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Catching-Up and Post-Crisis Industrial Upgrading: Searching for New Sources of Growth in Korea's Electronics Industry

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I. INTRODUCTION

Until the Asian crisis began to unfold during the fall of 1997, there was widespread consensus that Korea had consolidated a mix of institutions and policies that were conducive to rapid development and to catching up with the most advanced economies. Korea´s achievements had been impressive: within three decades a resource-poor and relatively small country at the periphery of the world economy became a leading exporter of manufactured products. No developing country exceeded Korea in the speed with which it expanded and transformed its manufacturing sector. Yet the Asian crisis illuminated a series of structural weaknesses that were already exerting profound pressures on the Korean model of development. The question confronting observers today is whether the Korean model of late industrialization has failed: are industrial policies no longer viable? Is there no alternative to convergence with the Anglo-American model of capitalism (KEI, 1999)? How can growth be sustained in the future? Answers to these questions depend on how one explains the crisis, and indeed on how one defines the Korean model. Whereas most observers of the crisis stress its financial aspects (Stiglitz, 1997; Veneroso and Wade, 1998; and Krugman, 1998), there has been a tendency to *neglect the contribution of underlying structural weaknesses in the real economy*. Those weaknesses are the focus of this chapter.

A central proposition of the chapter is that the economic structures and institutions that were conducive for catching-up in a particular context could not foster the capabilities necessary to guarantee sustained growth. The crisis has further exacerbated the situation: it has dramatically increased the need for *industrial upgrading*, while at the same time constraining financial resources needed to bring this about. Attempts to return to the *status quo ante* will not provide a solution; nor will success be achieved through the IMF's approach, with its focus on financial reform and a shift to Anglo-Saxon corporate governance structures. *Industrial upgrading,* defined as substantial changes in a country´s *specialization* and *knowledge base* that increase its capacity for rent generation (Ernst, 2000a**)**, constitutes the medium-term challenge that Korea must master in order to establish new sources of growth. *Industrial upgrading* needs to *complement* the current emphasis on financial and corporate restructuring. We present this argument through an account of the *electronics industry*, Korea´s most prominent example of rapid catching-up[i].

A novel contribution of the chapter is its analysis of how *limitations* inherent to the Korean model of late industrialization[ii] account for a *lack of flexibility* and *truncated upgrading*. The focus is on the role of economic institutions, and the co-evolution of policies, industry structure and firm behavior.[iii] The analysis centers on three basic limitations of the Korean model that result from a symbiotic relationship between governments and large business groups, the *chaebol*: i) an extremely *unbalanced industry structure* gave rise to ii) a *narrow knowledge* base, and iii) a *sticky specialization*. Catching-up has focused on expanding capacity and international market share for *homogeneous, mass-produced* products such as TV sets, monitors, DRAM and displays (*commodities*); very little upgrading has occurred into higher-end and rapidly growing

market segments for *differentiated* products and services that require *flexible production* (e.g., design-intensive ICs and computer products, software and Internet services). We label this pattern "truncated upgrading" and find it to be one of the principal reasons for Korea´s vulnerability to the financial and currency crisis.

Part I of the chapter describes key features of the Korean model that were responsible for rapid catching-up in the electronics industry. Part II addresses important structural weaknesses that existed well before the crisis. We review evidence on Korea's *sticky specialization* on *mass-produced commodities*, and its *narrow domestic knowledge base*, key causes of weak flexibility and truncated upgrading. We then discuss possible explanations, focusing on the role played by Korea's *unbalanced industry structure*. In both sections, comparisons with Japan and Taiwan highlight some peculiar features of the Korean model, and consideration is given to the impact of the crisis on economic governance and on prospects for growth. The chapter concludes with a brief discussion of changes that are necessary to overcome barriers to industrial upgrading. We sketch out one possible option for strategic response to the current crisis: an upgrading from product to technology diversification that broadens Korea´s knowledge base, and at the same time utilizes its traditional strengths in "quick follower mass production."

Catching Up in Electronics: Key Features of the Korean Model

Korea is arguably the most successful example of rapid catching-up in the global electronics industry, as well as the most controversial: although it leads Asian producers in its share of the global electronics market, Korea´s unprecedented *speed* of entry into high-risk and very demanding precision component manufacturing, such as DRAM and displays, may signal the limits of what is possible. Indeed, peculiar features of the *Korean model*, such as a heavy reliance on guided credit and industrial policies, and an industry structure dominated by a handful of chaebol, have invited heated debates about its strengths and weaknesses.

Korea´s success has been based on a development model that combines *international linkages* with a dense, almost *symbiotic relationship* between the *government* and the *chaebol*. This approach reflects the nature of the challenge facing Korea when it entered the international electronics markets in the late 1960s. Its main concern mirrored that of the Japanese electronics industry in the early 1950s: to master as quickly as possible those types of production technology that would enable it to capitalize on low labor costs while also reaping economies of scale. Logically, this implied a focus on rapid expansion of capacity and market share for commodity-type products, primarily through *exports*. Given the limited knowledge and capability base available during this period, the growth of the Korean electronics industry had to occur primarily on the basis of *foreign* technology. The effective absorption of the latter, however, required pro-active investment, industrial and technology policies.

The Catalytic Role of Foreign Direct Investment (FDI)

Despite the widespread perception, promoted by "statist" theories (e.g., Haggard, 1990; Hikino and Amsden, 1992), that FDI played only a minor role in the Korean model of development, electronics exports started to take off only when Korea became a final export platform for a handful of U.S. semiconductor firms (Ernst, 1994b: chapter 3). This was made possible by the early willingness of the Korean government to shift to export promotion. Combined with tough labor legislation and the ruthless suppression of labor conflicts, the Electronics Industry Promotion Law of 1969 and the opening of the Masan Free Export Zone in 1970 contributed to a positive foreign investment climate in the industry. The main attractions for foreign electronics companies were Korea's cheap female labor and the incredibly long annual work hours, together with policies favorable to the promotion of export manufacturing.

