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Institutions and Knowledge: The Dilemmas of Success in the Korean Electronics Industry

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Economic development is predicated upon the growth of industries. Given the centrality of electronics in the world economy in the late twentieth century it is doubtful that any developing economy can industrialize without significant electronics production. Electronics has disrupted the traditional path to development that is supposed to progress from light industries such as garments to the heavy industries such as steel and chemicals. In electronics it is possible to move from light assembly to 'heavy' manufacturing of semiconductors, cathode ray tubes and, most recently, flat panel displays. Because of this electronics is more than a convenient case study; it is the critical industry and, as such, provides an important window into the strengths and weaknesses of the Korean growth model.

Until late 1997, the Korean economy grew faster than almost any other economy in the world. Although Korea's earliest business growth was based on garments and shoes, the electronics industry is the sector responsible for the overall success of the Korean economy. The importance of electronics is reflected in its status as Korea's largest export sector, accounting for 27 per cent of total exports (KFTA, 1995) and 11 per cent of total manufacturing production in 1993 (Ernst, 1994). In 1998, Samsung Electronics was the largest producer of dynamic random access memory (DRAM) semiconductors in the world and the second largest producer of flat-panel computer displays. Korea also was the second largest producer of colour computer monitors in the world after Taiwan. Korea ranks behind only Japan as a producer of a number of consumer electronics devices including microwave ovens, televisions, and VCRs. Korea's success in electronics has made it a global economic powerhouse.

The success of the East Asian economies and especially Korea and Taiwan has spearheaded a rethinking of the nature of national economic development (Amsden and Hikino, 1994). Part of this rethinking has been the recognition that the accumulation of skill and knowledge is critical for development. For them the harnessing of a nation's human and social resources provides the impetus for the production of economic value. L. Kim (1997) has taken this even further, arguing the accumulation of knowledge is the central reason for Korean success.

For a national economy the ideal situation is one in which business

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activity becomes a virtuous circle of self-reinforcing growth. In such environments there is a natural process of learning-by-doing and path-dependent reinforcement of successful patterns.[1] With any set of institutional relations there are strengths and weaknesses. Because of the evolutionary nature of economic growth, previous arrangements can become blockages to further evolution. In the process, strengths can become weaknesses and vice versa. As Ernst (1994) pointed out, the development of the Korean electronics industry is a classic case in which the creation of particular institutions and routines created and concealed weaknesses.

This article explains the growth of the Korean electronics industry by discussing the salient aspects of the Korean political economy with special attention to the Korean electronics industry. These institutional features are highlighted by case studies of the television and its key component, the cathode ray tube, and DRAM semiconductors. Before turning to the substantive aspects of the paper, the first section briefly highlights the recent general debates about the growth of the Korean political economy. Here we argue that it is necessary to move beyond these general discussions and examine developments in electronics. Next we introduce the dualistic character of the Korean macroeconomy and the electronics industry, and outline the *chaebol*-centred structure of the Korean electronics industry. The next section discusses the difficulties the *chaebol*-centred structure creates for parts and component suppliers, many of which are small and medium-sized enterprises. Then we examine the role of foreign firms in the development of the electronics industry with special attention to their importance in transferring knowledge to Korean producers. The next section examines the dramatic increase in R&D spending by the Korean electronics industry. Then we outline the difficulties the Korean industrial relations system has had in mobilizing the talents and capabilities of the entire Korean work-force. The next section is devoted to case studies of three of the most important Korean electronics products: televisions, cathode ray tubes (CRTs), and DRAMs. The concluding discussion reflects upon Korean accomplishments and the difficulties Korea is experiencing. Here, we argue that the seeds of the current crisis were already in evidence in the Korean electronics industry.

CATCHING UP AND LEARNING

The contentious macro-level debate is between the theorists such as Amsden (1989), who credit the state for Korean economic success, and the free market economists (e.g., World Bank 1993), who minimize the importance of the state. More recently, Amsden and Hikino (1994) have credited the importance of knowledge and skill absorption for corporate success and national growth. Still, the state-centric theorists and the proponents of free-market explanations suffer from the same flaw; they do not provide the fine-grained analysis necessary to understand industrial development. These explanations overlook the creation of value by firms and the actual processes by which firms and industries upgrade their value-producing activities. Without historical analysis of specific industries and products, these previous debates are unable to illuminate actual events and thereby analyse the wellsprings of growth (Leonard-Barton, 1995).

Autarkic development is now completely discredited. For development to occur, it is necessary for firms and their constituent employees to absorb, integrate and use knowledge from overseas. To successfully integrate and create knowledge it is necessary for not only firms but also the government, the educational system, suppliers and a number of other institutional actors to learn.[2] It is not sufficient merely to create incentives to build large factories; the knowledge and capabilities necessary for industrial growth are lodged in human assets, institutional forms and organizational routines (Teece *et al.*, 1994). Effective institutions and routines are vital, because they ensure that knowledge is renewed, communicated to others and extended. However, there is a problem with learning. Routines, once learned, appear natural and are reproduced, even when their utility becomes suspect.

Since the end of the Korean War, Korean economic strategy has had a clear target, that of overtaking the developed countries. The model it adopted was a Korean variant on the pre-war model of its former colonist and neighbour, Japan (Westphal *et al.*, 1979).[3] In this model, the government took on roles as financier, cheerleader and co-ordinator. Beginning in the 1990s and especially after the crisis beginning in 1997, there has been some shift to the government as a regulator (Cho, 1992).

The Korean *chaebol* electronics firms have been superb followers and learners in the process of catching up with their Japanese rivals. In fact, in certain narrow sectors, especially DRAMs, they compete at the cutting edge of global industry. In other cases, they have dramatically shortened the time between new model introduction by developed country rivals and themselves. To accomplish this, Korean electronics firms have gathered both tacit and explicit knowledge from around the world and integrated it into their operations (L. Kim, 1996). This massive effort was central to the dramatic progress of the Korean electronics industry. Korea purposefully organized to absorb rapidly new skills and integrate them. However, as we shall see, this learning has been uneven. Most important, in the vital realm of creating globally relevant new knowledge, the Korean effort has been truncated and frustrated by its own institutional structures.

