This depends on whether competing local technologies are available, and, more importantly, whether there are sufficient funds available for domestic investment. Import substitution apparently has occurred for mobile phones and related equipment, which in the past have been heavily, import dependent. There are no signs for import substitution to occur on a broader scale.

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[43] Calculated from United Nations- TARS trade data. Storage units are defined here as HS 847193.

Ironically, trade liberalization may further complicate matters. Consumer products traditionally have played a marginal role: until June 1999, the so-called "system of import diversification" has prohibited the import of Japanese products. This restriction has now been loosened, with the result that consumer imports are rapidly increasing. This is likely to further sap Korea´s capacity for procuring input imports.

**Table 5** demonstrates that all major East Asian electronics producer countries[44] are vulnerable to a decline in critical input imports. They share a heavy reliance on component imports, especially for semiconductors. In addition, **table 8** documents that both NIEs and ASEAN countries are heavily dependent on component imports from Japan. This is illustrated by persistently large bilateral trade deficits with Japan. For both country groupings, dependence on Japanese component imports has rapidly increased until very recently. For NIEs, it reached its peak in 1995, the year before East Asia´s export crash in electronics, while for ASEAN-4, the bilateral trade deficit with Japan in components kept rising until the outbreak of the crisis**.(Table 8)**

Important changes however have occurred since the crisis. For NIEs, the overall trade balance in components has moved from a deficit of roughly $ 550 million to a surplus of about $1.3 billion. Even more important is the drastic decline in the bilateral deficit with Japan from $ 15 billion to less than $ 12 billion. There are two possible causes for this substantial change in the components trade balances: i) NIEs have succeeded to increase substantially their component exports; and ii) there has been a substantial decline in such imports. We have seen that the first explanation has to be discarded until mid-1999. Until then, a substantial reduction in component imports appears to be the main culprit. While in principle, this could be a positive development, reflecting successful secondary import substitution, this is unlikely to have happened in the current situation. Trade data available for 1998 show a substantial decline of critical input imports that are necessary for continuous industrial upgrading (**Table 9)**.

### ii) Devaluation and import prices

East Asia´s electronics industries heavily depend on imports of key components, subassemblies and production equipment (see part 2). This constitutes an important barrier to export expansion. For intermediates, import prices are normally quoted in US-dollars[45]. This implies that the massive devaluation imposed by the Asian crisis should lead to substantial price increases in input imports.

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[44] = Taiwan, Singapore, Malaysia, Thailand and the Philippines. The lower shares reported for Hong Kong and China reflect the still prominent role of CE, where component procurement is less import dependent. For Indonesia, the same was true before the crisis, albeit on a much lower level of sophistication ( see the very low RCA levels reported in **table II.6.**). Since then, its electronics industry faces a real threat of extinction.

[45] At the peak of the crisis, there were debates in Japan whether a shift to Yen-denominated prices would enable Japanese suppliers of materials and machinery to preserve their important markets in Asia. These debates however have come to nothing.

Any attempt to document this effect is confronted with serious methodological problems. For instance, many of these transactions take place as intra-firm trade - thus “transfer pricing” is of pervasive importance. There are no systematic data sets available in the public domain on import prices for key components and production equipment. This makes it practically impossible to conduct a reliable quantitative analysis of price effects resulting from currency devaluations. It is possible however to discuss some illustrative and stylized examples that should enable us to narrow down the range of possible outcomes[46]. Interviews that we conducted during 1998 with Asian electronics companies (both final producers and suppliers) that rely on open market purchases indicate that they all had to face considerable price increases for input imports.

This is likely to be very different for Asia-based flagship affiliates. Many of their transactions take place as intra-firm trade, where sophisticated “transfer pricing” techniques can shield these affiliates from an increase in import prices. To the degree that they buy from independent sources, they engage in global sourcing: large orders usually enable them to request substantial price discounts. This is an option which does not exist for most Asian electronics firms, with the exception of some chaebol and some large Taiwanese business groups[47].

### iii) Access to trade finance

Access to trade finance has not been a problem for flagship affiliates, especially if they are located in a country that has an open capital account. In Singapore for instance, foreign affiliates can bring in US-Dollars and transfer them abroad at their discretion. There are no foreign exchange regulations. Furthermore, flagship affiliates have no problems in obtaining letters of credit. Under pressure from the IMF, most countries in the region have moved in a similar direction and have opened up the capital account.

Smaller local electronics firms have been severely hit by the effects of IMF prescriptions, such as tight monetary policies and the restructuring of the financial systems. Many of them face great difficulties to find a bank willing to provide trade credit. Even if they get the credit, they are squeezed by high interest rates. An additional financial constraint to exports is the difficulty of securing letters of credit through local banks, none of which now is regarded internationally as creditworthy. During 1998, this has caused a dramatic decline in input imports.

Access to trade finance has been a major problem for Asian contract manufacturers and subcontractors. During 1998, many of these companies were in default on both interest and principal repayments, working capital had dried up, and letters of credit were impossible to obtain. In general, the lower a firm is positioned along a particular product´s supply chain, the more it has been negatively affected by restricted access to trade finance. This increasing inequality also applies in geographic terms:

[46] There is a need for systematic econometric studies of devaluation-induced price effects for input imports in major Asian export industries, like electronics.
[47] Kim Youngsoo, 2000, demonstrates the difficulties faced by Samsung Electronics in its attempt to develop a global sourcing network.

suppliers that are located in Malaysia and Thailand are much more affected by these credit constraints than Singapore-based suppliers. Indonesian suppliers are in the worst position: many of them have now lost for good their supply contracts.

This has two important negative implications for the long-term upgrading potential of East Asia´s electronics industries. For each individual country, it strengthens an industry structure that is characterized by an *inverted* production pyramid: the pyramid´s top, i.e. final assembly, keeps expanding, *despite* the weakness of the pyramid´s base, i.e. an immature set of support industries. In other words, capacity expansion proceeds *without* "industrial deepening". Second, and more general, this reduces the role that smaller firms can play as engines of export growth. Overall, the crisis is likely to have a negative cascading effect that increases inequality and that may block further industrial upgrading. In short, structural weaknesses inherent to East Asian catching-up strategies are further magnified.

In order to counter such negative trends, corrective policy instruments have been discussed in various forums, but so far very little has been achieved. Singapore´s government for instance established a US$ 2 billion trade financing scheme to enable Indonesia to buy essential supplies (Financial Times, March 31, 1998, p.1), but it apparently has failed to draw sufficient support. Likewise, the Japanese government has announced various measures to assist its Asian neighbors in their access to trade finance, as part of the US$ 30 billion Miyazawa initiative, but few details have been disclosed.

### 3.5. Demand Constraints in Export Markets

Another possible explanation for delayed trade adjustment are demand constraints in export markets. This raises two questions: Where are the main export markets for East Asia´s electronics industry? And can these markets absorb a substantial increase in the region´s electronics exports?

#### i) A basic dilemma

The outbreak of the Asian crisis has brought back into the limelight a basic dilemma that has accompanied the development of the region´s electronics industry almost from its beginning: How to balance different markets for its products? Should the focus primarily be on the US and Europe, or should there be a shift toward intra-regional trade?

Initially, a heavy reliance on exports to the US and Europe has helped to compensate for insufficient domestic market size and lack of sophisticated demand; it also helped to insulate individual Asian economies from economic turmoil within the region. Until well into the second half of the 1980s, the lion´s share of these exports went to the US and Europe: in 1987 for instance both markets together accounted for 84.4% of the exports of the four leading Asian NIEs; for ASEAN countries, this share was even higher, at 93.2%[48]. The US market alone accounted for more than 58 % for NIE exports, and 67% for those originating from ASEAN countries - only Mexico, unsurprisingly, displayed a higher degree of US market dependence. Both the Japanese market and the East Asian markets accounted for a very small share of East Asia´s electronics exports.

The flipside of this strategy however has been a heavy exposure to the highly volatile business cycles of a handful of electronics exportables. The response to this dilemma has been a rapid growth of intra-regional trade, which especially since the early 1990s, has become one of the hallmarks of the "Asian Miracle"[49]. Before the crisis, in 1996, the main concern was a demand glut for DRAM and consumer electronics which had caused a dramatic crash in the region´s exports. Trade regionalization was considered to be a powerful countervailing force that could help to mitigate this fundamental weakness. The result has been a significant increase in intra-regional exports, including exports to Japan.

**ii) Intra-regional trade**

Over the last few years before the crisis, East Asia has become a strategic growth market for its electronics industry. An increasing share of the region´s electronics exports is now staying within the region **(Table 10)**

Similarly, East Asia has become an important source of Japanese electronics imports[50]. Until the outbreak of the crisis in 1997, Japan's imports of electronics products have been growing very rapidly, and Asia has become the most important source of these imports. Asia´s share in Japan´s total electronics imports has surged from less than 31% in 1988 to almost 58% in 1996 (Ernst, 1998b)[51].

[48] Ernst and O`Connor, 1992, chapter III, table 13. NIEs here include Korea, Taiwan, Singapore and Hong Kong, while ASEAN countries exclude Singapore.

[49] Over the last decade, intra-regional trade has made an increasing contribution to growth: in 1996, its share in East Asia´s total exports accounted for about 40%, up from 32% in 1990. If Japan is included, the share of intra-regional trade rises to 50% (World Bank, 1998b). Trade theorists argue that this reflects the region´s increasing specialization, based on shifting comparative advantages (in line with Balassa, 1977). Recent research however has shown that the expansion of intra-Asian trade is due primarily to the spread of increasingly complex global production networks (GPN) (Ernst and Guerrieri, 1998; and Ng and Yeats, 1999)

[50] Despite its close proximity, East Asia has surprisingly played a much less prominent role as a source of Japanese electronics imports than it did for the US (Ernst and Guerrieri, 1998). Until 1990, Japanese electronics imports overwhelmingly originated from the US, and even in 1993, East Asia's share was significantly lower than that of the US.

[51] In absolute terms, Japanese electronics imports continue to be substantially smaller than those of the US: in 1996, Japan´s total electronics imports were $47.439 billion, less than one third of the US total of $ 151.5 billion. This however is a substantial improvement relative to 1991, when Japan´s total electronics imports were worth only 20% of the US worldwide electronics imports. The most rapid increase has occurred for electronic components, where the import ratio shot up from 16% in 1985 to more than 35% in 1993. While in 1988, the US was the only source of imported ICs and computers, Japan now imports roughly the same amount of ICs and computers from Asia and from the US.

Let us take a closer look at the four leading Asian electronics producers. Their intra-regional exports have increased in importance until 1995. In 1996, the year of the export crash, Taiwan experienced a decline in the share of its intra-regional exports, while this share remained stagnant for Singapore. In 1997, the share of intra-regional exports increased again for Singapore, but started to fall for Malaysia. The shift towards intra-regional trade has been most pronounced for Korea. East Asia´s share of its electronics exports has rapidly increased since 1994: while in 1991, roughly 21% of Korea´s electronics exports went to other countries in the region, in 1998 this share now exceeds 36% (**Table 11**). Between 1991 and 1998, the combined share of North America`s and Europe`s markets decreased from 52.2% to 44.2%, leading to a massive increase in the share of East Asia and other emerging markets**.(Table 11)**

In 1997, almost 60% of Korea´s electronics exports were destined for markets where demand was either stagnating or declining. This includes Japan, with 10.8%, and a 48.1% share for emerging markets in East Asia[52], Latin America, Eastern Europe, Russia and the rest of Asia, up from 39.4% in 1991. In 1998, this share declined to roughly 56%, reflecting the severe recession in Asia and other emerging markets. These figures indicate a disturbing dependence on markets that were highly vulnerable to contagion from the Asian crisis: during 1998, demand was falling in most of these markets. A high dependence on emerging markets may also discourage future industrial upgrading: i) there is less pressures to upgrade product performance and quality; ii) there is less exposure to sophisticated customers; and iii) it gives rise to an extreme vulnerability to exchange rate fluctuations. **(Table 12)**

Especially noteworthy about Korea is that the crisis has not interrupted this trend. **Table 12** shows that the main driver of this shift to intra-regional trade have been components, and in particular SC. Korea increasingly becomes a supplier of lower-cost key components for GPN established in Asia, especially for monitors, DRAM, and computer displays. This contrasts with the declining role of intra-regional exports in the other three major Asian electronics producers. This raises an important question: What are the costs and benefits of a shift towards intra-regional trade?