By opening export channels for assembled chips and for simple consumer devices, FDI played a catalytic role during the critical early phase of the development of the Korean electronics industry. In 1972, foreign firms, of which there were eight, accounted for about a third of Korea´s electronics production and 55 % of its exports; their share in exports fell below 40% only in 1980 (Bloom, 1992). FDI also exposed Korean workers and managers to new organizational techniques, which, while not necessarily "best practice," contributed to a gradual erosion of highly authoritarian traditional Korean management practices, with their inherent rigidities and inefficiencies. Cost-cutting and the need to comply to some minimum international quality standards undoubtedly gave rise to some limited indirect learning effects related to the formation of basic operational capabilities for final assembly, logistics and facility management (Ernst, 1983:156-166).

A key feature of Korea's catching-up in electronics is that, since the mid-1970s, a shift occurred in the center of gravity away from foreign to local actors. This was due to a number of factors that reflect the changing international investment environment as well as policy design.[iv] In semiconductor assembly, for instance, American firms became increasingly attracted by new, low-cost locations in the Philippines and Malaysia, and gradually shifted most of their assembly activities to these two countries. As their capital costs kept rising, these companies were keen to reduce their equity involvement and began to shift to much looser forms of contract assembly, subcontracting and OEM arrangements (Ernst, 1997c). In contrast to the U.S. firms' reliance on foot-loose offshore assembly, most Japanese firms concentrated on factory automation at home and gradually withdrew from offshore assembly activities both in Korea and Taiwan (Ernst, 1997a).

The Korean government imposed increasingly demanding requirements on foreign firms to contribute to local value-added and to increase the transfer of technology. By creating fears of a possible "boomerang effect" through involuntary technology leakages, this probably accelerated the withdrawal of foreign firms, which simultaneously faced rising competition from the increasingly powerful chaebol. Confronted with the alternative to either upgrade their existing investments beyond the

stage of assembly -- and to do so in cooperation with the chaebol -- or to shift production elsewhere within East Asia, most foreign firms chose the second option.[v]

Symbiotic Ties Between Government and Chaebol

Korean government policies played an important role in shaping the competitive strengths and strategies of Korean electronics firms. The defining element was the unusually close and symbiotic relationship between the "developmental state" that determined national industrial strategy and huge family-owned conglomerates, the chaebol. The latter's strategies were shaped by two closely related state policies: "infant industry" protection and "directed credit."

Korea made frequent use of selective "infant industry" protection as part of its industrialization strategy, especially in the electronics industry. Import protection enabled producers in a new industrial sector like electronics to exploit learning economies, while export incentives provided the opportunity to reap scale economies not available in the domestic market. Meanwhile, a rich arsenal of "directed credit" instruments was a hallmark of Korea´s industrial policy: access to subsidized credit and tax privileges was coupled with strict performance requirements. The development of Korea´s electronics industry fits the pattern of large-scale, capital-intensive latecomer industrialization described by Gerschenkron (1962): easy access to large amounts of patient debt capital was a critical source of competitive strength for the Korean chaebol. Korea´s heavy reliance on "guided credit" led to a disproportionately high debt[vi], which sets it apart from Taiwan, where companies have relied much more on equity markets and corporate retained earnings[vii]. Table 6.1 documents that debt-equity ratios in Korea have been consistently and substantially higher than in Taiwan[viii].

Table 6.1 Debt-Equity Ratios in Korea and Taiwan: 1985 - 1998

	1985	1998
Taiwan	120	30
Korea	350	180

Source: SBC Warburg Dillon Reed

This development model worked extremely well, as long as the goal was to catch-up, and as long there was no dependence on highly volatile, short-term capital flows. It succeeded in channeling Korea´s large household savings into investments that produced an incredibly fast expansion of industrial manufacturing capacity and international market share.

International Technology Sourcing

The Korean way of building technological capabilities in the electronics industry resembled the Japanese model most closely in its utilization of foreign technology. Rather than allowing foreign firms to establish local subsidiaries and determine the speed

and scope of technology diffusion, the government encouraged some of the leading chaebol to focus on learning and knowledge accumulation through a variety of links with foreign equipment and component suppliers, technology licensing partners, OEM clients and minority joint venture partners. The goal was to become *quick, lower-cost followers* for *standard, mass-produced products*.

By licensing well-proven foreign product designs and by importing most of the production equipment and the crucial components, Korean electronics producers were able to focus most of their attention on three areas[ix]: i) the mastery of production capabilities, initially for assembly, but increasingly for related support services and for mass production; ii) some related minor change capabilities, ranging from "reverse engineering" techniques to "analytical design" and some "system engineering" capabilities that are required for process re-engineering and limited product customization[x]; and iii) a capacity to ramp up new production lines quickly and at low cost.

The heavy reliance on international technology sourcing enabled Korean electronics firms to reverse the standard sequence of technological capability formation (Dahlman, Ross-Larson and Westphal, 1987). Rather than proceeding from innovation to investment to production, they focused on the ability to operate production facilities according to competitive cost and quality standards. Through "reverse engineering" and other forms of copying and imitating foreign technology, and by becoming integrated into increasingly complex global production networks of American, Japanese and some European electronics companies, Korean electronics firms were able to avoid the huge cost burdens and risks involved in R&D and in developing international distribution and marketing channels[xi].

Rapid expansion of capacity and international market share would have been impossible had Korean firms tried to start off with a more integrated production system. OEM arrangements have proven to be one of the most cost-effective methods for acquiring core capabilities in production and investment (Ernst and O'Connor, 1989). OEM arrangements provide the supplier with a high volume of business, which permits the realization of scale economies. The often tedious and grueling qualification process that any potential supplier has to complete successfully in order to compete for contracts opens up a variety of learning possibilities with regard to business organization and the use of technology. In addition, customers often provide technical assistance in engineering and manufacturing processes in order to ensure quality and cost efficiency.