THE STRUCTURE OF THE KOREAN ELECTRONICS INDUSTRY

These *chaebol* are responsible for the most salient feature of the Korean electronics industry, namely its dualistic nature.[4] The Korean electronics industry consists of a core of large *chaebol*-related firms and many small firms. The size of the *chaebol* is remarkable. As Figure 1 indicates, except for Japanese firms, Korean electronics firms are the largest in Asia, and Korea has the largest electronics industry in Asia outside Japan (Electronics

TABLE 1
TOP TEN NON-JAPANESE ASIAN ELECTRONICS FIRMS

Rank 1994	Rank 1995	Company	1995 electronics sales (US$ millions)	1994 electronics sales (US$ millions)	% change 1994–95 (local currency)	1995 operating profit/(loss) (US$ millions)
1	1	**Samsung Electronics** (Korea)	$15,100.7	$8,906.2	40.6%	$5,539.0
2	3	**Acer Group** (Taiwan)	$5,723.5	$3,202.2	78.7%	$404.9
3	2	**LG Electronics** (Korea)	$5,679.3	$4,102.7	28.0%	$674.3
4	4	**Hyundai Electronics** (Korea)	$3,997.4	$2,583.6	48.2%	NA
5	5	**LG Semicon** (Korea)	$3,255.9	$1,752.8	77.9%	$1,595.2
6	6	**Samsung Display Devices** (Korea)	$2,499.8	$1,703.9	40.5%	$189.9
7	7	**Daewoo Electronics** (Korea)	$2,166.2	$1,517.9	25.1%	$491.6
8	8	**Samsung Electro-Mechanics** (Korea)	$1,738.3	$1,175.6	41.6%	$164.5
9	13	**Lien Hwa - Mitac Group** (Taiwan)	$1,429.0	$823.3	49.1%	NA
10	10	**Anam Industrial** (Korea)	$1,249.1	$943.1	26.3%	$71.8

Source: *Electronics Business Asia* 1995.

Business Asia, 1997).

Most major electronics firms are members of a *chaebol* and bear the name of their *chaebol*.[5] In electronics, the most important *chaebol* are Daewoo, Hyundai, Lucky-Goldstar (LG), and Samsung. Samsung, Daewoo and LG each operate three of the top 15 Korean electronics firms. The largest non-*chaebol* firm, Anam Industrial Corporation, is only the ninth largest electronics firm in Korea and has formed its own 'mini-*chaebol*'.

The *chaebol* compete fiercely against each other and undertake a large amount of intra-*chaebol* trading and little inter-*chaebol* trading. Though the *chaebol* form an oligopolistic industrial structure, this does not stifle inter-*chaebol* competition. Each *chaebol* firm is the apex of a pyramid of weak dedicated suppliers that it tightly controls and discourages from selling to outside companies. The ferocity of this competition is indicated by Kirk (1994: 179), who quoted a former executive vice president at Hyundai's electronics operation in Silicon Valley, as saying that his company's large-scale investments were due to 'blind competition with Samsung'. The rivalries are so fierce that often *chaebol* firms would rather import from

FIGURE 1
COMPOSITION OF THE TOTAL COST OF A CONSUMER ELECTRONICS PRODUCT FOR A LARGE KOREAN ASSEMBLER

<table>
<tr><td rowspan="5">Sale
Price
(100)</td><td colspan="3">Internal Production
(29, including profit)</td></tr>
<tr><td rowspan="4">Purchase
(71)</td><td colspan="2">Imported
(14)</td></tr>
<tr><td rowspan="3">Purchase
Domesticially
(57)</td><td>Related Enterprises
(15)</td></tr>
<tr><td>Large Companies
(6)</td></tr>
<tr><td>Small and Medium
Enterprises
(36)</td></tr>
</table>

Source: Koike 1990.

Japan than purchase from each other. In *chaebol*-centred competition, market share is pursued relentlessly at the cost of short-term profit.

Due to their enormous size and centralized administration, the *chaebol* have a remarkable ability to mass human and financial resources to enter new product lines or even new industries. This ability to mobilize resources has made it possible to challenge and, at times, even overtake global leaders. Invariably, the targets are clearly delineated subsectors in which the evolutionary path of the technology is quite apparent and where economies of scale are possible. This strategy emphasized learning to produce by first assembling for foreign firms, then importing entire factories or technologies. In the initial period, foreign buyers were often actively involved in teaching the Korean firms how to produce for the world and, especially, the US market (Rhee *et al.*, 1984). Even while mastering assembly technology, the *chaebol* already began to integrate backwards to produce critical components, such as television tubes or microwave magnetrons (L. Kim, 1997). To accelerate knowledge transfer, Korean firms eagerly invested capital and personnel in developing systems for learning and learning how to learn (for discussions of this, see Amsden and Hikino, 1994; L. Kim, 1997).

The *chaebol* have used two important competitive advantages. First, Korea has relatively (to Japan) inexpensive, dedicated and well-educated factory workers and excellent inexpensive engineers. Second, the *chaebol* can mobilize enormous sums of capital (in earlier periods with government assistance and, more recently, from internal sources and overseas borrowing) to invest in massive production facilities capable of reaping economies of scale.[6] In the case of finished goods such as televisions, VCRs and microwave ovens, Korean firms began as OEM (original equipment manufacturing) suppliers to Western retailers and later even began supplying their Japanese competitors. More recently, especially in electronics, the *chaebol* have made massive investments in overseas production (see, for example, Choi and Kenney, 1997; Y. Kim, 1995a). In the last decade, *chaebol* electronics firms have become significant foreign investors operating large overseas production facilities. In sum, in electronics Korean firms developed sufficient capabilities to become global competitors in certain narrow sectors.