### iii)Reassessing Benefits and Costs of Intra-Regional Trade

The challenge to find the appropriate balance between benefits and costs of intra-regional trade has accompanied the development of East Asia`s electronics industries since the beginning. The crisis however has now added a new dimension: it has led to a demand-crash in regional markets, which has dragged down exports to the region.

Paradoxically, intra-regional trade became a liability after the crisis, because it provided a perfect channel for the contagion to spread swiftly through East Asia. During 1998, the computer market in Asia (including Japan) declined by 7% on a yearly basis, reflecting the fall in corporate investment. Most Asian countries were struggling with a severe decline in domestic demand, and with a lack of financial resources for imports.

[52] East Asia itself accounts for almost one third of Korea´s electronics exports, up from 21.5% in 1991.

Exports of consumer electronics and of related components have been most vulnerable to the impact of the financial crisis, for two reasons: i) Already before the crisis, East Asia had substantial surplus production capacities; and ii) the region´s demand for these products has dropped sharply by about 70 to 80% during 1998. With Japan in the throes of a severe recession, its imports from Asia have drastically fallen during 1998: while overall, Japan´s imports fell by 15% (during 1998), imports from every Asian country were down, with Malaysia, Vietnam and Indonesia suffering the biggest falls, down respectively 22 percent, 23 per cent and 30 percent. Taiwan´s exports to Japan, its third largest export market, fell by almost 24%.

In short, the coexistence of the Asian financial crisis and Japan´s deflationary downward spiral has created an explosive mixture of forces that delayed the region´s trade adjustment. During 1998, the primary concern has been to reduce the industry´s vulnerability to economic turmoil within the region: debates centered on the role that the electronics industry could play in sheltering the region against crisis contagion. In response to a drastic fall of their intra-regional exports, most Asian countries, including China, have all rushed to shift their exports away from Asia as well as Japan, to the U.S. and Europe.

### iv) Limitations to Export-Led Growth

The question of course is whether they will succeed in implementing such a shift in their export markets. Once a substantial increase in Asian exports would deteriorate the US current account, this may lead to vigorous trade restrictions. The US market dominates world electronics industry, accounting for a 37% share. US electronics imports grew incessantly until 1995, and then stagnated in 1996, the year of the world export crash. The next year, 1997, saw an almost 9% increase in US electronics imports. In 1998, however, their growth declined to less than 4 %. Import restrictions are again playing an important role. Their impact cuts across all major product markets[53].

In short, during 1998, a combination of trade restrictions in the U.S. and Europe and falling demand in Developing Asia (and emerging markets) provided only limited opportunities for export-led growth. This could change, however, once regional markets start growing again, and once the electronics industry returns from bust to boom and provides a new export stimulus. We will now turn to the role played by industry-specific factors in delaying trade adjustment.

## 3.6. Commodity Trap: Excess Capacity and Price Wars

Surplus capacity and price wars dominate many if not most of East Asia´s electronics industries. The root cause is a sticky specialization in commodities (see part 2). This has given rise to a further set of constraints to trade adjustment: even if Asian

[53] In the US for instance, Korean exporters are faced with import restrictions for picture tubes (CPT), DRAM, C-TV sets, and keyphone sets. In the EU, import restrictions affect an even larger product range: In addition to CPT, DRAM, and C-TV, this includes MWO, Car-CDP, FDD, Fax, Condenser, and V/Tape.

electronics producers succeed to expand their export volumes, negative pricing effects may erase such gains.

It is important to emphasize the unequal incidence of such pricing pressures: local Asian firms are likely to be more vulnerable than network flagship affiliates (3.6.1.). Of equal importance is to understand the underlying causes. Deflationary pricing pressures result from over-investment and excess capacity. Most debates have focused on country-specific causes, as embedded in East Asian catching-up strategies. In part 2, we have demonstrated how the latter have led to an industry structure and firm behavior that have fostered excess capacity. Our focus here is on a set of complementary industry-specific causes (3.6.2.). We use the example of semiconductors (especially DRAM), to demonstrate how the business cycle and structural characteristics of this industry give rise to periodic surplus capacity and price wars.

### 3.6.1. Unequal Incidence: Pricing Pressures on Asian Suppliers

Deflationary pricing pressures have very different effects for local Asian firms and flagship affiliates. The latter may actually benefit, in so far as they procure a substantial amount of products and services from within the region. Established market leaders with a strong global brand image can cope reasonably well with deflationary pricing pressures: they can charge premium prices, and they can shift the burden of cost reduction onto other shoulders, primarily their Asian suppliers. Global flagships like Compaq (for PC-related parts and subassemblies) and Seagate (for HDD-related supplies) have been quick to respond to the devaluation of local currencies and have requested substantial price reductions from their Asian suppliers. The latter do not have much choice but to comply.

At the same time, Asian suppliers are under tremendous pressure to broaden their capability base and to increase their investment outlays, simply to sustain their link with their main global customers. There is a substantial risk that, once devaluation is reversed, Asian suppliers will find themselves being caught in a higher-cost production structure than before the crisis. But then they will be unable to back away from the price reductions which they have granted in response to the currency depreciation.

Asian producers of final electronics products are caught in the middle: they must increase hard currency export revenues at almost any cost, in order to service their mounting debt. At the same time, they have to bear the full brunt of this ruthless cost reduction pressure, as they do not have someone else to whom they could pass it on. The root cause of this vulnerability is a sticky specialization in “commodities” that are characterized by periodic surplus capacity and price wars[54]. This leaves Asian electronics firms very little room for price increases; there is a constant squeeze on their profit margins, which constricts the funds required for continuous upgrading.

[54] See our analysis in part 2.

How does devaluation affect the prices paid by flagship affiliates to their Asian suppliers? In order to understand this important issue, let us look at the impact of devaluation on the production cost of a Malaysian supplier to a global flagship affiliate based in Singapore (author´s interviews in Singapore, March 1998). Most of the materials need to be purchased in US-dollars, due to the very high import content ratios of production; non-material costs (like labor and overheads) on the other hand are overwhelmingly in local currency. This implies that depreciation should lead to a reduction in the share of non-material costs (both labor costs and overheads). The Singapore-based flagship affiliate requests that this reduction in non-material costs be translated in proportional price reductions. The supplier does not have much choice but to give in to such pressure. Its main concern is to sustain the link with its customer, at almost any cost. Lower-tier suppliers, in particular those located outside of Singapore, have been pushed to the limit in granting such price reductions. This reflects the intense price wars in most sectors of the electronics industry (see below).

This is a very problematic development: it deprives lower-tier suppliers of the means that they need urgently for upgrading their product and technology portfolio. Such upgrading requirements are now much more demanding. The dominant global PC manufacturers have drastically reduced the duration of contracts for printed circuit board assembly (PCBA): typically, PCBA suppliers can now be dropped within a week. PC manufacturers have also off-loaded so-called "back-end" activities (related to logistics and global supply chain management) to contract manufacturers, in order to concentrate on their core competencies. This has forced Asian contract manufacturers to move beyond PCBA to the final assembly of PCs (so-called "box-build" contracts). The main concern is to stabilize the link with their main customers: the duration of box-build contracts typically is around six months. This however requires substantial investments which smaller suppliers have great difficulties to mobilize.

Even more problematic is a somewhat longer-term effect: once local currencies will start to appreciate again, this will leave lower-end suppliers in a very vulnerable position where they will be stuck with a higher-cost production structure that cannot sustain the currently granted price reductions. It is unlikely that they will be able to back away from these price reductions, which they have granted in response to the currency crisis. In other words, there is a real danger that current price reductions may force many of these suppliers out of the market.

In short, price pressures, which were already intense before the financial crisis, have now become even more severe. At the same time however, Asian suppliers are under tremendous pressure to recapitalize: in order to survive, they need to upgrade their product mix and their efficiency; they also need to proceed with a regionalization of their production base. This dual pressure has resulted in severe cash-flow problems, especially for smaller local suppliers. Asian contract manufacturers are confronted with an uneasy dilemma: if they invest in an upgrading of their facilities, they will be saddled with a higher-cost production structure than before the crisis, and thus are potentially more vulnerable to a potential new financial crisis.

### 3.6.2. Industry-Specific Causes

As for the causes for such drastic price falls, we need to distinguish the impact of *industry-specific* business cycles from over-investment and excess capacity due to East Asian catching-up strategies. Both causes are closely intertwined. For instance, Korean exporters of key components and semiconductors emphasize the important role played by "aggressive low-price policy of Southeast Asian competitors" (Author`s interviews, September 1998). For all practical purposes, this means that affiliates of American and Japanese global network flagships cut prices in line with crisis-induced local currency devaluations. If that happens, local actors, both firms and governments, do not have much choice but to follow suit. This is a clear case where flagship strategies that reflect the business cycle, interact with East Asian catching-up strategies. For analytical purposes, it is nevertheless important to separate out these two distinct sets of determining factors.

#### i) Excess capacity and price wars

Periodic excess capacity reflects a basic dilemma of technological change: a persistent tendency for production capacity to overshoot demand. Rapid capacity expansion and constant productivity improvements are its two most important defining characteristics. Yet there is no guarantee that demand growth will keep pace - Say´s law only applies under very restrictive conditions that are unlikely to occur in the real world[55].

Many sectors of the electronics industry are characterized by extremely rapid capacity expansion and productivity improvements. The unsurprising consequence is that they periodically face a vicious circle of surplus capacity, price wars, and profit squeeze[56]. Market forces cannot correct this basic imbalance. This task falls upon corporate strategy, whose main concern is to manage supply so that it matches demand, and to maintain profitability.

#### ii) A closer look at the semiconductor industry[57]

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

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

[57] If not mentioned otherwise, the following is based primarily on author´s interviews over the last decades in leading American, Japanese, European, Korean, Taiwanese and Singaporean semiconductor firms. (See , for instance, Ernst, 1983, 1987, Ernst and O`Connor, 1992, Ernst, 1997b). Our sources for pricing data include: a 24 months price data base for two current DRAM chip generations (from July 1997 to July 1999); a 2 years price comparison for major electronic components, prepared by EIAK (covering 1997 and 1998); and **Grimm, 1996.**

Trade and sales of semiconductors are a function of demand: end-use markets for semiconductors (SC) vary considerably across regions. They also vary in terms of their growth: computer and communications applications are the fastest growing segments in all regions. Until recently, the computer market used to be the largest user of semiconductors, producing approximately 62% of sales in the US, 41% in Europe, and 52% in Asia (Reed Electronics Research, 1998)[58]. It has been said with good reason that, when the PC industry catches a cold, the SC industry will get pneumonia. Given the intense price wars in the PC industry (e.g., Ernst, 1998b, chapter III), it is hardly surprising to find that, for SC, price competition and market share battles have both considerably intensified.

Take DRAM, where Asian producers (Korea, Taiwan and Singapore) play a major role. In response to the demand glut for DRAM since late 1995, Korean producers have shared a common interest with Japanese producers in supply regulation and in the re-establishment of a stable oligopoly. The main objective was to fend off attacks from new entrants in Taiwan and Singapore, and to frustrate attempts by Micron Technology Inc, one of the few remaining US manufacturers, and Siemens, to recapture market share.

The crisis frustrated these attempts. In order to understand why, let us take a look at recent changes in the semiconductor (SC) market, and how they have affected price behavior **(Table 13).**

During 1998, DRAM sales plummeted by -26%. This compares with a decline of -9% for worldwide semiconductor sales revenues. The result is that DRAM which once used to dominate the SC market at around 25%, has now fallen to a mere 10% of the global semiconductor market. This dramatic decline in demand coincides with a rapid capacity expansion that results from a massive investment push during the boom years of 1993-1995. The most substantial capacity expansion occurred in East Asia. Take Korea, the region´s industry leader. Between 1992 and 1995, Korean SC companies invested an average of 45% of their annual revenues, which were then extremely high due to the then prevailing DRAM boom. Korea´s capacity expansion continued until 1996, when almost $ 10 billion was invested. During this year, Korea´s share in world SC investment increased to 20%, making the country the hottest market for SC production equipment firms. We have seen that this capacity push facilitated Korea´s rapid export expansion. It however also had an important negative effect on pricing, creating, what we have called a "commodity trap".