OEM arrangements, however, can also have substantial drawbacks (Ernst and O´Connor, 1992). A firm may become "locked into" an OEM relationship to the extent that it is hindered from developing its own independent brand name recognition and marketing channels. Profit margins are substantially lower in OEM sales than in own brand name sales, which in turn makes it difficult for Korean companies to muster the capital needed to invest in R&D that eventually might lead to the introduction of new products. This constraint is of limited importance, as long as sales volumes through OEM

contracts are large and fairly predictable so that, despite low profit margins, total earnings may be substantial. But despite the optimism of many observers during the late 1980s, accumulated technological and organizational capabilities were not sufficient to enable Korean producers to move easily beyond OEM. Rather, the transition to original brand name (OBN) strategies has been exceedingly rough. After years of heavy advertising and PR promotion, Korean electronics firms must still contend with an image that their products are of inferior quality and reliability. Product development is still conceived mostly in terms of incremental improvement of a given foreign product design. Heavily reliant on OEM manufacturing, Korean companies are very much followers of the latest product designs developed elsewhere, mostly in Japan. Korean firms have a weak capacity to develop new designs and to gather early on the most relevant information about new market trends and customer preferences.[xii]

Strategic marketing continues to play a marginal role in the Korean innovation process. The goals of innovation are set by the established foreign benchmark firms. Almost no attempt has been made until very recently to identify undiscovered customer needs and to use this knowledge to develop new markets. It should be mentioned however that, over the last few years, all three chaebol active in consumer electronics have identified this passive acceptance of foreign product designs as a major barrier to sustained competitiveness. Since the crisis, there is widespread experimentation with organizational reforms that are expected to strengthen the link between strategic marketing and innovation management. Much of these attempts are frustrated, however, by the trend toward corporate restructuring arrangements that follow a purely financial logic (author`s interviews, September 1999).

The Case of Semiconductors

The essence of the Korean model becomes clear when we look at semiconductors (SC), the crown jewel of its electronics industry. The pace and scale of the capacity and market share expansion of Korea´s semiconductor industry is without precedent. Never before has a country been able to move so rapidly from the position of an insignificant outsider to that of market leader in a highly capital-intensive industry saddled with incredibly high risks and entry barriers. How was it possible that Samsung, together with LG and Hyundai, were able to enter the DRAM market at record speed and to erode the once seemingly watertight grip that a Japanese oligopoly had imposed over this industry since the mid-1980s? Of critical importance was Korea's approach to technological learning[xiii]. A first characteristic of this approach was a willingness and capacity to spend huge amounts of money on investment and technology acquisition. Between 1983 and 1989, the three chaebol are reported to have invested more than $4 billion on production equipment. And while catching-up is already quite costly, keeping-up and getting ahead leads to an even higher fixed capital cost burden. Thus, annual capital spending increased from $800 million in 1987 to an estimated $1.8 billion in 1993, constituting more than 20% of the world's total semiconductor facility investment in that year.

A second important prerequisite of Korea's successful entry into semiconductors

was a specific, three-pronged approach to *international technology sourcing.* This included: i) early establishment of subsidiaries in Silicon Valley as listening posts for intelligence gathering on technology and market trends. These subsidiaries were also used for R&D activities that complemented similar efforts at home; ii) a pervasive reliance on "second-sourcing" agreements, in which the chaebol were licensed by leading U.S. and Japanese semiconductor producers to manufacture some of their DRAM designs; and iii) *silicon foundry services* provided for leading American ASIC (application specific integrated circuit) companies, such as LSI Logic and VLSI Technology. Based on the gate array or standard cell designs received from these foreign companies, the chaebol used their strength in process technology and their capacity to rapidly improve yields to produce such devices at short notice. Being forced to comply to the stringent design rules typical for ASIC devices, the chaebol thus were able to deepen their knowledge about necessary process improvements.

More recently, there has been a tendency to combine these different individual approaches into somewhat broader *package* deals aimed at *cross-technology-sharing.* As the chaebol expanded their share in international DRAM markets, they were able to strengthen their bargaining position with regard to licensing agreements. The result is that today cross-licensing and mutual patent swaps link all of the chaebol with the leading Japanese and American semiconductor producers. More and more, the chaebol are involved in *international technology sourcing networks*, which include links with other firms (*inter-firm* networks) and attempts to tap into key elements of the national innovation systems of other countries (*inter-organizational* networks) (Ernst, 1997b). These networks now typically cover a great variety of arrangements, ranging from second-sourcing and fabrication agreements to technology licensing and cross licensing, patent swapping, joint product or technology development, the exchange of researchers and guest engineers, and standard coalitions. Technology acquisition approaches pursued by Korean semiconductor producers have experienced major changes, moving from the "reverse engineering" of licensed chip designs to much broader and increasingly *systemic* forms of international technology sourcing.

Advantages and Limitations of the Catching-up Model

It is important to emphasize that Korea`s successful catching-up in the electronics industry was based on *limited* and *achievable* technological learning requirements. One must 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. As discussed below, the main constraining factor remains a narrow specialization concentrated in mass-produced, commodity-type products. Knowledge creation has been confined largely to operational production capabilities of a fairly conventional, mass production type. While this approach originally constituted the country’s chief advantage, making possible a quick late entry into global markets, it also engendered fundamental structural weaknesses that act today as barriers to industrial upgrading in Korea.