PART AND COMPONENT SUPPLIERS

If the *chaebol* are strong, smaller parts and components makers are weak (L. Kim and Nugent, 1994; Ernst, 1994; Bloom, 1992; Hong, 1995; Lim, 1999). To some degree this can be attributed to government policy, which until the late 1980s consistently promulgated policies favouring *chaebol* growth, while handicapping smaller firms (Lim, 1999). However, blaming government policy is not a sufficient explanation for this weakness.

Korean suppliers can be divided into two groups: The largest group, nearly 70 per cent, subcontracts for a single *chaebol* customer and is discouraged from supplying other *chaebol* (personal interviews with Korean suppliers and assemblers, 1994–5; Koike, 1990). This near-total dependence means the suppliers are vulnerable to customer pressure. Given lax enforcement of laws meant to protect smaller firms, the *chaebol* have enormous latitude in squeezing profit margins. The squeezed suppliers have little opportunity to accumulate sufficient surplus to reinvest in R&D or production upgrading, so even the most successful suppliers find it difficult to achieve the critical mass necessary to become global-class suppliers. Insufficient profitability inhibits R&D investment, and insufficient R&D investment retards development of higher value-added and more profitable products. Curiously, given the very close and long-term relationship between assemblers and captive suppliers, one might expect a policy of encouraging supplier improvement; however, this is not the case.

The exclusive supplier relations insisted on by *chaebol* firms provide little opportunity for interactive learning from other assemblers through common suppliers. As von Hippel (1988) pointed out, isolation inhibits user feedback, a vital avenue of learning and competence upgrading. This was illustrated by the comments of a manager at one Korean parts supplier. He described the relationship they had with Sony: ‘Sony gave us more support than [a major Korean electronics assembler customer] ever gave.’ Sony even sent engineers to his factory to teach employees how to upgrade component quality (personal interview with Korean supplier).

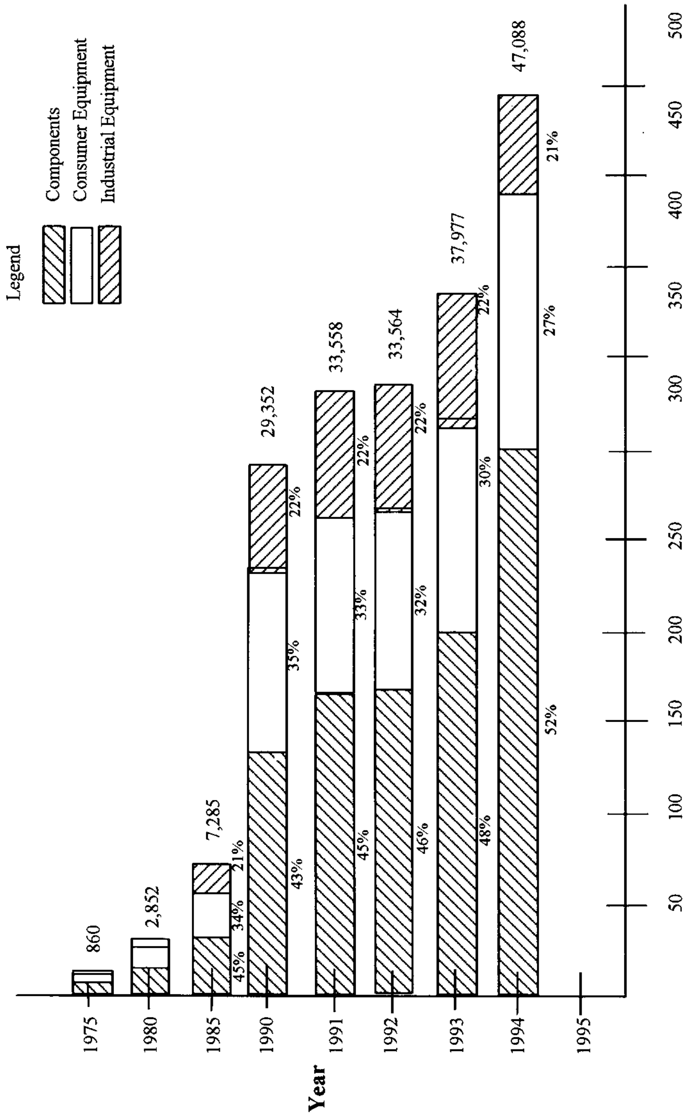
The other supplier group consists of independent firms. The independents supply general electronic components, such as resistors, capacitors and switches. They also experience difficulties in this environment. In their case, the assemblers have the dominant position with no obligations. So, until recently, the *chaebol* would withhold payments for as long as 90 days after delivery, the small supplier providing the equivalent of an interest-free loan to the *chaebol*. Even though illegal, the Korean government did not enforce the law (Korean parts supplier, 1994). There was little information sharing or quality improvement discussion. The result is that Korean independents also are weak and unable to invest extensively in R&D to accelerate technological progress.

Unable to purchase the newest and most sophisticated components in Korea, the assemblers must purchase them from foreign producers, usually Japanese. This is the root cause of one important Korean dilemma: increasing Korean electronics exports invariably result in a greater trade deficit with Japan. Seo (1994: 6) found that for every ten per cent appreciation of the yen against the US dollar, Korean electronics products gain only a three to four per cent price advantage over their Japanese competitors. The remainder is offset by the need to purchase more expensive Japanese components and producers' goods. With the recent exception of DRAMs, Korean firms never have had the latest product, thus locking them out of the most lucrative markets. When all costs are considered, inferior products, especially if they require significant after-sales repair, are often too expensive for retailers to handle, so Korean firms have difficulty getting shelf space.