The growing mismatch between demand and capacity expansion gave rise to a massive excess capacity, which in turn generated ruthless price wars. Two types of prices need to be distinguished: "contract" and "spot market" prices. Most price quotations in the business press are for spot markets. This is somewhat misleading, as most

[58] One important distinguishing feature of the Japanese SC market is its still quite heavy reliance on consumer goods applications; it is however now moving rapidly away from consumer-oriented analogue products, towards digital electronics, communications and computer products.

transactions in the SC industry are covered by contracts that freeze prices for a specified period, typically three to six months. As a result contract prices fluctuate much less than spot prices.This distinction explains why SC firms differ in their sensitivity to price fluctuations. The higher the share of its sales that is sold on spot markets, the more a company will benefit from price surges. By the same token, it will suffer more, when prices fall. This has important implications for capacity planning: the higher the share of spot market sales, the quicker the company needs to adjust production capacity.

A comparison of Samsung and Hyundai can help to illustrate this important point. Hyundai depends much more than Samsung on spot market sales: 20%[59] relative to 5%. This explains why Hyundai suffered much more than Samsung from the DRAM price decline since 1996, and why it was much faster in cutting down production capacity. On the other hand, this also explains why, once DRAM spot prices began to climb again in the third quarter of 1999, Hyundai`s share prices increased much faster than Samsung`s (Financial Times, September 22, 1999). It also explains why Hyundai has rushed to ramp up production in its Scottish and Welsh SC plants that it had mothballed in late 1997[60].

The following data are for *spot* market prices. Since 1996, prices for DRAM have plunged due to accumulated world-wide over-capacity: while the price for a staple 16-megabit DRAM chip in late 1995 was $60, it has crushed to $3 in late 1997. At that stage, this price was considered to be at or below the manufacturing costs of all but the most efficient manufacturers in the industry. Since then the price for 16 Mb devices has declined further to a low of $ 1.42 in July of 1999. Spot market prices also fell quite dramatically for the leading-edge 64 MB DRAM chip: from $ 38 on August 11, 1997, the unit price fell by 88% to a low of $4.43 on July 5, 1999. Such aggressive price slashing has turned the DRAM business into the "bleeding-edge" of the semiconductor industry, with all leading players experiencing huge losses. For instance, Korean chip makers are estimated to have lost a combined $2.7bn in 1997. In response to such dramatic losses, they were reported to have cut capital spending by around 40% in 1998[61] Such losses increased during 1998, when DRAM producers collectively lost about $ 1.5 billion per month. This forced all major DRAM producers to generate foreign exchange through increasing exports at almost any cost. This explains why, despite a possible substantial increase in export volumes, export hard currency revenues have declined.

There is however reason to doubt that drastic price slashing can be sustained: the threat of dumping procedures is very real; and worsening terms of trade will make it more difficult to purchase essential input imports. Most important however is the historical evidence of continuous "boom-and-bust cycles". After a long downturn from 1996 till mid-1999, the industry has moved again into a renewed recovery. It is to these most recent developments that we will turn our attention in the concluding part

[59] This figure predates Hyundai`s acquisition of LG` SC operations in 1999.
[60] Apparently, Hyundai is now discovering that it can use these plants as safety buffers to ride out the markets` price fluctuations.
[61] These figures are courtesy of VLSI Research Inc, a market researcher in San José, California that specializes on the market for semiconductor production equipment, and hence is a reliable source for investment and capacity planning.

## 4. PERSPECTIVES: FROM A VICIOUS TO A VIRTUOUS CIRCLE OF INDUSTRIAL UPGRADING?

### 4.1. What Is Feasible?

Until mid-1999, earlier expectations of a crisis-induced export boom have largely remained unfulfilled. The mood however has changed since then. Electronic exports are booming: in Korea, they grew by almost 28% in 1999, and are projected to grow by nearly 25% during 2000[62]. There is now growing optimism that, at long last, exports will be re-established again as engines of growth. However, far too little attention has been paid to longer-term perspectives: Will there be a shift from a vicious to a virtuous circle of export-led industrial upgrading?

It is too early to answer this question. Undoubtedly, the crisis has imposed some quite fundamental changes in economic structures and institutions within the region[63]. This is especially true in a fast-moving and highly globalized industry like electronics. Various Asian electronics firms have announced attempts to move beyond trade adjustment, based on export price slashing, to more fundamental changes in product specialization, knowledge management and industrial deepening. It will however take another two years or so before we can judge the results of such intentions to proceed with industrial upgrading (IU). By then it should be possible to construct systematic data sets across the region on changes in the product composition of electronics production and trade. By that time, we should also be able to judge the development of the domestic knowledge base in major electronics producing countries in the region.

In light of these data limitations, we will concentrate on a critical conceptual issue, trying to deepen our analysis of industry-specific dynamics. Focusing on semiconductors (especially DRAM), we will ask how current changes in global competitive dynamics affect East Asia´s industrial upgrading options. In 4.2, we demonstrate the importance of this industry for East Asia`s electronics exports. In 4.3., we discuss whether this industry is in another expansion phase worldwide, distinguish cyclical and structural drivers, and assess conflicting scenarios on the sustainability of the current recovery. In 4.4., we ask what this implies for upgrading perspectives in this industry, highlighting the challenge of moving beyond the commodity trap.

### 4.2. The Importance of Semiconductors for East Asia

The semiconductor industry figures prominently in East Asian electronics exports **(Table 14)**

[62] One source claims that, during the first half of 2000, electronics exports have grown by more than 90% (?) in Korea, 50% in China, 30% in Taiwan, 27% in Malaysia, 23% in Thailand, and roughly 8 % in Singapore. Deutsche Bank figures, quoted in: "Asia`s rollercoaster rides", The Economist, October 21, 2000, p.82.

[63] Examples of such changes can be found in Kim Linsu (2000), Lee Keun & Kim Sungsoo (2000), and Ernst, 2000d

In terms of the geographic dispersion of its production sites and markets, the semiconductor industry is one of the most *globalized* industries: there has been a massive shift of production and assembly by US and Japanese firms outside of their respective countries, primarily to locations within Asia (e.g., Ernst, 2000c, and Ernst 1983).Until the crisis broke out in 1997, Asia has been the fastest growing supplier and consumer of semiconductors - not the U.S. or Japan. The crisis suppressed demand growth until mid-1999. Since then, East Asia has shown the strongest growth as a global supply base, with the result that it is now the second most important location for semiconductor manufacturing after North America (**Table 15)**. The region also has regained its role as an engine of demand growth for semiconductors**. (Table 15)**

### 4.3. Industry-Specific Dynamics: From Bust to Boom in the Semiconductor Industry

#### 4.3.1. Signs of recovery?

During 1999, prices of DRAMs have started to rise again after three years of steady fall, reviving hopes that this may signal the beginning of a recovery. **Table 16** documents a massive, albeit volatile increase of spot market DRAM prices during 1999: For 64Mb devices, spot prices shot up from a low of $ 4 in May to almost $25 in response to Taiwan´s earthquake in September, and then fell back to $12.50 in November. Spot prices have started to fall however again since September 2000: in November 2000, prices had declined to $ 3 for 64Mb devices, with leading-edge 128Mb devices also falling to $ 8 (data courtesy of Dataquest and U.S. Semiconductor Industry Association). **(Table 16)**

As long as prices rose, leading DRAM producers experienced rising profits and share prices. Shares of Micron Technology, the leading American DRAM supplier, have risen from a $34 1/2 low in May 1999 to above $80 by the first quarter of 2000. And Samsung, the world`s biggest DRAM producer experienced a massive increase in market capitalization, based on a profit boost from higher prices[64].A simple hypothetical calculation illustrates the orders of magnitude involved. Korean producers currently produce roughly 700 million 64Mb DRAM devices. An increase of $1 per chip thus would result in a rise in revenues of $ 700 million. An increase of spot market prices from $4 to $12.5 would lead to a rise in revenues of $ 5.59bn. Another example may further illustrate this point: Samsung`s current DRAM production volume is 20 million chips per month. As one of the most efficient worldwide producers, the company is estimated to make a bout $ 5 on a single chip. On an annual basis, this would lead to a profit of $1.2bn.

How sustainable is this recovery in DRAM prices? The answer to this question obviously matters for the region`s industrial upgrading perspectives. Over the last two years, projections on demand growth for semiconductors have gone through the typical cycle that starts with excessive optimism and that has now reached the stage where cautious optimism is attacked by pessimistic projections. This simply indicates that the

[64] Note however that there has been a drastic fall in the P/E ratio of Samsung Electronics since the summer of 2000, which has pulled down Korea´s stock exchange.

SC industry cycle has remained as volatile as ever; some observers argue that it has in fact become more unpredictable (Daniel and Foremski, 2000). To cut through this maze of conflicting announcements, let us start with two simple facts: First, chip shortages began in the second half of 1999 with flash memories and microprocessors. By early 2000, they had spread to a wider range of semiconductor devices including DRAM. As we know, the latter devices, until then, were in such abundant supply that many producers had pulled out of the market. This has produced a reversal in pricing trends. For instance, spot market prices for 64MB DRAMs increased by roughly 10% during the first three months of 2000 (Semico Research (Phoenix, Arizona) data, quoted in The Economist, June 3, 2000, p.64).

Second, in response to the spread of commercial internet-related applications, a massive change has occurred in the final user markets of semiconductors. While PCs accounted for 49% of semiconductor revenues in 1994, that share had shrunk to about 25% by 1999. Communications increased from 15% of the total to 21% over the same period, while servers and large corporate computer systems grew from virtually nothing to 25% (data courtesy of U.S. Semiconductor Industry Association, August 2000). This change initially has created hopes that a more diversified end user demand will help to smoothen out the SC cycle. However, renewed doubts have been raised since the third quarter of 2000 by the simultaneous decline in SC demand from the PC, communications and networking equipment markets. During periods of such simultaneous demand decline, the volatility of the SC cycle is actually increasing.

### 4.3.2. Drivers of recovery: Cyclical versus structural causes

We need to dig deeper, and ask what forces determine the competitive dynamics of this industry, especially in its most volatile sector, DRAM. There are two possible explanations for the SC business cycle (Ernst, 1983): while some observers stress *cyclical* causes, others highlight the over-riding importance of *structural* causes that reflect fundamental changes in markets and technology. Let us take a closer look at both sets of explanations, and see what they can tell us about recent developments. More specifically, what are the causes for the semiconductor industry downturn since 1996? Are these primarily cyclical and short-term, or are more fundamental structural factors at work? What explains the massive build-up of surplus capacity? Why did it take so long to reduce it? How sustainable is the current recovery in semiconductor demand? And what are possible implications for competitive dynamics and industry structure?

#### i) Cyclical causes

There is a widespread perception that *cyclical* causes are primarily responsible for the recent downturn in the SC industry. By late 1999, the consensus was that these cyclical factors have now largely be resolved, paving the way for a sustained recovery. A closer analysis however sheds doubt on this optimistic interpretation: fundamental structural transformations in the SC industry may increase its volatility.

Proponents of the cyclical nature of the 1996-1998 downturn point *first* to the over-capacity that has been accumulated in the mid-1990s during rapid demand growth. That capacity has now been exceeded by increased sales volumes, and by older plants becoming obsolete. In addition, it is argued that the expanding memory requirements of many new internet-related software programs and computer applications have further stimulated DRAM demand.

The Asian crisis is treated as a *second* cyclical factor. It is argued that the dramatic fall in chip demand in Japan, Korea, Taiwan and other parts of Asia is only a temporary aberration that is now being corrected. Since mid-1999, semiconductor sales in the region have dramatically improved: in June 2000, sales revenues in Asia/Pacific and Japan grew 53 and 51 % respectively, relative to June 1999, compared to 43% for the Americas, and 48% for Europe (data courtesy of U.S. Semiconductor Industry Association (SIA), August 2000).