II. Pre-Crisis Weaknesses: Barriers to Industrial Upgrading

Exogenous and Endogenous Factors

In 1996, before the crisis, Korea experienced a dramatic export crash, leading to a substantial current-account deficit and a dramatic slowdown in growth.[xiv]. This decline was especially prominent in the electronics industry, and affected all major Asian producers (Table 6.2). Korea displayed the most dramatic fall: after extremely rapid growth in 1994 (+ 24%) and 1995 (+35.5%), its 1996 exports fell by more than 3% in US dollar terms. First and foremost this reflects Korea´s heavy reliance on SC, and in particular DRAM, both of which have been subject to intense deflationary pricing pressures since 1996.

Table 6.2. 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

Two types of causes for the export crash can be distinguished: *external* causes driven by changes in the international economy, and *internal* ones that reflect structural features peculiar to the Korean model. External causes are relevant, and Korea confronted a substantially more hostile international environment: in 1996, the fall in world export growth from its cyclical peak in 1995 was the largest in 15 years -- from about 20% to about 4% in US dollars in just one year (World Bank, 1998). Much of this was due to accumulated excess capacity in the electronics industry (Ernst, 2000c). The sharp depreciation of the yen in 1995 further compounded this negative impact, especially so for Korea, whose export structure is similar to Japan´s. In 1996, Japan´s imports from Korea fell by 8.5%.[xv]

Of greater importance for our purposes were the *endogenous* barriers to industrial upgrading. These impediments reflected peculiar features of Korea´s successful catching-up strategy which limited opportunities to increase flexibility: an *extremely unbalanced industry structure* led to a *narrow knowledge base*, and a *sticky pattern of specialization*. Easy access to large amounts of patient debt capital 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. Korea's successful entry into the electronics industry was a forced march to develop a *mass production* capacity that could serve *high-growth export markets* for *homogeneous* products. In the process, there occurred very little upgrading into higher-end and rapidly growing market segments for *differentiated* products and services.

Upon deciding to enter a sector, the chaebol normally move in on a massive scale and in a highly integrated manner. By channeling funds at concessionary terms to a handful of *chaebol*, the state has created powerful domestic oligopolies. Korea´s extremely *unbalanced* industry structure has spawned a peculiar form of competition strategy: firm growth has occurred through *octopus-like diversification* into many different and unrelated industries rather than through an accumulation of knowledge through industrial upgrading. The narrow domestic knowledge base that results has made it difficult to move up the ladder of specialization.

A narrow specialization and limited learning requirements were ideally suited to the original task of overcoming overcome latecomer disadvantages. A focus on commodities was the only realistic entry possibility - it guaranteed access to rapidly growing and relatively open markets. *Homogeneous* products are based on widely accessible and mature technology and are thus easy to replicate. This allows for *limited* and *achievable* technological learning requirements. At the same time, changes in demand patterns are fairly predictable, and interactions with customers play a role only at the margin. Market entry thus essentially depends on the availability of patient capital. In the case of DRAM for instance, very high investment thresholds have been the main entry barrier.

This development model worked well as long as major export markets kept growing rapidly. This is no longer the case, however, and the result is over-capacity and price wars, as well as a dramatic increase in the country's exposure to debt. A narrow specialization on commodities reduces the scope for rent generation (*the commodity price trap*): commodities such as DRAM are prone to *deflationary* pricing pressures, which result from periodic over-capacity and price wars (Ernst, 2000c). Commodities also display a limited upgrading potential, in terms of technological learning requirements, as long as key inputs are imported. A heavy reliance on imported inputs fosters an *inverted industry pyramid*: a rapidly growing mass production sector is based on a very weak base of domestic support industries. Concentration in industrial commodities thus fails to provide sufficient pressure for improving the domestic knowledge base, a weakness that has now become a major barrier to a continuous industrial upgrading. A narrow domestic knowledge base constrains necessary improvements in specialization, and indeed may constitute a recipe for *immiserising growth* - an increase in economic activity which results in lower per capita incomes[xvi].

Sticky Specialization

Specialization is an important indicator of the degree of *industrial upgrading* that

a country has achieved. Industrial economists (e.g., Baumol, Panzer and Willig, 1982; 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 taxonomy is based on two criteria: the complexity of technology, and the characteristics of demand. It is argued that different market structures will result from these different product compositions and production processes. For differentiated products, for instance, firms can charge premium prices, while for homogeneous products, price competition is the over-riding concern. A similar distinction is made for production processes: flexible production is linked to premium pricing, and mass production to price competition.

Modern growth theories have brought *technological learning* back into the analysis as a key explanatory variable (e.g., Lipsey and Bekar, 1995). It is now widely accepted that peculiar features of economic structures and institutions offer quite distinct possibilities for learning and innovation, and hence shape the economic performance of a country (Lundvall, 1992). The *economic structure determines specialization* (i.e. the product mix) and *learning requirements* (the breadth and depth of the knowledge base). *Institutions*, on the other hand, *shape learning efficiency*: they define how things are done and how learning takes place. An important concern is the *"congruence"* (Freeman, 1997:13) of different subsystems, which is necessary to create a *virtuous* rather than a *vicious* circle.

A fundamental problem of Korea´s electronics industry is a narrow and sticky *product specialization*: 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 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 6.3). 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%.

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 (FPD) 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 6.3: Trade specialization profiles: RCA and leading export products, 1993-1998

Country	Share of Electronics in Merchandise exports (%)					
	1993	1994	1995	1996	1997	1998
Korea	28,0	29,7	30,9	28,8	29,2	28,3

Special-ization	RCA						Share in Electronics exports (%)					
	1993	1994	1995	1996	1997	1998	1993	1994	1995	1996	1997	1998
EDP	0.9	0.8	0.8	0.9	0.9	0.7	14.4	11.9	12.2	14.5	15.5	13.9
Storage	0.2	0.3	0.4	0.7	1.3	1.1	0.5	0.8	1.0	1.8	4.1	4.1
COMP	2.4	2.7	2.8	2.7	2.8	2.7	50.1	56.2	62.4	60.8	62.3	63.4
SC	3.3	3.8	4.1	3.6	4.0	3.8	30.4	37.2	45.7	40.3	42.9	45.3
CE	2.3	2.4	2.0	2.0	1.7	1.5	22.5	20.5	16.1	15.6	12.8	12.7
Telecom	0.9	0.9	0.8	0.8	0.6	0.5	3.0	2.7	2.4	2.4	2.1	1.9

Sticky Specialization in Semiconductors

Korea´s semiconductor industry displays some important weaknesses: 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. In addition, the industry 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. It will be extremely difficult to reduce this dependence. Only joint production with leading overseas manufacturers is likely to help.