The weakness of suppliers determined the strategy of initiating production as an OEM assembler using many imported parts. Later, where possible, the *chaebol* substituted internal production for the high value-added (and often capital-intensive) imported components. For example, in the case of microwave ovens, initially nearly all parts were imported, but eventually almost all major parts including magnetrons were produced in Korea (Magaziner and Patinkin, 1989). The exceptions are smaller components requiring very high quality or extremely small size, such as the newest capacitors, resistors, or quartz crystals or knowledge-intensive capital goods, such as semiconductor steppers or fine dies and moulds (Whang, 1995). These continue to be imported.

Korean dependence on imported parts is illustrated in Figure 2, which depicts the origins of the added value that makes up a typical (though unspecified) Korean consumer electronics product. The added value and profit of the assembler is 29 per cent; of the other 71 per cent, small and medium-sized enterprises contribute 36 per cent and other *chaebol* family firms contribute 15 per cent. The critical factor, however, was the 14 per cent of the value still imported. Almost invariably, these are high value-added (knowledge-intensive) parts. Though, in the 1990s, some low-value-added components began to be imported from Korean-owned factories in China.

FIGURE 2
ANNUAL KOREAN ELECTRONICS PRODUCTION BY MILLIONS OF DOLLARS
AND SECTORAL SHARE



Source: Electronics Industry Association of Korea 1995.

These imported high value-added components embody accumulated skills, tacit knowledge, and R&D. Moreover, such components are evolving rapidly as developed country producers continue to innovate. So, even as Korean part makers reverse-engineer previous models, overseas competitors continually introduce new models. Also, in response to competition from Korea and Taiwan, these overseas parts makers, and especially the Japanese, moved production of older models to Southeast Asia, where the lower cost of labour provides the margin to compete (personal interviews with Korean and Japanese electronics assemblers and suppliers, 1994–5).

Though changing, the purchasing pattern of Korean assemblers differs from those of the Japanese. For example, in the 1980s Japanese television assemblers did far more subcontracting than did Korean assemblers (Yaginuma, 1993: 20; Whang, 1995). Whereas both Korean and Japanese assemblers purchased components such as resistors, condensers, and switches, Koreans also purchased structural parts such as television cabinets and moulds for plastic injection through market transactions. After the steep wage increases of the mid 1980s, Korean firms increased their subcontracting. The goal was not to create a learning network, but simply to circumvent rising labour costs. Despite recent increases in subcontracting, the Korean electronics industry still has fewer layers of subcontractors and suppliers than Japan. The truncated Korean industrial pyramid means that there are far fewer specialists available and there are fewer corporate nodes at which specialists are improving and innovating (L. Kim, 1994). Put differently, there are fewer points at which deep pools of knowledge are being created.

Supplier difficulties are not confined to pricing and information flow. In contrast to Japan, Korean labour markets are not closed. This openness has positive and negative effects. On the positive side, the mobility is an effective method for knowledge diffusion as the recruited employees are bearers of embodied knowledge. Mobility also permits the concentration of assets in the *chaebol*, thereby contributing to their competitiveness.

The negative aspect is that Korean suppliers experience a constant and palpable risk when investing in worker skill-upgrading (i.e., human capital formation), because employees can and do move to *chaebol* firms. With higher pay, prestige, and the offer of greater security, the *chaebol* can easily raid smaller firms. The manager of a medium-sized component maker lamented that it was difficult to retain engineers and technicians at his firm because they were constantly recruited by larger companies (personal interview, 1994). This inhibited his company's ability to upgrade. A manager of an independent supplier making plastic injection-moulded parts for the electronics industry reiterated this, saying that his company's greatest difficulty was the retention of highly trained labour, especially mould-makers. Raiding goes beyond individuals. To accelerate entry into a new business sector, *chaebol* firms often recruit entire teams from smaller firms and suppliers (personal interview with Korean supplier, 1994).

Korean capital goods and raw material suppliers are also weak and so most of these inputs are purchased either from Japan or the US (Bloom, 1992). For example, in the semiconductor production sector, Korean manufacturers purchase more than 65 per cent of their materials, such as silicon wafers, from foreign sources, though recently a Korean firm is entering this market in a joint venture with a foreign firm (for a further discussion of semiconductor capital goods, see Mathews, 1995). Also, some foreign firms opened joint ventures and subsidiaries in Korea to produce semiconductor materials and equipment (Shin and Song, 1994: 43; Ernst, 1994).

The dualistic structure of the Korean electronics industry created enormous difficulties for the suppliers. However, they were not entirely blameless for the state of affairs. Too often, suppliers used government policy, providing protection from foreign firms and *chaebol* for certain components, as an opportunity to secure profits that were then invested in land speculation or other unproductive purposes. Many are ineptly managed and exhibit an extremely short-term orientation. In this way, the suppliers also contributed to their difficulties.[7]

Today, the Korean supplier infrastructure remains one of the glaring weaknesses in the entire electronics industry. The Korean *chaebol* firms have invested in the newest equipment and conduct significant amounts of R&D, improving their competitiveness significantly. But the rapid improvement at the peak of the production pyramid was not matched by learning among the suppliers. As a result the entire value chain cannot migrate rapidly to higher value-added products and Korean firms are forced to import the highest-value components, in the process assisting foreign parts suppliers.

LEARNING FROM FOREIGN FIRMS

In contrast to Taiwan, which welcomed foreign investment, the Korean position was always ambivalent.[8] In the 1960s and 1970s, Korea recruited foreign firms and joint ventures to newly established free enterprise zones. The objective was not merely to earn foreign exchange; rather, the government encouraged joint ventures to allow Korean partners to learn from the foreign investors. However, the government also actively protected its internal market from foreign and, especially, Japanese competitors.

Foreign investment began in the 1960s, but most investments were small and relatively short-lived. Increasing wages and government policy fluctuations made the climate increasingly inhospitable and most foreign firms sold their investments to their Korean partners. Quite early, US firms, which were mostly involved in semiconductor assembly, closed their Korean operations and relocated to Southeast Asia. Japanese firms left for a variety of reasons. Some felt they were transferring technology and know-how to their Korean joint venture partners while securing few profits (personal interviews with Japanese electronics assemblers and suppliers, 1994–5). Still others saw the environment become more difficult due to changes in government policy meant to weaken or discourage the foreign partners in joint ventures (Ernst, 1994). Only a few joint ventures, such as the one between Alps and Goldstar begun in the early 1970s, operated in 1998. Finally, increasing wages discouraged manufacturing predicated on low-cost Korean labour.