There is no doubt about a temporary recovery. The SIA predicts 31% demand growth for the global chip market for the whole of 2000. It acknowledges however that this growth rate is unsustainable. It is unlikely that the SC industry will cease to act like a roller coaster, with sharp revenue falls followed by soaring gains. A first reason for such skepticism is that some *cyclical* factors may actually work against a sustainable recovery. Take for instance *seasonal* factors. The third quarter of the year traditionally is the busiest time for PC manufacturers, the biggest consumers of DRAMs, as they prepare for the Christmas selling season. When the holiday PC boost eases, typically in October or November, DRAM prices may again come under pressure. A similar backlash may occur for memory requirements designed into PC motherboards. As long as DRAM were cheap, it did not matter how many of them were required. But once their prices surged, PC vendors have quickly responded with changes in motherboard design that reduce the number of required memory devices. Such changes in board design can apparently be done at very short notice, with the result that they have a pronounced counter-cyclical effect: decreasing the demand for DRAM devices, when prices rise, and vice versa.

The same may be true for *technical teething* problems that arise as chipmakers shrink chip dimensions. This may have temporarily constrained DRAM supplies, leading to price increases. It is however unclear whether this effect will last. It is in fact possible to argue that the new process technologies required for leading-edge miniaturized product generations will further depress chip prices. By shrinking chip sizes, chip makers can now increase output since more chips can be produced from each wafer of silicon, the base material of semiconductor chips. This could substantially increase DRAM output, hence starting a new cycle of surplus capacity and price wars.

*Temporary supply disruptions*

It is also necessary to mention temporary determinants of DRAM prices that are unrelated to the business cycle but which reflect the high sensitivity of chip-making equipment to environmental disruptions. Wafer fabrication critically depends on uninterrupted power and clean water supplies[65]. Even a minor earth tremor requires some weeks of recalibration of extremely sensitive clean room and production equipment. In an industry where time-to-market is of the essence, such disruptions of production can have a major impact, especially on spot market prices.

During 1999 for instance, Taiwan was hit twice by such temporary price-boosting supply disruptions. The island`s chipmakers now account for roughly 7% of the world DRAM market (courtesy of Market Intelligence Center, Institute for Information Industry, Taipei). Their share however rises to 12%, once outsourcing to Japanese chipmakers is taken into account. In late July of 1999, an extraordinary power failure temporarily paralyzed the country`s DRAM exporters. It is estimated that this single event has reduced world DRAM supply by about 2 %. And the massive earthquake of September 1999 has apparently led to much more serious disruptions[66]. This has led to a further boost in DRAM spot market prices, which temporarily shot up to $25, before settling back to a range from $ 12.50 to $ 15 per unit (see **Table 14**).

Such exogeneous, i.e. market-unrelated production disruptions extend beyond DRAM, and cover various important PC components, such as graphic chips, sound chips, and memory control chip sets. Japanese customers believe that it could take two to three months before shipments begin, and as long as five months for supplies to reach pre-earthquake levels. This is likely to cause serious disruptions for the world PC industry: Taiwan makes 21% of all video cards, 31% of graphic cards, 48% of sound cards, as well as 80% of all PC motherboards. Taiwanese manufacturers have tried to compensate for the damage caused by the earthquake by increasing production in their overseas facilities. They are for instance reported to have doubled their component shipments from the Philippines (according to the Semiconductor and Electronics Industries Association of the Philippines, as quoted in Financial Times, November 5, 1999). Yet this is unlikely to prevent further quite substantial price increases. For instance, the price for a standard 128Mb memory module has risen more than six fold from $60 at the end of July 1999 to $370 during the fall.

### ii) Structural Causes

There is strong evidence that the causes for the current downturn of the semiconductor industry are not just cyclical and short-term; fundamental structural transformations are reshaping this industry, covering both supply and demand. Will these transformations lead to a sustained rise in DRAM prices, or will the current price surge

[65] The chipmaking process involves high temperatures, corrosive gases and precision at a level of less than one millionth of a meter. It is thus highly sensitive to violent motion and sudden losses of power.
[66] For SC fabrication, the main production bottleneck appears to be caused by damage to the manufacturer`s chemical vapour deposition furnaces, which contain large delicate quartz tubes. The earthquake seems to have shattered many of these tubes; much of the replacement stock, held on site, is also damaged. Leading Japanese suppliers of quartz tubes report the backlog of orders has surged dramatically and that they cannot meet demand. This is denied by Taipei-based analysts. These sources claim that Taiwanese chipmakers were able to ship in the quartz tubes from plants overseas (Financial Times, October 25, 1999)

again be disrupted? Two conflicting scenarios are currently discussed in the industry: an *optimistic* scenario that assumes a two to three years period of price increases, and a *pessimistic* one that highlights factors that are pushing for renewed excess capacity.

*Optimistic scenario*

The extended downturn in the DRAM market between 1996 and early 1999 has severely restricted new facility investment: almost all major players have reduced substantially their investment; there have also been many closures of existing plants. The typical gestation period for major new wafer fabrication facilities is two to three years. This implies that supply will lag behind demand, once the latter starts to grow again. Depending on the strength of demand growth, this gap could last for a number of years.

Earlier described changes in the sources of demand provide a second cause for optimism. SC demand in the PC industry has been relatively sluggish, which indicates that this industry may have lost its dominant position as the engine of growth for the SC industry. The main drivers of SC sales are new Internet-related devices (e.g., cellular phones, networking equipment, and TV set top boxes), and car electronics. For instance, the demand for hand-held Internet devices is projected to almost double from 6.6. million units in 1998 to 13 million in 2000 (IDC data, September 1999). A proxy for the mismatch between constrained capacity expansion and vigorous demand growth is the so-called “supply ratio” which measures operational production capacity relative to demand. For DRAM devices, this ratio has fallen to 81 by July 1999. The supply ratio is projected to drop to 61% in 2000, and to fall to 43% in 2003, just before the start of the next capacity renewal cycle (Figures are courtesy of Dataquest, August 1999).

This has already led to renewed attempts to stabilize the global DRAM oligopoly. Take the changing attitude of Korea, which well before the crisis, had become an accepted member of the global oligopoly. As one of the world`s four semiconductor powers, Korea is a member of the World Semiconductor Council (WSC), established in April 1997 to reduce the high volatility of the industry`s business cycle. It is also a signatory to the Information Technology Agreement (ITA), signed in March 1997 with the objective of reducing non-tariff barriers and of strengthening intellectual property rights. Korea´s membership in the global oligopoly is also reflected in a growing participation in international cooperation agreements. For instance, the three major Korean SC producers have participated in the American “13001 project” to develop the next-generation semiconductor wafers (with a diameter of 300mm) and related equipment, as well as in Japan`s “J300 project”. All of this indicates that, while the crisis has pushed Korea into an aggressive price slashing strategy, this may only be a temporary aberration. Given its dominant market position, Korea´s interest is now more on the side of the industry incumbents, whose aim is to establish a stable global oligopoly.

In case this *optimistic* scenario materializes, East Asian producers, and especially the two Korean giants (Samsung and Hyundai) are well placed to benefit. Due to their earlier heavy capacity investments, which as we saw, lasted until 1997, Korean DRAM producers have now in place some of the most advanced fabrication lines, that are efficient enough to cope with prices in the $ 4-5 range[67]. Once prices increase, this will provide them with substantial windfall profits, over and above those that result from the evolving supply shortage.

*Pessimistic Scenario*

It would however be naïve to place all one's bets on this outcome. We already discussed some factors that may counter the current trend towards scarce capacity. More specifically, the following industry-specific developments could well disrupt the current surge in DRAM prices. First, PC sales have slowed down substantially, especially for cheaper ones. This reflects serious supply bottlenecks for major PC components, which has led to massive price increases. As PC vendors cannot increase their sales prices, they would face huge losses if they would try to buy in the required component volumes. Instead they could reduce production and sales volumes, hoping that this may restore their margins[68].

Second, all major PC vendors have rushed into longer-term supply contracts. A typical example is Compaq`s five-year supply contract for memory chips with Micron Technology, the fourth largest global DRAM supplier. This follows a similar wave of long-term supply contracts for DRAM as well as computer displays, where both Apple and Dell have linked up with Samsung. Those Asian firms that become members of such "Preferred Suppliers Clubs", will obviously benefit; those suppliers however who are left out from this privileged circuit, may well be driven from the market. Third, PC vendors have also responded with changes in motherboard design that reduce the number of required memory devices. This ties in nicely with the trend towards integration at the circuit level. Fourth, major producers have quickly responded to the surge in DRAM demand with new investment in production capacity. This is especially so for Korean producers, who are swamped with unexpected windfall profits that are available for long-planned, yet delayed projects. Furthermore, a number of modern wafer fab facilities have been mothballed during the crisis, and can now be ramped up again at short notice. Fifth, the introduction of 12-inch wafers, which is expected for 2002, will also increase supply, as it allows to produce a greater number of chips per wafer.

Finally, additional constraints to the growth of semiconductor demand have emerged during the third quarter of 2000: There are clear signs of demand saturation, not only for PCs (which was to be expected), but also for internet-related semiconductor applications (which comes as a big surprise). For instance, demand for flash memories and specialized devices for networking equipment, which has boomed until September, has slowed down considerably since then. It is too early to judge whether the latter developments represent only a temporary downward blip, or whether demand for these

[67] Note however that, by November 2000, spot market prices for 64Mb DRAM have fallen to US-$ 3 (see table 17).
[68] This would obviously require some degree of oligopolistic collusion, or, to put it more nicely, joint capacity planning. This may well be feasible today, given the extremely high degree of concentratíon (see Ernst, 2000, IEBM)

devices will soon gather momentum again. In any case, the abrupt fall of SC demand from internet-related applications clearly indicates the growing volatility of the SC cycle.

### 4.4. The Challenge: Moving Beyond the Commodity Trap

Given the uncertainty of the SC industry`s medium term outlook for capacity and prices, what does this imply for East Asia`s upgrading perspectives? In order to capture these implications, we need to distinguish particular product markets and market segments. Of critical importance is the distinction between "commodities" like DRAM and higher-end "differentiated products", like flash memories, microprocessors, digital signal processors (DSP), application-specific integrated circuits (ASIC), and so-called "systems-on-a-chip" devices.

In what follows, we confront upgrading perspectives for commodities (4.4.1.) and differentiated products (4.4.2.). We then discuss implications for competitive dynamics and upgrading strategies at the firm level (4.4.3.). Our analysis centers on three propositions. First, for commodities, periodic surplus capacity and price wars are likely to prevail despite increasing concentration. If true, this would be a perplexing finding that contradicts some basic propositions of traditional *industrial organization* analysis. According to Richard Lipsey (2000), "most I.O. theory is about competition in prices, quantities (short run) and capacity (long run) when in fact the competition that really matters, and that drives firms´ successes and failures, is competition in technologies (very long run). …(This) has led to increasingly fierce competition among oligopolistic firms even when there are only a few in any one industry."

Second, the length and intensity of business cycles can differ *within* the same product market. We will illustrate this for the market for computer memories, where we compare DRAM, the commodity-type workhorse for the PC industry, with flash memories, the much more design-intensive storage devices for mobile phones, hand-held computers and Internet devices. Finally, the distinguishing feature for differentiated products is a much lower exposure to deflationary pricing pressures. This is in line with our stylized model in part 1. It is true even for highly concentrated product markets like microprocessors.

### 4.4.1. Commodities: Surplus Capacity, Price Wars, and Concentration

#### i) Pricing trends

DRAM are a primary example of high-tech *commodities* that are prone to periodic surplus capacity and price wars. A recent study by the Bureau of Economic Analysis (BEA) of the Department of Commerce [69] shows that each type of chip has a typical life-cycle pattern for prices and quantities: For a particular type of memory chip, quantities of shipments begin with small numbers, grow to a peak, and then decline to insignificant

[69] Reported in **Grimm, 1998**. Most of the price and quantity data that are used in that study were purchased from Dataquest, a commercial consultancy firm. Some early-year price and quantity data for some types of memory chips were provided by IBM.

numbers. Unit prices are initially very high, then decline - rapidly at first and then less rapidly - to reach a low range, and finally tend to increase as the chip nears the end of its lifespan. One important finding is that the lows for unit prices may coincide with peak shipment rates, but this is not necessarily so - there may also be a lag of several years.