Probably the most important weakness of Korea´s semiconductor industry is a very *narrow* product range. The three leading Korean semiconductor producers are all heavily dependent on computer memories: 80% of Samsung's semiconductor revenues come from memories (most of them DRAMs), and in the case of Goldstar and Hyundai, this share is even higher, i.e., 87% and 90%[xvii]. Korea's competitive position in semiconductors thus remains highly fragile. This type of specialization clearly handicaps rent creation: DRAMs are the “bleeding-edge” of the semiconductor industry: they are prone to periodic surplus capacity and price wars. Current excess capacity for DRAMs is estimated to be around 40%. During 1998, 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.

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.[xviii] 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" made the chaebol among the few firms world-wide 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. 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.[xix] In other words, competition in DRAMs is of a fairly conventional nature, with size, economies of scale and first mover advantages being of primary importance.

A Narrow Domestic Knowledge Base

A second important weakness of Korea´s electronics industry is a *narrow domestic knowledge* base. This reflects the *co-evolution* of *technological learning* and *specialization* that is central to our model. Co-evolution implies that causality works both ways: a narrow specialization on commodities, which is typical for catching-up, fails to provide sufficient pressure for an improvement of the domestic knowledge base. In turn,

a narrow domestic knowledge base constrains necessary improvements in specialization.

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.[xx] Korea thus needs to broaden its knowledge base to compete in product design, market development, the design of key components and the 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[xxi]. 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, 1998c 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[xxii]. 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 (Mahmood, 1998, table 7). In terms of *patent intensity,*[xxiii] 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).[xxiv] This gap is likely to increase, as the crisis has dried up funds available for this *patent portfolio race*.

ii) Inefficiencies of corporate technology 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).[xxv] Serious problems have been detected with regard to the effectiveness of the chaebol's innovation management (e.g., Bloom, 1992; Kim Sun G., 1995; Kim Youngsoo, 1997). 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.[xxvi] 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.[xxvii] 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[xxviii]

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 serious lack of coordination among R&D programs of different ministries has wasted scarce resources. The current mechanism for setting priorities awards each ministry 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).[xxix] 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 innovation system, paradoxically enough, relates to the established educational system. Its heavy focus on the training of mid-level managers, engineers and technicians was an important prerequisite of success during the catching-up phase. Yet today, as the focus shifts to research, product design and market development, the educational system is poorly equipped to cope with these new requirements.[xxx]

In short, its earlier success has led Korea's innovation system to a series of new challenges which it is ill prepared to meet. Structural weaknesses of the system have been well known and extensively debated within the government and in management circles for some time, yet the inertia resulting from past success and established power structures have crippled Korea's ability to adapt its institutions in ways that can respond to the requirements of industrial upgrading. The search for new policy approaches and new corporate strategies remains constrained by a highly unequal distribution of economic and political power. We now turn to some of the structural causes for Korea´s truncated industrial upgrading.

An Unbalanced Industry Structure

A distinguishing feature of the Korean model is a dominance of large business groups that is unrivaled elsewhere:[xxxi] the combined sales of the five largest chaebol grew from 12.8% of GNP in 1975 to 35% in 1980 and to 52.4% in 1984 (Kim Linsu, 1993, p. 2). The chaebol dominate sales and exports; they can recruit the best workers, technicians, engineers and managers; they have privileged access to investment capital; and their strategies determine the product mix and the capabilities of Korea´s industry.

The extreme degree of concentration is a key variable that distinguishes Korea´s electronic industry from that of Japan (Kohama and Urata:1993, 152). Until recently, Korea's electronics industry was controlled by four chaebol -- Samsung, LG, Hyundai and Daewoo. In 1988, 56% of electronics production came from these four groups, with the first two alone accounting for 46 % of production (Bloom:1992, p. 12). In 1992, the total semiconductor and electronics sale of one company alone, Samsung Electronics, accounted for 20 per cent of the Korean electronics industry's exports (Dataquest, 1993). None of the big electronics groups in Japan comes close to such an overwhelming position of dominance.

Ironically, post-crisis attempts to reform the chaebol may reinforce their dominance: concentration has increased following the break-up of the Daewoo group and the Big Deal acquisition of LG`s semiconductor operations by the Hyundai group (Yoo, 1999). The Korean electronics industry retains a structure which, according to textbook wisdom, should no longer exist: a tight national oligopoly controls both domestic

production and the domestic market.

Implications for corporate strategy: "octopus-like diversification"

Korea´s unbalanced industry structure has given rise to a peculiar form of competition strategy that focuses on incessant product diversification, often into technologically unrelated areas.[xxxii] Each time a chaebol has reached the limits of "easy" capacity and market share expansion for a particular product, it moves on to a new product group that promises rapid market expansion. Such "opctopus-like" diversification has been pushed to the extreme: the top five chaebol are in an average of 140 different sectors each. No other country, not even Japan and Sweden, comes close to such an extreme reliance on unrelated diversification.