Though short-lived, the foreign investments provided Korea opportunities for some learning.[9] Ernst (1994) argues that when the foreign firms abandoned these joint ventures, Koreans lost an important source of learning-through-transfer. Certainly, by the 1990s, Korea had very low levels of inward foreign direct investment and thereby could not learn from foreign competitors blocking this knowledge transfer channel.

The demise of joint ventures did not deter Korean firms, as they secured OEM contracts from foreign buyers. This provided rapid entry, but Korean firms shared their profits with their customers (see Ernst, 1994 for an excellent discussion). This provided a learning opportunity because the foreign firms had to teach the Korean firms how to produce to acceptable standards. Soon, Korean firms were able to design new products, but the problem was that, as OEM producers, they were unable to build distribution and marketing channels and develop strong brand name recognition.[10] This can be seen as a truncated form of learning because they only mastered manufacturing and not distribution and marketing.

R&D IN THE KOREAN ELECTRONICS INDUSTRY

Initially, Korean industry learned by doing and there was little organized corporate R&D. This changed in the mid 1980s as foreign firms became less willing to license advanced technology and growing Korean firms had greater discretionary funds. By 1993, Korean firms invested 2.17 per cent of total GNP in R&D, a greater share than the United Kingdom (2.11 per cent) or Taiwan (1.73 per cent). In 1997, no non-OECD country was investing as much in R&D. Moreover, in sharp contrast to nearly all other developing countries, where most R&D is government-supported, the private sector funds approximately 80 per cent of all R&D investment (Y. Kim, 1995b :95; Simon and Soh, 1994).

The dimensions of Korean electronics R&D investment growth are startling. In 1993, the top 15 Korean electronics firms spent more than $3 billion on R&D. This is substantial, though still dwarfed by Japanese electronics R&D investment (see Table 2). In 1996, some Korean electronics firms invested more than five per cent of annual sales in R&D. Of these, the R&D investment leader was Samsung Electronics Corporation (SEC). One-fifth of SEC's employees are reportedly assigned to R&D activities and the company invested 6.5 per cent of sales in R&D in 1994. As an example of SEC's success, it is now ranked 38th in new US patent registrations (Crane, 1993; *Electronic Business Asia*, 1997). SEC and the other Korean makers are outstripping firms from other developing countries and many European firms.

TABLE 2
R&D BY KOREAN AND JAPANESE ELECTRONICS ASSEMBLERS IN 1995

Korean Assemblers		Japanese Assemblers 1995 ($ = 100¥)		
1 Samsung Electronics	1,403	Matsushita	3,900	1
2 LG Electronics	511	Hitachi	3,800	2
3 Hyundai Electronics	479	Toshiba	2,900	3
4 LG Semicon	391	NEC	2,900	4
5 Daewoo Electronics	324	Fujitsu	2,800	5
6 Samsung Aerospace	169	Sony	2,391	6
7 Daewoo Telecom	104	Mitsubishi Electric	1,650	7
8 Samsung Display Devices	100	Canon	1,400	8
9 LG Information & Communications	93	Sharp	1,150	9
10 Samsung Electro Mechanics	87	Sanyo	820	10

Source: Various.

Despite the dramatic increases in R&D investment, Korean electronics firms still lag far behind the US and Japan. For example, In 1992 Korean firms filed only 120 semiconductor-related US patent applications (though this was increasing rapidly), while Japan and the US submitted 1,800 and 2,100, respectively (Shin and Song, 1994: 43). Nonetheless, Korea developed a set of R&D competencies (particularly in DRAMs, cathode ray tubes, and magnetrons), as shown by the increasing numbers of leading Japanese and US electronics firms agreeing to joint ventures going beyond simple OEM relations. Korean firms have not confined their R&D activities to Korea. All the *chaebol* have research laboratories-cum-listening posts in Silicon Valley and Japan. These laboratories provide the access that comes only from proximity to the most advanced technology centres.

The government also plays a role in organizing and financing R&D projects, though success has been mixed. Some government efforts were important in assisting the electronics industry to enter sectors such as 1M DRAM and flat panel displays (FPDs) (Bloom, 1992; Ernst, 1994). Government targets have almost always been the development of sophisticated capital-intensive technologies, such as DRAMs, television tubes, FPDs and digital telephone switches. The participants were invariably the *chaebol*. There has been less success in government R&D to assist suppliers (L. Kim and Nugent, 1994).

R&D investment is one of the Korean electronics industry's strengths and sets it apart from most other developing country companies. The large size of the *chaebol* firms provides them with the wherewithal to invest in R&D. In semiconductors and FPDs, Korean researchers in corporate and government laboratories were fundamental to the Korean catch-up process.

LEARNING AND INDUSTRIAL RELATIONS

The current labour situation in Korea must be understood historically. There can be little doubt that the Korean labour force has played a significant role in the success of the electronics industry. Until the mid 1980s, the well-educated Korean labour force worked long hours for relatively low pay, contributing greatly to Korean success (L. Kim, 1997). There has been only limited research on Korean industrial relations and work organization. Most important, there has been almost no attention given to whether Korean firms have organized their factories for learning.