Overlaying these periodic price cycles, there has been a dramatic long-term price decline: According to the U.S.-Semiconductor Industry Association (SIA), one megabyte of DRAM, which cost $2500 in 1980 when there was a global shortage of memory chips, now sells for a bout $1. While billions of dollars have been invested into developing new DRAM generations with higher data storage capacities, unit prices keep tumbling. It is unlikely that this will change. There are strong forces that tend to increase the periodic boom-and-bust cycle of the market for traditional commodity-type devices like low-end, standard DRAM devices. One is the high volatility of demand growth for such devices, which makes it impossible to synchronize supply expansion and demand growth. Of equal importance however are fundamental characteristics on the supply side that are bound to increase concentration.

### ii) Increasing Concentration

Commodity-type products like DRAM experience increasing concentration, because economies of scale and scope coexist with highly volatile income streams. The former result from a combination of very high investment thresholds (a new chip factory now costs up to $2 billion), the long lead time for implementation (typically two years from decision to full production), and extended learning curves. Income streams vacillate between high profits during periods of supply shortage and heavy losses during capacity glut. Only very large, capital-rich companies can bear such risks. Concentration is also bound to increase because surplus capacity and price wars periodically squeeze profits, sometimes to the bare minimum (Ernst, 1983, chapter I): second-tier producers retreat, and the remaining firms engage in strategic partnering, and/ or mergers and acquisitions. Over time, this has increased the semiconductor industry´s concentration.

Surprisingly however, increasing concentration has not reduced the industry`s exposure to persistent surplus capacity and deflationary pricing pressures. There is a paradoxical logic at work: overcapacity enables mergers, but mergers do not automatically lead to a reduction of surplus capacity[70]. Equally puzzling is the impact on market volatility. The trade press is full of predictions of an irreversible trend towards a tight oligopolistic market structure. Yet, there is sufficient evidence to indicate that this may not happen. Let us take a closer look at revenue and market share data. The last two rows of **Table 17** document an increasing degree of concentration, which however is not unduly high. **(Table 17)**

A very different picture emerges however for DRAM, the archetypal high-tech commodity. **Table 18** displays an extremely high and increasing concentration. The crisis

[70] For a theoretical treatment, see Ernst, 2000c. The car industry apparently is faced with a similar puzzle (see, e.g., Sturgeon and Florida, 1999).

has substantially increased the concentration (see the last two rows of the table): six business groups now control almost 88% of the world market, up from 67.1% in 1998). Even more important is that the four top firms now control more than two thirds of this market, up from 50.8% in 1998.**(Table 18)**

An important source of such high concentration has been a recent M&A wave. In Japan, NEC and Hitachi have joined forces to share the costs and risks of the next generation of DRAM chips. Due to declining capital expenditures, the new group however has failed to expand its market share. In Korea, Hyundai has acquired LG`s semiconductor operations as part of the "Big Deal" restructuring arrangements imposed by the government. When the acquisition took place, Hyundai hoped that the combined group would become the world largest DRAM supplier. This hope however soon had to be abandoned: Hyundai Electronics has been dramatically weakened by the financial restructuring of the Hyundai group that may well lead to its complete break-up. Samsung has clearly forged ahead, based on substantial advantages in product development, patent portfolio and productivity (yields). This reflects its first-mover advantages relative to Hyundai: it has been in the chip business for much longer[71].

Of greatest interest for our purposes however are recent developments in the US, where Micron Technology is now the only big DRAM producer, after buying Texas Instruments` memory chip operations. The combined group has succeeded to become the world´s largest DRAM producer, overtaking both Samsung and Hyundai, and the once almighty Japanese market leaders. This is a somewhat ironic development. While DRAM originated in the U.S., with Intel being the early market leader, American firms were beaten off the market by the Japanese (during the 1980s), who then had to give way to the Korean chaebol (during the late 1990s). Now it seems that the industry has moved back full circle, with an American company recapturing world market leadership. Micron`s two main advantages are a superior access to capital and leadership in efficient production. The irony is that, before the crisis, it was precisely these two features that had catapulted the Korean chaebol into market leadership positions.

There are however also counter-vailing developments. For commodities, and especially DRAM, some major producers (especially Japanese ones) now rely more on outsourcing in East Asia, especially in Taiwan and Singapore. This has facilitated the entry of Taiwanese and Singaporean firms into the DRAM market. These new entrants are certainly not strong enough to block the powerful trend towards increasing concentration. Their presence however makes a difference: these new entrants are not members of the *Club*, i.e. the global oligopoly, and hence do not necessarily share the incumbents` interest in price stabilization during periods of capacity glut. In other words, despite growing concentration and a comeback of an American producer, DRAM markets are likely to remain volatile, and periodic surplus capacity and price wars will not go away any time soon.

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[71] Again and again we find that path dependency matters: it is very difficult to overcome "first mover advantages" through "leap-frogging" For an early analysis of the barriers to technological leap-frogging, see Ernst and O´Connor, 1989, chapter II. On "first-mover advantages", see Chandler, 1990.

### iii) Impact on capacity

Increasing concentration through M&A is unlikely to produce capacity reduction. Its immediate effect has been to intensify existing specialization patterns, and to give rise to new capacity investment races. The main reason is that scale economies increase in importance, the fewer competitors survive. Take the example of Samsung Electronics. The main purpose of its new facility in Hwasung, Kyunggi Province, is to expand production beyond the capacity available at its Kihung complex. The new plant will use leading-edge 300-mm wafer processing technology, to produce memory devices. Earlier statements had claimed that this new facility would be dedicated to upgrading into more sophisticated devices, primarily SOC (= system-on-chip) and non-memory devices. But those claims are now given much less prominence. In short, capacity expansion rather than product diversification appears to be the primary concern.

Another factor which is likely to preserve for some time Korea´s heavy emphasis on DRAM are current geographic concentration trends in the location of manufacturing. The redeployment of DRAM manufacturing to a few volume manufacturing sites in East Asia, which has started since the early 1990s, will continue. Rather than involving FDI, much of this in fact will increasingly rely on outsourcing to leading-edge OEM suppliers and silicon foundries in Korea, Taiwan and Singapore. Korea is well placed to benefit from this trend, based on its earlier strategy of aggressively building-up production capacity. Time and again, we find that it does not make sense to paint things in black-and-white. The positive side is that a continuous reliance on DRAM exports can create some breathing space for Korea´s diversification into higher-end non-memory devices. The dark side however is that this temporary relief may well reduce the pressure again to proceed with the necessary restructuring and industrial upgrading.

### 4.4.2. Differentiated Products

With increasing market volatility and downward pricing pressures from DRAM and other commodity devices, semiconductor firms are under tremendous pressure to upgrade into higher-end, design-intensive devices. Their great attraction is a generally much stronger demand growth, driven by powerful new applications, such as the internet and cellular phone markets. It is important to emphasize that entry into these product markets is not easy, as proposed in our stylized model. Technological complexity is one important reason. Of even greater importance is that some differentiated products are characterized by high entry barriers that may result in heavy concentration. High concentration prevails for instance for flash memories and microprocessors. The situation may be different however for products that have been introduced only recently, like for instance SOC devices. For the latter markets, concentration is relatively low, and we find a large number of specialized producers. Let us take a closer look at such product-specific differences.

### i) Microprocessors

Since 1997, Intel`s dominant position has been strengthened: its share in the global SC market has increased to almost 20% today from 15.9% in 1997. This is in contrast to earlier expectations that the shift to low-priced PCs would erode its market leadership. Instead, two of Intel`s main competitors are now in deep trouble. National Semiconductor has just withdrawn from the microprocessor market, selling its struggling Cyrix unit to Via Technologies of Taiwan (Ernst, 2000f). While no direct challenge to Intel, Via Technologies provides an interesting example of how an electronics firm from East Asia can upgrade into microprocessors and penetrate this market from the sidelines. Based on Cyrix microprocessor design, Via Technologies has now launched an aggressive strategy to define a new market segment between low-cost computers and dedicated information appliances. Priced between $ 199 and $ 499, these devices will offer web-browsing and email as well as other common computing functions such as word processing.

And AMD, the most effective and persistent challenger of Intel, is also in turmoil, with its president forced out after the company announced a net loss of $162 million for the second quarter of 1999. This clearly indicates that upgrading possibilities for Asian semiconductor producers into this market segment are very limited.

### ii) Flash memories

These are lightweight storage devices for mobile phones, hand-held computers and Internet devices that retain memory when power is switched off. Flash memories pose much more demanding design requirements than DRAM; they are also more difficult to mass produce. The resultant high entry barriers have led to a high degree of market concentration: Intel dominates, followed by a handful of other American, Japanese (Fujitsu), and European companies (especially STMicroelectronics).

In 1997 and 1998, demand was flat, and prices were falling, stifling new investment. This drastically changed, in response to the exploding demand for mobile personal devices. Global demand for flash memories jumped by 50% from 160 m units in the fourth quarter of 1998 to 240m units in the third quarter of 1999. This has resulted in a drastic price increase: the price of an 8 Mb flash memory chip has doubled to about $4. In value terms, the market for flash memories has increased by 30% from $2.49bn in 1998 to $3.24bn; for 2000, it is forecast to grow by another 25% to $ 4bn. This has resulted in a huge increase in profitability for the dominant flash memory producers, providing them with ample cash for R&D and entry deterrence strategies.

### iii) The rise of system integration at the circuit level

Probably the most important change is the rise of "systems-on-a-chip" devices. Due to its relatively recent emergence, this market is still up for grabs, and concentration is low. Early entrants include Motorola, LSI Logic and National Semiconductor from the

US; Philips (through its acquisition of VLSI Technology[72]), and ST Microelectronics from Europe; Samsung from Korea; and NEC, Fujitsu, Hitachi and Matsushita from Japan.

There is a widespread move towards integrating memory, logic and other circuit types on to one silicon chip. A typical example is Motorola, which plans to tap its portfolio of 50,000 chip designs, including the Power PC microprocessor to compile a huge catalogue of modules and components for building a variety of dedicated "systems-on-a-chip". This strategy is complemented by acquisitions. Take for instance Motorola`s acquisition of General Instrument, a leading supplier of technologies that combine interactive digital TV, Internet and voice services over high-speed networks (Financial Times, September 16, 1999: p.22). The main purpose of this acquisition is to strengthen Motorola`s leadership in integrated communications solutions, "embedded" on a circuit, that are required for high-speed integrated data, video and voice services.

The rise of system integration at the circuit level will drastically change the semiconductor industry: higher levels of chip integration will reduce the number of chips required per system. Only the most complex systems will need more than a couple of chips. Many products, such as advanced digital telephones, will just have one. This will substantially reduce the demand for semiconductors in unit terms. Producers obviously expect that this will be compensated by an increase in unit chip prices. Whether or not this will happen, remains to be seen.

### 4.4.3. Implications for Competitive Dynamics and Upgrading Strategies

We have seen that for commodity-type markets, increasing concentration does not reduce market volatility and possible excess capacity. Downward pricing pressures continue. At the same time, differentiated products provide substantial upgrading possibilities. Due to high entry barriers, however, East Asia's entry possibilities are limited. The basic laws of competitive dynamics will shape upgrading strategies at the firm level, both with regard to the organization of production and knowledge management.

#### i) Competitive dynamics

Overall, there is a clear trend towards a *two-tier* structure of the SC industry, leading to a bifurcation of markets into "commodities" and "differentiated products". The industry has reached a stage where specialization determines competitive success or failure. There are now two classes of SC producers: those that heavily depend on DRAM face extreme volatility, irrespective of their earlier success in yield improvement, while companies fare much better that have diversified into higher-value-added, design-

[72] Whether this hostile acquisition will work is an open question in light of the dismal performance of earlier hostile take-overs in this industry, where key personnel simply left the acquired company and started up a new company.

intensive devices. East Asian producers so far play only a marginal role in these knowledge-intensive and high-value-generating products.