Here lies one of the most important differences between chaebol-type business strategies and those pursued by Japanese electronics firms, which typically have been reluctant to engage in product diversification. A survey of the 200 largest Japanese industrial firms (Fruin, 1992: 318) found that only 40 per cent engaged in a limited amount of diversification, with 41 per cent of new goods being in the same two-digit SIC category as the firm's established products.[xxxiii] Gerlach (1993) also has shown that Japanese diversification has resulted predominantly in the "spinning-off" of new subsidiaries that retain a certain degree of autonomy from the parent company.

"Octopus-like" diversification has had important negative implications for capability formation. The chaebol have typically used diversification as a short cut to rapid market share expansion, without much concern for the depth of the production system that can be generated by such shallow forms of diversification. This has made it very difficult for most Korean companies to accumulate systematically a broad range of technological capabilities for a given set of products. It also has also left very little scope for upgrading into higher-end market niches where premium prices could be reaped. Finally, this opportunistic form of unrelated diversification has precluded a shift to technology diversification.

A dearth of innovative small-and medium-sized enterprises (SMEs)

The pervasive role that the chaebol have played as engines of growth and industrial transformation sets Korea apart from Taiwan, where small-and medium-sized enterprises (SMEs) have been the main carriers of industrial development. Among Asian countries, Taiwan probably has made most progress towards a balanced industry structure that allows for close and flexible interaction between large business groups and SMEs: this has enabled small firms to grow and to respond quickly to changes in international markets and technology (Ernst, 1998b); it may also explain why Taiwan has been able to shield itself better than Korea from the financial melt-down that swept through much of Asia in 1997-98. By contrast, in Korea directed credit has focused consistently on the development of large domestic conglomerates. This has prevented the development of a vibrant domestic SME sector: until very recently, small, innovative

start-up companies had little chances to gain access to such credit.[xxxiv]

The lack of a vibrant domestic network of SMEs has important negative consequences for learning and specialization. A key issue is whether a firm succeeds to move beyond imitation based on reverse engineering and moves on to apprentice-type learning where a link with a foreign company provides access to both tacit and explicit knowledge (Kim Linsu (1997a, pp. 208-209). This distinction allows us to highlight an important difference in technological learning between South Korea and Taiwan. In Korea, most SMEs continue to remain stuck with a focus on imitation based on reverse engineering (Kim Linsu, 1997a, chapters 8-9). This has led to a very low learning efficiency of SMEs in Korea. The situation is radically different in Taiwan (Ernst, 1998b): especially in the computer industry, SMEs have been exposed early on to apprentice-type learning arrangements with large firms, both foreign and domestic. These relationships have strengthened significantly the flexibility of SMEs, enabling them to shift rapidly from relatively simple to increasingly complex forms of international subcontracting.

The chaebol's dominance in the electronics industry also has had a negative effect on the role of SMEs engaged in the supply of parts and components and other complementary support activities. Although formally independent, most of these firms are tightly integrated into the chaebols' vertical production networks. Until the early 1980s, this had resulted in an industry structure where the leading chaebol tended to produce almost everything in-house, from electronics components and electrical accessories to transistors, semiconductors and precision engineering parts (Wong, 1991: 53). One peculiar feature of the Korean electronics industry is that subcontractors work only for one manufacturer, and are thus locked into a fairly closed production network controlled by a particular chaebol. Small- and medium-sized suppliers have very limited decision-making autonomy, which significantly limits attempts to improve their international competitiveness.

An equally important concern is the extreme concentration of private R&D. Before the crisis, the five leading chaebol accounted for nearly 37% of Korea´s total private sector R&D investment, and the twenty leading chaebol for more than 53%[xxxv]. After the crisis, such concentration is likely to have further increased. The chaebol control the key assets and capabilities of Korea's innovation system, and science and technology decisions thus are overwhelmingly shaped by their strategies. This perpetuates Korea´s extremely unbalanced industry structure, despite recent government attempts to give greater attention to the promotion of SMEs capable of developing their own component designs and to improve the competitive conditions for innovative start-up companies.[xxxvi]

In sum, a dearth of innovative and aggressive SMEs has severely constrained Korea´s attempts to develop higher-end niche markets, one important element of industrial upgrading. This again differs markedly from the situation in Taiwan and in the Japanese electronics industry, where SMEs have played an active role in developing such

strategies. Once again the chaebol-dominated structure that created economies of scale and scope and opportunities for substantial cross-subsidization, appropriate to an era of rapid catching-up, has proven ill equipped to foster a dynamic SME sector that could provide key components and critical complementary support services to those very chaebol.

III. Conclusions: A Paradigm Shift in the Korean Model?

The *vicious* circle of *weak flexibility* and *truncated industrial upgrading* has increased Korea´s vulnerability to the turmoil in international finance and currency markets. In fact, Korea´s economy was already weakened when the financial crisis hit[xxxvii]. The exhaustion of the Korean model for catching-up has important policy implications for other developing economies. While drastic changes in the financial system are important, they need to be supplemented with changes in the real economy: a long overdue process of industrial upgrading requires institutional and policy innovations that can help to remove the barriers to greater flexibility.

Unfortunately, the crisis may have reduced the opportunity for making this move. Recent data on production, trade and market share show that very little upgrading has occurred in response to the crisis (Ernst, 2000c). Korea`s electronics industry is confronted with a major dilemma: it must upgrade its competitive position through improved product differentiation and market development capabilities, without losing its traditional strengths in mass production. In contrast to their Japanese, American and European counterparts, a medium-sized country like Korea, which only recently joined the international market, is less well-endowed to cope with the impact of globalization. As a result, head-on competition with market leaders in “high-end” applications is out of the question.

Rather than jumping directly into "technological leadership" strategies, recent research has shown that industrial latecomers may have an intermediate option, *technology diversification.*[xxxviii] Defined as “the expansion of a company´s or a product´s technology base into a broader range of technology areas” (Granstrand (1992: 291), such strategies are an attempt to reap technology-related economies of scope.[xxxix] Technology diversification differs substantially from so-called “technology leadership” strategies, which are defined by their focus on products with a high R&D content. Instead, technology diversification focuses on products which are "... based on several... crucial technologies which do not have to be new to the world or difficult to acquire" (Granstrand, 1992: 300)[xl].