Prior to the mid 1980s, Korean workers were oppressed by a coalition of big business and the state. However, in the 1980s, there was labour unrest that earned workers the right to unionize and dramatically increased wages. Park (1995) concludes that the result of the unrest was a major redefinition of the Korean labour-management system to be more like that of Japan. However, recent events suggest that the system is not yet stable and management has not developed effective means to harness the positive aspects of a Japanese-like system, such as worker involvement in increasing efficiency and a commitment to upgrading all workers.[11]

The organization of Korean factories is apparently extremely hierarchical and not geared for worker-level knowledge creation. First, there is a distinct separation of high school-educated blue-collar workers and college-educated white-collar employees. Even the terms for male and female factory workers are derogatory and reflect disdain for industrial labour (Koo, 1993: 151–3). Korean firms 'generally regard [production and technical workers] as second-class citizens' (Park and Lee, 1995: 51). It is extremely rare for production employees to be promoted to the managerial categories, although they can and, sometimes, are promoted to supervisor (Park and Lee, 1995). The highest position an industrial high school-educated production worker can achieve is factory section chief. This contrasts with Japan, where, in principle, there is no upper limit on any regular worker's promotions and in factories it is not surprising for industrial high school graduates to be department heads and even factory managers. The limited opportunities for mobility and the general discounting of the capabilities discourages factory floor-level learning and knowledge creation.

Learning among factory workers seems to be limited. Korean firms have not had active and well-planned training programs (Park and Lee, 1995: 41). T. Kim (1995: 224) reported that workers had a 'very limited understanding of the production process'. Even senior workers developed few skills, and repairs were usually made by mechanical engineers, so knowledge accumulation among workers is minimal. On-the-job training techniques, such as rotation, were also limited, though there was some unplanned rotation due to the relatively high turnover. Senior workers undertake many of the training responsibilities, even though there is little incentive for them to impart skills to their juniors (T. Kim, 1995: 224).

Before the 1990s, few Korean firms were practising continuous process improvement or small group activities. This is explainable because one way for workers to resist managerial prerogatives is to stay uninvolved in improving the work process and to exhibit a lack of concern for quality

(Janelli, 1993: 164–5). T. Kim (1995) found that quality control efforts were not so successful because workers, in an attitude reminiscent of the military, felt they needed only to perform the work ordered. Apparently, most quality control efforts did not address the problems workers found significant, so they had little interest in taking any initiative. As a result, these avenues of incremental learning and innovation apparently continue to be underutilized in Korea.

Decision-making in Korea is generally unilateral, top-down, and almost militaristic. Corporate control is often exercised by the owning family and its relatives (Janelli, 1993; Kang, 1996). Generally speaking, decisions are made by superiors and simply transmitted to subordinates, a practice that truncates information-sharing and knowledge creation. In such environments spontaneity and innovation is discouraged. There are no studies demonstrating this; however, there are anecdotes. For example, Janelli (1993: 164–5) reported an incident in which one young manager suggested to his section chief a technique for computerizing some record-keeping. The section chief responded that the innovator should devote his energies to his assigned work and refrain from making unsolicited suggestions. There was no consideration of the merits of the idea. From such anecdotes, one can tentatively conclude that the entire firm has not been mobilized for innovation, rather innovation is reserved for the R&D laboratory and high-level managers.

Still, during the last decade the environment has changed. Korea now has a democratically elected president and active unions. Wages have increased dramatically and Korean labour is no longer inexpensive. However, still extant are the work organization and industrial relations designed for the earlier period of inexpensive labour and low technology governed by an authoritarian management structure and backed up by a repressive government. It is uncertain whether the recognition of the need for change and the upheaval are creating the transformative forces capable of redrawing the Korean industrial landscape to allow new economic institutions and structures meant to encourage innovation to arise. Until such a redefinition occurs, Korean firms will find it difficult to mobilize factory-level and middle-level management based knowledge creation.

CASE STUDIES

The foregoing general discussion of the political economy of the Korean electronics industry provided an outline of the industrial structure. The following two case studies indicate how this environment affected the development of two of the most important Korean electronics products: televisions and DRAMs.

Colour Televisions and CRTs

Televisions were the first Korean electronics product that had an important impact on the world economy and are an excellent illustration of the more general development pattern in Korean electronics.[12] Moreover, the television production infrastructure created the basis for success in the later movement into computer terminal and monitor production. As a measure of this success, in 1994, Korea exported, directly or indirectly, televisions or finished monitors worth approximately $2.2 billion in value (Electronics Industry Association of Korea, 1995). In 1995, in unit terms, Taiwan produced 38 per cent of the world's monitors, while Korea produced 24 per cent (Electronic Business Asia, 1996: 72). As mentioned earlier, by 1994 Samsung was the largest producer of colour picture tubes and monitors in the world (Samsung Display Devices, 1994). In 1998, Korean firms were major global suppliers of cathode ray tubes and completed televisions.

Though Korean firms had some experience assembling transistor radios and televisions for US firms, it was in televisions that Korean firms pioneered their strategy of assembling imported parts for OEM customers and then moving upstream. In 1966, two factories began producing black-and-white televisions, and the government initiated infant industry protection (S.J. Kim, 1972: 4C). Initially, nearly all the parts, components, and equipment were imported from Japan. In 1969, Samsung began production of black-and-white (b/w) CRTs and in 1970 began exports (Bloom, 1992: 29). Korean firms quickly found price-sensitive OEM customers, such as Sears and Montgomery Wards, were looking for low-cost suppliers and Korean firms began to replace Japanese firms. The early Korean television industry entrants had numerous joint ventures with Japanese firms. For example, NEC owned 20 per cent of Goldstar's television venture (Porter, 1983: 500) and Matsushita owned 50 per cent of Korea National (Porter, 1983: 528). In 1965 LG, then a transistor radio assembler, approached Hitachi to train its workers and license b/w television technology (L. Kim, 1997: 136). Samsung entered joint ventures with two of the weaker Japanese consumer electronics firms, NEC and Sanyo. The first joint venture was established in 1970, when Samsung-NEC was established to start vacuum tube production (Samsung Display Devices, 1994: 8). In 1969 and 1970 Samsung sent engineers to NEC to learn the skills necessary to assemble vacuum tubes and b/w CRTs. Also, NEC technical experts went to Korea to train Samsung-NEC technicians. Simultaneously, in 1969, Samsung signed a joint venture agreement with Sanyo to learn to assemble radios and b/w televisions (Hobday, 1995).