Market bifurcation is reflected in the highly unequal development of market shares and profit performance of SC firms. **Table 17** documents that product specialization is largely responsible for a firm`s growth and competitive success: only firms with a strong position in non-memory devices, such as Intel, Philips, ST Microlectronics and Siemens, were able to increase both revenue and market share. During 1998, global revenues in seven of the top 11 manufacturers fell by at least 14% - these are all firms that continue to rely heavily on DRAM and other memory devices. Four of the top SC producers however bucked the trend, all of them with a strong position in non-memory devices.

### ii) Implications for upgrading strategies

This has important implications for firm behavior. Take organization of production. The move from today`s single function semiconductors to integrated SOC (="system-on-a- chip") devices necessitates a drastic change from a highly complex "mass production"system to "flexible mass customization" (e.g., Deyo, et al, 2000). This poses extraordinary challenges for East Asian producers.

Especially Korean chaebol will find it very difficult to make this transition, due to the deeply entrenched structural weaknesses of their development model, that we have analyzed in part 2. Taiwanese and Singaporean firms, on the other hand, may have better chances, due to a combination of accumulated learning from a fairly long participation in global production networks (GPN) and sophisticated industrial policies that emphasize the development of flexible domestic support industries (e.g., Wong, 2000; and Ernst, 2000a).

Equally important changes are required in knowledge management (**Table 19).**

Commodities (like DRAM) are characterized by stable and predictable technological trajectories. East Asian producers, and especially the Korean chaebol have learned to cope with the resulting technological learning requirements. For differentiated products, like SOC devices, Asian producers must cope with very different requirements that are unlikely to match with their existing economic structures and institutions. Differentiated products face abrupt trajectory-disrupting innovations. The main challenge is to excel in complex circuit and system design. This requires close interaction with users, especially sophisticated "lead users"[73] in the US, Japan and Europe. It also requires strong system engineering capabilities.

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

Let us take a closer look at Korea´s post-crisis upgrading requirements in the semiconductor industry. The most important upgrading requirement is to increase the share of non-memory devices. Before the crisis, the Korean government had planned to increase the non-memory production ratio from 10% to 50% in the year 2010. A shift of such magnitude requires far-reaching and coordinated changes in the development of core technologies, the required infrastructure, the necessary production equipment, and in the curriculum for engineers and technicians. This cannot be achieved at short notice. Even without the crisis, a change in the product composition away from memories thus would have been painstakingly slow.

So far, the crisis has failed to act as a catalyst for change. Semiconductors, especially DRAM, continue to dominate Korea´s electronics exports after the crisis. The share of SC increased from a bit more than 30 % in 1993 to almost 46% in 1995, falling off to 40.3% in 1996, the year when the most recent DRAM price crash started. After the crisis, the 1998 export share of SC has increased by almost 6 % to more than 45%, making it by far the most dynamic driver of the country´s electronics exports. Most recent figures for 1999 confirm the lead role played by SC exports. However, its share has declined again to around 38 % during the first half of 2000 (computed based on EIAK data).

Most of these exports consist of DRAM, with SRAM following as a distant second. This clearly indicates a *sticky* product specialization. Apparently, the crisis has increased Korea´s dependence on this particular product group during 1998. Once recovery set in during 1999, this brought a return to the pre-crisis levels of specialization. In short, nothing much has changed in Korea´s sticky product specialization described in part 2 of this chapter. Exporting more of the same at lower prices has been the first response to the crisis. Since mid-1999, the Yen appreciation provided provided additional opportunities for Korean DRAM exporters, reducing the pressure for product diversification[74].

Substantial cuts in investment and R&D budgets are an additional post-crisis constraint to successful product diversification. The gradual introduction of Anglo-Saxon governance structures will reduce the availability of patient capital (Shinn, 2000). This brings us back to a fundamental dilemma: The crisis has increased industrial upgrading requirements. At the same time, it has also drastically reduced the growth of the resources that are needed to implement such upgrading. Take R&D spending (Kim, 2000). Measured in Won, Korea´s total R&D expenditures declined by 7% during 1998. However, as international sourcing of knowledge becomes an increasingly important part of R&D (e.g., Ernst, 2000e), it is more important to look at R&D figures denominated in US-dollars: the latter declined by almost 26% (from US-$ 12.8 billion to US-$ 9.5 billion).

[74] Since mid-1999, the Yen appreciation has become again a major boon to Korean SC exports. It has forced Japanese DRAM exporters into the defensive: they cannot cut their export prices in line with the increase in the value of the Yen. They responded by cutting back investment and production volumes, and by increasing their reliance on OEM.

Equally noteworthy are important changes in the sources of R&D funding: during 1998, leading chaebol drastically cut their R&D budgets by about 13%. The government tried to compensate for part of this fall by raising its share in total R&D from 23% in 1997 to 27% in 1998. But, given the overwhelming importance of corporate R&D funding, this clearly failed to stem the decline in resources available for innovation. According to a survey by the Korea Industrial Technology Association (KITA), corporate R&D has only reached its pre-crisis level in May 1999. Research staff of corporate research centers has been cut by 7% since the beginning of the crisis, giving rise to a quite substantial brain drain, primarily within East Asia.

There are however also signs of hope. The crisis of the chaebol, combined with more vigorous promotion by the government of small-scale venture businesses has significantly increased the number of such firms. This could help to improve the efficiency of Korea´s private knowledge management (e.g., Lee Keun and Sungsoo Kim, 2000). It is however unclear how many of these firms have survived the dramatic fall in the KOSDAQ share price index since the summer of 2000, where most of these firms have been registered.

Finally, there are signs that the crisis has acted as a catalyst for reforming Korea´s innovation system. Kim (2000: 11-12) for instance documents an increase in granted patents, indicating a qualitative improvements of R&D outputs. Between 1997 and 1999, the number of patents granted more than tripled from 24,579 to 80,642. Korea now ranks second, only after Japan, in terms of intellectual property applications by local residents per population. Of greater importance is what happened to U.S. patents granted to Koreans: they almost doubled from 1,891 in 1997 to 3,679 in 1999. Note however that Samsung Electronics alone accounts for 42% of U.S. patents granted to Koreans, up from 31% in 1997. This indicates a disquieting increase of concentration in R&D output.

## CONCLUSIONS

By focusing on East Asia´s electronics industries, this study has highlighted substantial structural weaknesses in the real economy. A stylized model of "industrial upgrading" (IU) has helped to identify primary causes for the pre-crisis crash in the region´s electronics exports. It also helped us to explain the delay of post-crisis trade adjustment. Moreover, the model provides a sense of how demanding the task is to move beyond the commodity trap: shifting to higher value-added products and production stages through increasing specialization and "industrial deepening" necessitates a strong domestic knowledge base. This is especially difficult in knowledge-intensive and highly globalized industries like electronics, where markets and technologies keep changing rapidly, increasing competitive pressures and uncertainty. We have demonstrated these challenges in detail for semiconductors, especially DRAM.

While the crisis could have acted as a powerful catalyst for "creative destruction", removing barriers to industrial upgrading, we have seen that apparently little upgrading has occurred thus far. This preliminary finding however needs to be thoroughly tested, once systematic data sets become available across the region on changes in the product composition of electronics production and trade, and on the development of the domestic knowledge base. It is already clear however that there is a need for public policy response. We conclude by spelling out some generic policy suggestions that could facilitate both continuous trade adjustment and longer-term, industrial upgrading[75].

For Asian economies, the challenge is to broaden their domestic knowledge base and generate specialized capabilities. This cannot be left to market forces alone. Markets are notoriously weak in generating knowledge and capabilities, as both are subject to "externalities": investments are typically characterized by a gap between private and social rates of return (K. Arrow, 1962). Reducing this gap requires corrective policy interventions that provide incentives, as well as the necessary infrastructure, support services and human resources.

While the neo-classical concept of "market failure" provides a rationale for policy intervention, it is of limited value for designing its contents (Lipsey, 1997). A fundamental weakness of this concept is its "general equilibrium" assumption: defined as a deviation from the market clearing equilibrium under conditions of perfect competition, the remedy is to return to a theoretically achievable static optimum. It is now well accepted that perfect competition hardly ever reigns in markets that characterize modern industry. It is thus misleading to think of market failure as something that can, or should, be `remedied` so that the economy can be brought back to a desired static optimum

In any case, this concept is patently inappropriate for defining the agenda for public policy response in the context of rapid technological change (such as ICT) and globalization. Both accelerate the pace of change in markets and technology and increase uncertainty and the volatility of market structures, industrial organization and firm behavior (e.g., Ernst, 2000c). Equally important, almost all aspects of knowledge creation and learning are characterized by market failure: this is true for information and codified knowledge, and even more so for tacit knowledge. Information is difficult to trade in a market: whenever information is imperfect, "externalities" diffuse and markets incomplete, which is invariably the case with technical change, free markets cannot in principle meet the strict requirements of optimal resource allocation (Stiglitz, 1998). And "… tacit knowledge is plain market failure in the sense that it cannot, as such, be transacted in the market." (Lundvall and Borras, 1997: 49).

The result is that there is now a much greater need for public policy that goes well beyond the "market failure" rationale. This does not imply a return to the *status quo ante* of the "strong developmental state" (as suggested for instance by Wade & Veneroso, 1998). The challenge is to redefine the role of government intervention (Rodrik, 2000). The real question, then, is no longer whether national policies and institutions can make a difference. Instead, it is what kind of policies and institutions will prove most conducive for unlocking new sources of economic growth.

[75] For a theoretical treatment, see Ernst, 2000e.

Globalization, paradoxically enough, has increased the necessity of such policies. But there is also now more space for national policy and politics to vary and to make a difference. A growing body of research on economic policy-making in advanced industrial countries has demonstrated that choice is possible, in terms of institutions and policy instruments, and that this applies to macro-economic policy-making as well as to industrial and technology policies (e.g. Berger and Dore, 1996). The same is true for Developing Asia.

There is now a growing consensus that liberalization of trade and investment flows should not be equalized with a retreat of the state (e.g., Rodrik, 1999; UNCTAD, 1999). Liberalization needs to be complemented with proactive and sophisticated industrial, innovation and investment policies. Without such policies, it may well produce negative results: instead of improving allocative efficiency and growth, liberalization may increase a country's vulnerability to highly volatile international finance and currency markets; and it may divert attempts to strengthen local capabilities and innovation. As the example of small Nordic countries and the Netherlands demonstrate, the scope for pro-active technology and industrial policies in a liberal ownership regime is far greater than commonly assumed. Taiwan, Singapore and recent developments in Korea also illustrate that a variety of approaches is possible to such policies, involving a variety of interesting hybrid combinations. The choice is much larger than normally assumed.

## Generic Principles

The following *generic* principles can help to delineate key components of such policies. There is a broad consensus that monetary and macroeconomic stability is of the essence to provide appropriate incentives for investment and innovation. These fundamentals are a necessary, but not sufficient condition for economic growth. Equally important are sector-specific policies that take into account the peculiar requirements of particular industries, as well as the strengths and weaknesses of sectoral production, support and innovation systems, as documented in Mowery and Nelson (1999: 377). This study has provided ample evidence for the necessity of such non-neutral, sector-specific policies.

A third important generic policy principle is that competition policy is of critical importance (e.g., OECD, 1999b and 2000; Mowery and Nelson, 1999): firms will only invest in productivity-enhancing technology, learning and innovation if competition and regulatory reform force them to do so. Competition may also help to lower costs, say access charges for telecommunications and internet services - a key factor in the diffusion of knowledge. Fourth, implementing such policies however poses daunting political and administrative challenges. Combining liberalization with sustained industrial upgrading requires fundamental changes in the objectives and policy instruments, and a deep understanding of the global competitive dynamics. Not less, but actually more knowledge and expertise are required in the public sector of sectoral specificities, rather than a sector-neutral and minimally active policy stance. It requires an understanding of the widely varying technological properties of specific industries, the logistical and strategic concerns of multinational businesses, the fundamental transformations in the organization of their global production networks, and the rapidly evolving international investment environment.