For Korean electronics firms, technology diversification could have a number of important advantages. It builds on existing strengths of Korea´s approach to technological learning. As technology diversification normally goes hand-in-hand with an extensive reliance on external technology sourcing, Korean firms could make use of their accumulated capabilities in external technology sourcing, imitation and adaptive engineering. Technology diversification can also reduce the financial burden and high

debt that result from over-ambitious "technology leadership" strategies. To the extent that their expenditures on R&D will be reduced by the financial crisis, technology diversification can help Korean firms to reduce these costs, and to spread them not only over many markets (countries and segments), but also over many products. Finally, technology diversification may also help to open up new windows of opportunity for international market penetration and for the development of new market niches.

Leading chaebol claim that they have already vigorously moved into this direction. They point to a series of technology agreements with leading American and Japanese electronics producers and to a massive increase of R&D expenditures and productive investment. Since 1993, the four leading Korean electronics producers have indeed drastically increased their R&D and capital outlays; they were also planning to increase them even further before the crisis hit (Ernst, 1994b). What is important, however, is not the amount of investment expenditures per se, but their allocation among different types of products and production activities.

The real question is to what degree such investments are used to correct some of the basic weaknesses of the Korean electronics industry with regard to product specialization, the organization of production and accumulated technological deficits. Recent research (Ernst, 2000c) has shown that capital spending has been overwhelmingly concentrated on the rapid expansion of mass production lines for two products (DRAM and LCD). The huge capital spending binge of Korean electronics firms thus clearly has had the primary effect of consolidating the existing product *specialization* and production *organization*. In other words, we appear in for more of the same rather than a shift to new products and production activities

Yet a radical paradigm shift is overdue, as Korea has reached the limits of the old export-led industrialization model with its emphasis on standardized mass production, OEM exporting and catching-up. Moving beyond these limits will require fundamental changes in the *Korean model* of *economic governance*. This is true for government policies and industry structure, as well as for firm organization and strategies. There is an urgent need to redefine the role of government interventions. This does not imply a weakening of the coordinating function of the state (Chang, 1998a). Rather, overcoming the barriers to industrial upgrading necessitates a strengthening of policies and institutions that can provide the incentives and externalities for technological learning[xli]. National policy interventions are required to compensate for these market failures. In addition to the subsidies and tax incentives suggested by Arrow (1962), this also implies a variety of organizational and institutional innovations in policy implementation. A growing body of research on economic policy-making in advanced industrial countries has demonstrated that choice is possible, both in the domain of macro-economic policy-making and with regard to industrial and technology policies (e.g. Berger and Dore, 1996). This volume suggests that the same holds true for developing countries: 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 *upgrading* domestic *capabilities* and *product specialization*.

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Notes

[i] 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), and the Ministry of Commerce, Industry and Energy (MOCIE). Additional data sources include the United Nations-COMTRADE trade data base, updated to include 1998; market and production figures for electronics industries are taken from the Yearbook of World Electronics Data 1998/99, and the 1998 Yearbook of the Information Technology Industry Council, Washington, D.C.; plus author`s interviews over the last two decades.

[ii] Important sources on the Korean model include Amsden (1989), Wade (1990), Haggard (1990), Kim Linsu (1992 and 1997a), Evans (1995), and Chang (1994). Much of this literature is dominated by the *developmental state* theory. The complementary, *catalytic* role played by FDI and global production networks (GPN) is emphasized in Bloom (1992); Ernst and O`Connor (1992); and Ernst, (1994a, 1994b).

[iii] I use a conceptual framework based on evolutionary theories of innovation and the firm, e.g., Penrose (1959/1995); Richardson (1960/1990); Freeman (1982); Nelson and Winter (1982); Dosi et al (1988); and Kogut and Zander, (1993), and their application to economic development, e.g., Bell and Pavitt (1993); Nelson and Pack (1995); Lall (1997); Ernst and Lundvall (1997); and Ernst (2000a).

[iv] A weakness of "statist" theories has been their neglect of the international investment environment.

[v] As a result, Korea today has one of the lowest rates of inward investment in East Asia, even after the crisis-induced attempts by the Korean government to bring foreign investment back into the country as a vehicle for accelerated technology diffusion (Beck,1998).

[vi] Korea´s debt burden is estimated to consist of $450 billion in domestic debt, and more than $150 billion in foreign debt. The chaebol have an average debt-equity ratio of 4 to 1, and ten of the top 30 chaebol have debt-to-equity ratios exceeding five-to-one. Before the crisis, the following debt-equity ratios were reported by SBC Warburg Dillon Reed: Samsung (473 %), Hyundai (453%), LG (378%), and Daewoo (316%). Note, however that the absence of transparent consolidated accounting rules in Korea causes great confusion about effective debt-equity rations. Estimates of Hyundai`s debt-equity ratio, for instance, range from 1,378 % (excluding asset revaluations) to 341 % (the latest official estimate by Korea`s Financial Supervisory Commission).

[vii] In contrast to the Korean government which used its control of the financial sector to direct credit to a handful of chaebol, the Taiwanese government did not try to promote large national champions. Taiwan´s industrial policy focused on flexibility and competition: relatively low entry barriers and non-discriminatory policies enable small firms to enter targeted sectors and to grow. At the same time, the legal system puts relatively few obstacles in the way of bankruptcy. Thus, Taiwan´s smaller companies had

to rely more on equity markets and corporate retained earnings than did the chaebol (Ernst, 2000b).