The government also assisted in developing picture tube production capability. For example, to avoid excess competition the government awarded Samsung the initial exclusive right to produce television tubes in Korea. Samsung established a joint venture with the US company Corning Glass to produce glass funnels and face plates. Meanwhile, LG was assigned the production of electron guns. However, after a couple of years the other *chaebol* were permitted to enter the reserved areas. In 1973 Samsung also formed a relationship with Sanyo to produce tuners, deflection yokes, transformers, and condensers. In 1977, NEC licensed Samsung-NEC to produce colour television tubes and once again trained

Korean technicians (Y. Kim, 1995a). By the end of the 1970s, Samsung was capable of assembling nearly 10 million black-and-white sets (Y. Kim, 1995a).

In 1978, the Korean content for colour televisions was merely 28 per cent (Y-B. Kim, 1979); in 1988, it had increased to 63 per cent (Bloom, 1992) and by the 1990s had increased to over 95 per cent. At the time, television assembly was quite labour-intensive, giving Korean manufacturers a significant price advantage over Japanese competitors. For example, in 1978 the export cost of a Korean colour television was $162 per unit, whereas for a comparable Japanese unit the cost was $300–330. This advantage was almost entirely due to lower labour costs (Y-B. Kim, 1979). Given this advantage, Korean exports grew so rapidly that by the end of 1978 the US government implemented a quota on Korean CTV imports, an action that drove Korean capacity utilization down to between 30 and 45 per cent. Moreover, because Korea did not have colour TV broadcasting, there was no domestic market. In 1980, as a response to this overcapacity problem and after much agitation by the Korean assemblers, colour broadcasting commenced (Y-B. Kim, 1979).

In 1982 Korea became the fourth largest television producer in the world, and in 1983 surpassed Japan to become the largest exporter (in units) of televisions to the US (US International Trade Commission, 1984: 12).[13] Today as then, Korean TV production is extremely concentrated. In 1982 Samsung and LG accounted for 42 per cent each of total CTV Korean production, and Taihan Wire (which was purchased by Daewoo in 1983) produced approximately 12 per cent (US International Trade Commission, 1984: A31). Today, Samsung, LG, and Daewoo are responsible for over 90 per cent of total production.

Though initially relying on inexpensive labour, *chaebol* soon exhibited the other characteristic mentioned previously: a willingness to invest large sums of capital to achieve economies of scale. For example, Cohen (1975: 111) found that foreign firms assembling televisions in Korea were less capital-intensive than their Korean competitors. The Korean strategy of combining low-wage costs with large capital investment resulted in very competitive prices and an enormous need to export and capture market share to pay for the expensive imported equipment.

The relative weakness of Korean television part suppliers is expressed by an inability to produce more sophisticated components. For example, Koreans continue to import high value-added key components, such as shadow masks and deflection yokes (personal interview with manager at Japanese trading company, 1995). Korea produces shadow masks, but in 1994 nearly 24 per cent of the units used were imported from Japan. These imports account for 59 per cent of the total value of shadow masks used (Electronics Industry Association of Korea, 1995). This indicates that domestic shadow masks have a lower average value than imports. This is also true for deflection yokes. Korea currently produces 34.4 million deflection yokes valued at $135 million or approximately $5.31 each

(EIAK, 1995).[14] It imports 6.9 million yokes valued at $74.9 million or $10.86 each. The imported yokes and shadow masks, nearly all of which are from Japan, are more sophisticated and are used for products such as high-end computer monitors and wide-screen televisions (personal interview with major Japanese producer of electronic components, 1995). This is also true for the most sophisticated electron guns.

In the 1990s, there was a major change in Korean-Japanese competition. Japanese firms retreated from some low-end commodity televisions and became customers for Korean CRTs and televisions in the under-20-inch television screen size. For example, virtually all the 14-inch and 15-inch televisions that NEC sells in Japan are made in Korea by Daewoo (Wall Street Journal, 1995: B9). Japanese firms also purchased some television components from Korean firms. Similarly, in Malaysia, many smaller televisions assembled by Japanese firms use CRTs made at Samsung's Malaysian CRT factory.

By 1998, for low-cost televisions, there are few differences between Japanese and Korean televisions (interviews with Japanese and Korean television assemblers, 1994–5). Price-sensitive purchasers of these televisions are rarely willing to pay much more for what may be only slightly better quality. And yet, despite fierce Korean competition, Japanese firms have been able to retain their technological and marketing lead. For example, Korean manufacturers did not introduce wide-screen televisions until January 1994, when Samsung Electron Devices manufactured its first flat CRT for wide-screen televisions. Not only was this five years after the Japanese introduction, Samsung licensed the technology from Japan (Pacific Rim Economic Review, 1994: 35).

Televisions and CRTs exhibit the paradoxical nature of Korean electronics success. Initially, Korean firms used joint ventures as a method of securing access to Japanese technology. In the 1970s, Korean firms established production capabilities. By the late 1970s, they had made substantial advances absorbing new technologies and entered the global market, undercutting Japanese firms. Rapid growth and a willingness to invest aggressively made Korean firms unit volume leaders in the production of capital-intensive components such as CRTs and microwave magnetrons. In the mid-1980s, Japanese firms responded by increasing production in Southeast Asia. This permitted them to retain competitiveness in the price-sensitive end of the market and dramatically slowed Korean efforts to enter the more profitable high-end market. Still, by 1995 global television tube production by three Korean firms was greater in unit volume than that of Japanese firms (51.9 million versus 48.9 million units) and even Japanese firms are purchasing low-end televisions from Korean firms.