Finally, this raises a fundamental dilemma. On the one hand some degree of stability must exist in policies and institutions: without such stability it is very difficult to mobilize resources and to provide incentives for learning and industrial upgrading. On the other hand, globalization, combined with ICT, imposes disruptive changes on the very same institutions and policies. While the latter may have been successful during certain periods, for instance for rapid catching-up, they may well become barriers at a later stage. Any attempt to preserve the *status quo ante* of institutions and policies in the context of rapid change and increasing uncertainty is likely to constrict learning and innovation that are necessary for industrial upgrading.

In short, continuity needs to be combined with continuous adaptation in institutions and policies. It is obviously very difficult to achieve the right balance. Change however should be constrained by the need to build on accumulated capabilities. "Big Bang" change, which discards the latter, often involves prohibitively high opportunity costs; it may also destroy social consensus, i.e. the most fundamental prerequisite for economic development.

**Table 1. Specialization-Upgrading Matrix**

| Variables | Complexity/Uncertainty | |
|---|---|---|
| | Low | High |
| **Product specialization** | **Homogeneous (commodities)**<br>• mature technology<br>• established design<br>• easy to replicate<br>• predictable changes in demand & tech<br>• limited interactions with customers | **Differentiated**<br>• new technology<br>• fluid design<br>• difficult to replicate<br>• unpredictable changes<br>• close interaction with customers |
| **Process Spec`n** | **Mass Production**<br>• economies of scale & scope | **Flexible Specialization**<br>• speed of response |
| **Market Structure** | • low entry barriers<br>• price competition<br>• limited value generation: periodic over-capacity & price wars ⇒ deflationary pricing pressures | • high entry barriers<br>• premium pricing<br>• significant value generation |
| **Upgrading Potential** | • limited technological learning requirements<br>• limited pressure to develop forward & backward linkages | • substantial pressure to broaden & deepen local knowledge base<br>• ditto for linkages |

**Table 2. A Decline in the Growth of East Asian Electronics Exports, 1992-1998 ($million; %)**

| Growth (%) | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|
| Korea | 5.8 | 6.7 | 23.7 | 35.5 | -3.3 | 6.5 | -6.7 |
| Taiwan | 10.3 | 10.9 | 15.4 | 32.4 | 8.5 | 10.5 | 1.4 |
| Singapore | 16.9 | 25.1 | 45.0 | 26.2 | 5.6 | 0.0 | -10.9 |
| Malaysia | 24.4 | 30.4 | 37.8 | 31.2 | 5.7 | 2.6 | -4.1 |
| Thailand | 25.7 | 16.1 | 40.3 | 29.3 | 12.6 | 8.9 | |
| Philippines | | | | | | 29.2 | 31.7 |
| China | | 21.5 | 49.6 | 36.0 | 9.1 | 23.6 | 13.6 |

**Table 3. Korea´s Semiconductor Exports, 1992-1996 (US-$ m; % growth)**

| | 1992 | 1993 | 1994 | 1995 | 1996 | Annual growth Rate (%) 1992-95 |
|---|---|---|---|---|---|---|
| Exports | 2,784 | 4,591 | 7,582 | 14,602 | 10,680 | |
| Growth | - | +64 | +65 | +93 | -31 | +74 |

Computed from data provided by Korea Semiconductor Industry Association (KSIA)

**Table 4. Singapore's Electronics Industry: Average Growth p.a., 1960-1997**

| Average. Growth p.a. | Output Electronics Industry | Total Mfg. |
|---|---|---|
| 1960-70 | 32.4 | 23.6 |
| 1970-80 | 34.2 | 23.3 |
| 1980-90 | 18.0 | 8.5 |
| 1990-95 | 15.7 | 9.7 |
| 1960-95 | 26.1 | 17.0 |
| 1996 | 8.9 | 3.0 |
| 1997 | 3.1 | 4.3 |

Source: calculated from EDB, January 26, 1998, Annex 2; and Reed Electronics Research, 1998

**Table 5 Share of Components (Semiconductors) in Electronics Imports and Merchandise Imports**

| | | Share of Electronics imports in % | | | | | | Share of Merchandise imports in % | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **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 |

**Table 6. A Decline in Korea´s Electronics Production and Exports, 1998/1997 (%)**

| Product | Production (based on current production data in Won) | Exports (based on current US-$ denominated export figures) |
|---|---|---|
| CE | -36.3 | -18.0 |
| Industrial | -20.4 | -4.8 |
| Components∗ | -22.8 | -9.3 |
| Semiconductors | -13.8 | -2.4 |
| Total | -21.4 | -6.7 |

Source: EIAK. ∗ = EIAK´s definition of *components* excludes semiconductors. This differs from the definition in the trade data used in this study, where *components* include semiconductors.

**Table 7. Price Declines for Korea´s Semiconductor and Component Exports 1998/1997, US-$, (% decline)**

| | 1997 | 1998 | |
|---|---|---|---|
| Monitors (15``) | 225 | 145 | (-35.6) |
| HDD (3.4G Byte) | 150 | 109 | (-27.3) |
| DRAM (64mb) | 17.2 | 9.8 | (-43.0) |

Source: Computed from EIAK price data

**Table 8. Trade Balances in Electronics Components**

Millions US$ **NIEs and ASEAN-4**

| Country/Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| **NIEs∗** | | | | | | | | |
| Trade Balance in Components | -6.634 | -6.541 | -4.401 | -4.885 | -3.130 | -2.111 | -548 | 1.274 |
| ditto, with Japan | -8.532 | -10.081 | -12.587 | -15.090 | -17.867 | -14.868 | -15.028 | -11.961 |
| **ASEAN-4∗** | | | | | | | | |
| Trade Balance in Components | -2.462 | -2.516 | -1.660 | -5.820 | -6.606 | -4.164 | -4.537 | |
| ditto, with Japan | -2.681 | -3.596 | -4.747 | -6.574 | -8.690 | -9.018 | -7.802 | |
| **ASEAN-3 (excl.Philippines)** | | | | | | | | |
| Trade Balance in Components | -1.929 | -1.907 | -983 | -5.048 | -5.914 | -2.641 | -1.801 | -2.013 |
| ditto, with Japan | -131 | 338 | 1.565 | -43 | -71 | 2.209 | 1.693 | -141 |

∗ = NIEs here include Korea and Taiwan, while ASEAN-4 includes Singapore, Malaysia, Thailand, and Philippines

**Table 9. Bilateral Electronics Exports and imports with East Asia: US and Japan, 1991-1998 (US$ billion)**

| | | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|---|
| | **Telecom** | | | | | | | | |
| US | Exports | 0.4 | 0.5 | 0.7 | 1.0 | 1.1 | 1.2 | 1.5 | 1.2 |
| | Imports | 1.5 | 1.7 | 1.7 | 2.0 | 2.2 | 3.6 | 3.8 | 4.0 |
| Japan | Exports | 1.0 | 1.2 | 1.5 | 1.8 | 1.5 | 1.3 | 1.5 | 1.1 |
| | Imports | 0.2 | 0.2 | 0.3 | 0.5 | 0.8 | 1.1 | 1.0 | 0.9 |
| **Consumer Electronics** | | | | | | | | | |
| US | Exports | 0.7 | 1.0 | 1.3 | 1.7 | 2.3 | 2.1 | 2.3 | 1.2 |
| | Imports | 7.9 | 9.3 | 10.3 | 13.1 | 13.8 | 11.5 | 12.1 | 13.3 |
| | Balance | -7.3 | -8.3 | -9.0 | -11.5 | -11.5 | -9.4 | -9.8 | -12.1 |
| Japan | Exports | 5.6 | 6.0 | 6.0 | 6.5 | 5.8 | 4.4 | 4.2 | 3.1 |
| | Imports | 1.3 | 1.6 | 2.0 | 3.0 | 4.5 | 4.8 | 4.4 | 3.9 |
| | Balance | 4.3 | 4.5 | 4.0 | 3.5 | 1.3 | -0.3 | -0.3 | -0.9 |
| | **EDP** | | | | | | | | |
| US | Exports | 2.7 | 2.8 | 3.2 | 4.0 | 5.7 | 6.2 | 6.9 | 6.1 |
| | Imports | 11.4 | 14.5 | 18.8 | 23.4 | 31.1 | 35.4 | 40.3 | 42.5 |
| | | **1991** | **1992** | **1993** | **1994** | **1995** | **1996** | **1997** | **1998** |
| US | **EDP** | | | | | | | | |
| | Balance | -8.7 | -11.8 | -15.6 | -19.4 | -25.5 | -29.2 | -33.4 | -36.5 |
| Japan | Exports | 3.0 | 3.2 | 3.9 | 4.7 | 5.7 | 6.5 | 7.0 | 5.8 |
| | Imports | 1.3 | 1.5 | 2.3 | 3.6 | 8.3 | 10.5 | 9.9 | 9.0 |
| | Balance | 1.7 | 1.7 | 1.7 | 1.0 | -2.6 | -4.0 | -2.8 | -3.1 |
| | **Electronic components** | | | | | | | | |
| US | Exports | 7.8 | 8.6 | 10.7 | 13.6 | 17.3 | 17.9 | 22.3 | 21.6 |
| | Imports | 10.0 | 11.8 | 14.8 | 19.6 | 28.4 | 29.1 | 31.0 | 30.0 |
| | Balance | -2.2 | -3.2 | -4.1 | -6.1 | -11.2 | -11.2 | -8.7 | -8.4 |
| Japan | Exports | 14.3 | 16.8 | 21.3 | 27.8 | 36.7 | 33.5 | 33.5 | 28.4 |
| | Imports | 3.2 | 3.5 | 4.4 | 6.5 | 10.4 | 10.9 | 10.9 | 9.7 |
| | Balance | 11.1 | 13.4 | 16.8 | 21.3 | 26.3 | 22.6 | 22.6 | 18.7 |
| | Balance | -21.5 | -27.5 | -32.9 | -42.9 | -54.2 | -56.1 | -57.8 | -65.1 |
| Japan | Exports | 28.2 | 31.9 | 38.3 | 47.1 | 57.8 | 53.4 | 54.1 | 44.0 |
| | Imports | 7.0 | 7.8 | 10.3 | 15.4 | 26.7 | 30.1 | 29.4 | 26.3 |
| | Balance | 21.2 | 24.1 | 28.0 | 31.7 | 31.2 | 23.4 | 24.7 | 17.7 |

**Table 10. Share of Electronics Exports to East Asia (exclusive of Japan) out of Total Electronics Exports (%)**

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| Korea | 21.1 | 25.4 | 25.1 | 27.6 | 29.8 | 32.0 | 34.3 | 36.2 |
| Taiwan | 21.1 | 22.9 | 26.2 | 28.7 | 29.7 | 28.6 | | |
| Sing`e | 25.6 | 26.3 | 29.8 | 36.4 | 37.1 | 37.2 | 38.2 | 35.8 |
| Malaysia | 34.8 | 34.2 | 33.2 | 34.9 | 35.2 | 38.4 | 38.0 | 33.1 |

**Table 11. Korea Direction of Electronic Exports, 1991-1998 (%)**

| Share/Year | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| US | 32.4 | 32.8 | 33.0 | 31.4 | 30.3 | 27.3 | 26.1 | 26.4 |
| Mexico | 2.0 | 2.3 | 2.5 | 2.8 | 1.6 | 1.7 | 2.0 | 1.7 |
| Japan | 9.8 | 8.8 | 9.6 | 11.1 | 12.7 | 10.7 | 10.1 | 8.5 |
| EU-15 | 19.8 | 16.7 | 15.2 | 13.8 | 14.0 | 14.7 | 16.8 | 17.8 |
| East Asia | 21.1 | 25.4 | 25.1 | 27.6 | 29.8 | 32.0 | 34.3 | 36.2 |
| US&EU-15 | 52.2 | 49.5 | 48.2 | 45.1 | 44.3 | 42.0 | 42.8 | 44.2 |
| US&EU-15&Japan | 62.0 | 58.2 | 57.8 | 56.2 | 57.0 | 52.8 | 52.9 | 52.7 |
| East Asia & RoW | 38.0 | 41.8 | 42.2 | 43.8 | 43.0 | 47.2 | 47.1 | 47.3 |