[viii] It has been argued that such high debt is a necessary prerequisite for successful catching-up (Veneroso and Wade, 1998). However, Ernst, (1998a) demonstrates two important weaknesses in this argument: it fails to explain why debt-equity ratios are much lower among Taiwanese companies; and it fails to address some negative consequences of high debt for firm strategies and industrial upgrading.

[ix] For the underlying conceptual framework of capability formation, see Ernst, Mytelka and Ganiatsos (1998).

[x] The last two features are typically thought of as strengthening flexibility. Yet as we shall see below, Korean firms remain mired in homogenous products and mass production. Flexibility improvements thus occurred *within* the mass production paradigm.

[xi] On knowledge outsourcing through global production networks, see Ernst, 1997 b and 2000 b .

[xii] This contrasts sharply with Taiwan's PC industry, in which early access to market intelligence enables firms to accelerate speed-to-market and to continuously upgrade their products. For evidence, see San Gee and Wen-Jeng Kuo (1998) and Ernst 2000b.

[xiii] Two external factors provide the context for discussion of how the Korean way of building technological capabilities may have contributed to this success. The first is a probably unintended, yet very consequential side effect of the September 1986 U.S.-Japanese agreement on trade in semiconductors: due to the unrealistically high price floors set for DRAM imports into the United States, Korean producers were able to outprice their Japanese rivals at price levels that, in 1989, began to generate substantial profits (Ernst, 1987). A second external factor was the strategic decision of U.S. semiconductor producers and computer companies to create an alternative, low-cost source for DRAMs in Korea to tame oligopolistic pricing and supply behavior of major Japanese producers (Ernst and O'Connor, 1992).

[xiv] The magnitude of East Asia´s export slow-down 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 and turned negative for other East Asian countries, including China and the NIEs (World Bank, 1998, chapter 2). Korea´s average annual growth of exports for instance fell from 14% between 1990-1995, to 3.7% in 1995-96 and -2.4% between January and April 1997.

[xv] 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, 1998, figure 2.2., p.21).

[xvi] *Differentiated* products, on the other hand, are based on new technology whose design features are still fluid and are thus difficult to replicate. This is due to the high entry barriers that result from the substantial R&D outlays required. Close interaction with customers is a critical prerequisite for success. *Differentiated products* thus require considerable up-front preparatory efforts to enable entry. Their great advantage, however, is that once those initial hurdles have been overcome, these products provide significant rent creation and industrial upgrading potential.

[xvii] 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.

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

[xix] For an early model of the volatility of demand and recurrent periodic surplus capacities in semiconductors, see Ernst (1983, chapter I).

[xx] 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.

[xxi] Explanation for limited R&D expenditures up to that point are provided in Ernst, (1994a, chapter 4).

[xxii] 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).

[xxiii] Patent intensity is measured as the share of a country´s patent applications at the European Patent Office per 1 million inhabitants (EPAT data base, as quoted in BMBF, 1998, figures 4.3. and 5.2.).

[xxiv] 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.

[xxv] 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)

[xxvi] 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).

[xxvii] 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.

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

[xxix] *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.*

[xxx] *Higher education remains a glaring bottleneck in Korea´s technological learning. 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).*

[xxxi] The only exception is Sweden, where the Wallenberg group, through its holding company Investor, controls companies accounting for more than 40% of the Swedish market, while holding only 4 % of the capital.

[xxxii] Literally translated as "financial clique," chaebol is defined as " a business group consisting of large companies, which are owned and managed by family members or relatives in many diversified business areas." (Yoo and Lee, 1987, p. 97)

[xxxiii] The latter figure would be higher-- 46 per cent-- if the United States SIC code did not classify computers in a different category (35) from other electrical devices (36 and 38).

[xxxiv] In his important book on the dynamics of Korea´s technological learning, Kim Linsu (1997a, pp. 6 and 10) argues that : "The most serious consequence of the asymmetric promotion of chaebol was the impediment to the healthy growth of SMEs."

[xxxv] Oki, 1993, p.46. The same study found that in the U.S. and Japan the share of the 20 leading firms in total R&D investment was less than 31% and less than 37%.

[xxxvi] Most observers agree that such policies have had only limited success. A recent survey by the School of Small Business at Soongsil University indicates that 70 per cent of government-allocated credit goes to a few relatively large SMEs with strong ties with the leading chaebol through subcontracting arrangements. One particularly ironic finding is that many of these small businesses are becoming "mini-chaebol" by branching into various businesses but keeping each of the companies small to maintain access to cheap credit. (Far Eastern Economic Review, 19 November 1992, p. 70). It remains to be seen whether new policy initiatives after the crisis will succeed in breaking this deeply entrenched pattern.

[xxxvii] A survey of the Korean economy, published well before the financial crisis, states unequivocally: "The South Korean economy is heading for a crisis as the growth that sustained the country´s outward-oriented expansion over the past three decades is beginning to run out of steam." "Focus. South Korea: Trade and Investment," Far Eastern Economic Review, October 23, 1997, p.70.

[xxxviii] For a detailed analysis, see Ernst, 1999 a.

[xxxix] Japanese firms have played a pioneering role in the development of technology diversification strategies. The underlying rationale has been threefold: an attempt to compensate for the increasing constraints on their existing manufacturing exports; a deliberate strategy to develop generic technologies that could form the base for penetrating future growth markets; and finally, a reaction to the increasing technological complexity and rising R&D cost of new products (Odagiri and Goto (1992)).

[xl] Empirical research on Japanese, U.S. and Swedish companies has demonstrated the relevance of this strategy: it has shown that "...technological coexistence is more predominant than technological substitution, as seen from the larger number of old technologies in a current product generation, compared to the number of obsolete technologies (Granstrand (1992), p. 305.).

[xli] Markets are notoriously weak in generating technological learning. They are subject to externalities: investments in capabilities are typically characterized by a gap between private and social rates of return (Arrow, 1962).