**Table 12. East Asia's Share of Korea's Electronics Export**

| | 1991 | 1992 | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 |
|---|---|---|---|---|---|---|---|---|
| Electronics, total | 21.1 | 25.4 | 25.1 | 27.6 | 29.8 | 32.0 | 34.3 | 36.2 |
| Consumer electronics | 6.6 | 9.2 | 12.4 | 15.6 | 17.0 | 20.1 | 22.7 | 20.6 |
| Components | 35.8 | 40.0 | 36.6 | 36.5 | 37.5 | 40.2 | 42.2 | 44.6 |
| Semiconductors | 41.1 | 46.6 | 39.7 | 36.7 | 36.3 | 39.0 | 41.2 | 44.4 |

**Table 13. Changes in the semiconductor market, 1998 - 2000**

| | 1998 | 1999 | 2000 |
|---|---|---|---|
| SC Total Sales Revenues (value, $bn) | 124.6 | 141 (Return to 1995 peak) | 232∗ |
| Growth, SC Total (p.a., %) | - 9<br>- 5<br>(Excluding DRAM) | +12 | + 15 |
| Memory, Total (value, $bn) ( % Growth) | | 28.6<br>(+24) | 38.5<br>(+ 35) |
| DRAM, total (Value, $bn) | 14∗∗ (Down from $41bn, 1995) | 18,7 | 27.4 (52.1 Projected for 2003) |
| Growth, DRAM Sales Revenues (p.a., %) | -26 | + 33 (First increase in four years) | (Proj. P.A. Sales Growth ≥ 25% 1999 - 2002) |
| Flash Memories Total (value, $bn) | 2.49 | 3.24 | 4.00 |
| Major growth Markets | | "Systems-on-a-Chip", MPU, DSP & ASIC | "Systems-on-a-Chip", MPU, DSP & ASIC |

Source: computed, based on data provided by Semiconductor Industry Association (SIA),EIAK, and KSIA.
∗ = Projection for 2003
∗ ∗ = Share of DRAM in the total SC world market has fallen from 25 % in 1995 to 10%.

**Table 14. Trade specialization profiles: RCA and leading export products. 1993-1998**

**Country/Specialization**

| | Share of Electronics in Merchandise exports (%) | | | | | | | RCA | | | | | | | Share in Electronics exports (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | '93 | '94 | '95 | '96 | '97 | '98 | | '93 | '94 | '95 | '96 | '97 | '98 | | '93 | '94 | '95 | '96 | '97 | '98 |
| | | | | | | | EDP | 0.9 | 0.8 | 0.8 | 0.9 | 0.9 | 0.7 | EDP | 14.4 | 11.9 | 12.2 | 14.5 | 15.5 | 13.9 |
| Korea | 28.0 | 29.7 | 30.9 | 28.8 | 29.2 | 28.3 | Storage | 0.2 | 0.3 | 0.4 | 0.7 | 1.3 | 1.1 | Storage | 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 | COMP | 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 | SC | 30.4 | 37.2 | 45.7 | 40.3 | 42.9 | 45.3 |
| | | | | | | | Consumer Elec | 2.3 | 2.4 | 2.0 | 2.0 | 1.7 | 1.5 | Consumer Elec | 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 | Telecom | 3.0 | 2.7 | 2.4 | 2.4 | 2.1 | 1.9 |
| Taiwan | 29.5 | 31.0 | 34.3 | 35.8 | | | EDP | 2.5 | 2.7 | 3.0 | 3.4 | | | EDP | 39.4 | 39.0 | 41.6 | 45.0 | 44.62 | 45.29 |
| | | | | | | | Storage | 0.3 | 0.3 | 0.5 | 0.6 | | | Storage | 0.8 | 0.6 | 1.0 | 1.3 | 2.10 | 1.97 |
| | | | | | | | COMP | 1.9 | 2.0 | 2.1 | 2.2 | | | COMP | 37.2 | 39.3 | 41.6 | 40.2 | 41.93 | 40.86 |
| | | | | | | | SC | 1.6 | 1.8 | 2.0 | 2.2 | | | SC | 13.7 | 16.8 | 20.4 | 19.6 | 22.05 | 21.77 |
| | | | | | | | Consumer Elec | 1.4 | 1.5 | 1.2 | 1.1 | | | Consumer Elec | 12.9 | 12.0 | 8.5 | 6.8 | 6.42 | 5.98 |
| | | | | | | | Telecom | 1.7 | 1.7 | 1.6 | 1.6 | | | Telecom | 4.9 | 4.8 | 4.1 | 4.0 | 3.59 | 4.20 |
| Singapore | 53.0 | 58.8 | 60.7 | 60.7 | 60.6 | 61.4 | EDP | 4.6 | 5.1 | 5.1 | 5.4 | 5.5 | 5.2 | EDP | 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 | Storage | 17.6 | 15.7 | 16.0 | 18.8 | 19.3 | 19.8 |

**(Cont.) Table 14. Trade specialization profiles: RCA and leading export products. 1993-1998**

**Country/Specialization**

| Country | Share of Electronics in Merchandise exports (%) '93 | '94 | '95 | '96 | '97 | '98 | | RCA '93 | '94 | '95 | '96 | '97 | '98 | | Share in Electronics exports (%) '93 | '94 | '95 | '96 | '97 | '98 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | COMP | 2.7 | 3.4 | 3.4 | 3.6 | 3.7 | 3.7 | COMP | 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 | SC | 15.7 | 19.4 | 23.8 | 23.9 | 25.0 | 27.4 |
| | | | | | | | Consumer Elec | 3.1 | 3.2 | 2.9 | 2.9 | 2.3 | 1.7 | Consumer Elec | 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 | Telecom | 1.9 | 1.9 | 1.6 | 1.3 | 1.1 | 1.1 |
| Malaysia | 47.6 | 52.5 | 54.9 | 54.7 | 55.8 | 57.5 | EDP | 1.4 | 1.8 | 2.0 | 2.3 | 2.9 | 3.0 | EDP | 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 | Storage | 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 | COMP | 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 | SC | 30.5 | 28.3 | 29.8 | 29.3 | 30.1 | 30.7 |
| | | | | | | | Consumer Elec | 4.2 | 5.0 | 5.1 | 5.0 | 4.1 | 3.5 | Consumer Elec | 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 | Telecom | 3.8 | 4.0 | 3.2 | 3.3 | 3.1 | 2.8 |
| Thailand | 20.8 | 24.0 | 24.9 | 28.4 | 29.6 | | EDP | 1.4 | 1.8 | 1.9 | 2.4 | 2.5 | | EDP | 32.2 | 34.0 | 36.8 | 41.4 | 40.9 | |
| | | | | | | | Storage | 2.8 | 5.4 | 4.6 | 4.5 | 2.0 | | Storage | 9.8 | 15.5 | 14.0 | 11.9 | 6.2 | |
| | | | | | | | COMP | 1.4 | 1.5 | 1.5 | 1.6 | 1.6 | | COMP | 38.4 | 38.8 | 39.9 | 36.5 | 35.8 | |
| | | | | | | | SC | 1.7 | 1.6 | 1.4 | 1.6 | 1.7 | | SC | 20.8 | 19.3 | 19.5 | 18.8 | 18.3 | |
| | | | | | | | Consumer Elec | 1.3 | 1.6 | 1.4 | 1.5 | 1.7 | | Consumer Elec | 16.7 | 16.4 | 13.3 | 12.0 | 13.1 | |
| | | | | | | | Telecom | 1.2 | 1.1 | 1.0 | 1.2 | 1.2 | | Telecom | 5.2 | 3.9 | 3.7 | 4.1 | 3.9 | |

**Table 15. Geographic Dispersion of Semiconductor Production 1990-2000 (% share of world total)**

| | 1990 | 2000 |
|---|---|---|
| North America | 28 | 31 |
| Japan | 39 | 23 |
| East Asia | 14 | 25 |
| Europe | 19 | 21 |

Sources: computed from data provided by Dataquest and U.S. Semiconductor Industry Assoc.

**Table 16. DRAM Spot Market Prices, 1999-2000 (US-$)**

| Year/Device | May | August | Sept 1 | Sept 22 | Nov 1999 | Nov 2000 |
|---|---|---|---|---|---|---|
| 64Mb | 4 | 10 | 12 | 20 | 12.5 | 3<br>8 (for 128 Mb) |

**Table 17. Revenues and Market Share: Top Ten World Semiconductor Companies**

| Rank (last year) | Revenue of shipment ($bn) | | %change 1998/97 | Market share (%) | |
|---|---|---|---|---|---|
| | 1997 | 1998 | | 1997 | 1998 |
| 1 (1) Intel | 21.8 | 22.8 | +4.8 | 15.9 | 18.3 |
| 2 (2) NEC | 10.2 | 8.2 | -19.5 | 7.5 | 6.6 |
| 3 (3) Motorola | 8.1 | 7.1 | -12.1 | 5.9 | 5.7 |
| 4 (5) Toshiba | 7.3 | 5.9 | -18.5 | 5.3 | 4.7 |
| 5 (4) TI | 7.4 | 5.8 | -20.8 | 5.4 | 4.7 |
| 6 (7) Samsung | 5.9 | 4.7 | -19.0 | 4.3 | 3.8 |
| 7 (6) Hitachi | 6.3 | 4.7 | -25.9 | 4.6 | 3.8 |
| 8 (9) Philips | 4.4 | 4.5 | + 0.2 | 3.2 | 3.6 |
| 9 (10) STMicro-electronics | 4.0 | 4.2 | +4.5 | 2.9 | 3.4 |
| 10 (12) Siemens | 3.4 | 3.9 | +13.6 | 2.5 | 3.1 |
| **Total** | **136.9** | **124.6** | **-9.0** | | |
| Market Share of Top Five (%) | - | - | - | 29.2 | 32.0 |
| Market Share of Top Ten (%) | - | - | - | 42.0 | 46.3 |

Source: Computed from data provided by Dataquest

**Table 18. World market share, DRAM producers, 1998 - 2000(%)**

| Firm | 1998 | 1999/2000 |
|---|---|---|
| 1 (3) Micron Technology | 9.2 | After acquiring TI, the group has aggressively expanded to become market leader in 2000 |
| 2 (1) Samsung | 20.1 | Strengthens position relative to Hyundai, but declines relative to Micron |
| 3 (2)Hyundai | 12.4 | After acquiring LG, the group has lost market share. High debt limits its capacity to invest |
| 4 (4) NEC | 9.1 | After merging with Hitachi, the group`s 1999 market share has remained constant |
| 5 (6)Toshiba | 7.9 | |
| 6 (7) Mitsubishi | 6.9<br>(strong links with Taiwanese firms) | |
| | | |
| (5) LG Electronics | 8.4 | |
| (8) Hitachi | 6.5 | |
| Other | 22.5 | |
| Market share of top six firms | 67.1 | 87.5<br>(1999) |
| Market share of top four firms | 50.8 | 66.4<br>(1999) |

Source: Computed from data provided by Dataquest, IDC, VLSI Research, EIAK, KSIA, and various business newspapers

**Table 19: Product composition and Knowledge Management in the Semiconductor Industry**

| | Technological Learning Requirements |
|---|---|
| **Commodities (DRAM)** | ∗ Stable & predictable technological trajectory<br>∗ complex manufacturing process ⇒ steep learning curve<br>∗ Experience-based tacit knowledge critical for rapid ramping-up & yield<br>∗ broad patent portfolios as bargaining chip for cross-licensing |
| **Higher-end differentiated products (“Systems-on-a-chip”, MPU, DSP and ASIC)** | ∗ abrupt trajectory-disrupting innovations<br>∗ main challenge: complex design requirements<br>∗ close interaction with users ⇒ strong system engineering capabilities |