Seen from a knowledge absorption and learning perspective, the television industry is paradoxical. The *chaebol* learned how to mobilize capital and engineering talent, secure access to technology, and rapidly learn to produce. But they were not able to create the routines necessary to develop innovative new products, so they were in a position of constantly learning. Also, their quality was acceptable for low-end, price-sensitive products, but unacceptable for high-end products, which is where the profits are greatest. Thus the Koreans could gain market share, but in the global economy greater rewards accrue to the creators of new products embodying design and quality. One further point: the pattern pioneered in televisions became a standard mode of market entry for Korean electronics firms in yet other products.

Semiconductors

If televisions were the opening wedge, semiconductors and, especially, DRAM production was the Korean electronics industry's most spectacular success. In 1995, components had become the Korean electronic industry's largest product (see Figure 2) and, within components, DRAMs were most important. There were three important *chaebol* in the semiconductor industry: Samsung, LG, and Hyundai. Daewoo, an important television producer, was less significant. Of still less importance is Anam, though it was the world's largest semiconductor assembly firm and recently announced its intention to enter the ASIC fabrication business (Mathews, 1995). The clear leader in the Korean semiconductor industry was Samsung, the world's largest producer of DRAMs and the sixth largest semiconductor firm in 1996. In the 1995 global rankings, Hyundai was in eleventh place and LG Semiconductor was in thirteenth place. Samsung's profits in 1995 grew to $3 billion, of which 80 per cent was from DRAMs (Pereira, 1996; Schuman, 1996: B7A), though in 1996 profits in DRAMs dropped to less than $200 million and sales fell from nearly $21 billion to under $20 billion. In 1997 and 1998, Samsung's DRAM profits disappeared and the other Korean firms lost millions.

Korean semiconductor production began in the mid 1960s as US-owned and -operated assembly and test operations were established in Korea. In the early 1970s, Japanese firms joined the Americans. The most interesting early operation was a joint venture between Korea Electronics Co. (KEC) and Toshiba Corporation to assemble diodes and resistors. In 1974, KEC purchased all but ten per cent of the joint venture. In 1970, Anam began assembling transistors and diodes (Y. Choi, 1994: 59–61). In 1979, KEC commenced production of discrete semiconductors and transistors (Y. Choi, 1994; Mathews, 1995).

Even though these operations were simple, according to Y. Choi (1994: 61ff), 'the Koreans and foreigners who once worked at those subsidiaries contributed very much to the assembly technology of other Korean firms and they also delivered managerial understanding and know-how' to other Korean firms. In 1972, a joint UNIDO-IEEE expert working group on the electronics industry predicted that 'Korea will be one of the countries of component products [*sic*]' (S.J. Kim, 1972).' In other words, this Korean observer understood already that one of Korea's major strengths would be component production.

The mid-1970s opened a new stage in the development of the Korean semiconductor industry. In 1974, a start-up firm, Korean Semiconductor Inc., built a three-inch wafer fabrication facility. KSC was purchased by Samsung in 1977 after it ran out of capital and renamed Samsung Semiconductor Company. Then, in 1977, Taihan Electric Wire acquired technology from Fujitsu to start a semiconductor fabrication facility meant to supply its consumer electronics division. In 1979, Goldstar acquired Taihan's semiconductor operations, which became the base of Goldstar Semiconductor Ltd. In an effort to gain technology and markets, in 1980 the Taihan venture was made part of a joint venture, 43 per cent owned by AT&T. So, by 1980, Samsung, Goldstar, and KEC were fabricating semiconductors.

In the 1980s, Korean firms had developed sufficient internal expertise to be no longer entirely dependent upon technology imports. So, when no foreign firm was willing to provide a designs for the 1M DRAM, the Korean government organized a joint project consisting of Samsung, Goldstar, and Hyundai researchers. This research project developed the 1M DRAM in 1988, only two years later than Japan. In 1990, a similar consortium developed the 4M DRAM so quickly that Korea was only one year behind Japan. By the 16M generation, Korea (read Samsung) had overtaken Japanese firms (C.-W. Kim, 1995: 14).

By the mid-1990s, Samsung was the world's leader in 64M DRAMs and demonstrated the first fully functional 256M DRAM chip (Periera, 1996). Table 3 demonstrates that, across the spectrum of DRAM technologies, Samsung moved from being a follower in 1980 to a leadership role. Hyundai, though definitely behind Samsung, is also in the first rank. LG is a follower in the DRAM area, but has a technology relationship with Hitachi. In 1994 and 1995, another unrelated event, the precipitous rise of the Japanese yen, gave Korean firms an enormous price advantage over their Japanese competitors, allowing Korean electronics firms to reap large profits – and the largest of all profits came from DRAMs. In 1996, the situation changed dramatically as DRAMs prices collapsed due to oversupply and the yen fell against both the dollar and the Korean won. This allowed Japanese firms to regain significant pricing flexibility and Korean profits plummeted.

DRAMs were an excellent target. DRAMs evolve quickly so there are opportunities to enter, but the evolutionary trajectory is stable and predictable, moving from 64K to 256K, 1M, 4M etc. Moreover, the production technology was available from many sources. Further, much of the knowledge needed to fabricate semiconductors is embedded in the equipment, and equipment vendors are willing to teach entrants how to use their equipment.

Korean firms have amassed a significant base of experience and know-how in DRAMs. Recently, this knowledge has provided the leverage to negotiate more equal business partnerships with US and Japanese firms. For example, Samsung and NEC were conducting joint research on improving production efficiency and sharing sensitive information on manufacturing

TABLE 3
TECHNOLOGY ROADMAPS FOR THE MAJOR DRAM SUPPLIERS IN 1996

	Fast page mode			EDO			Burst EDO			Synchronous			Rambus		
	4M	16M	64M	4M	16M	64M	4M	16M	64M	4M	16M	64M	4M	16M	64M
Fujitsu	IP	IP	US	IP	IP	US	NP	NP	NP	IP	IP	S	NP	NP	NP
Hitachi	IP	IP	US	IP	IP	US	NP	NP	NP	IP	IP	US	NP	NP	US
Hyundai	IP	IP	S	IP	IP	A	NP	A	NP	NP	S	A	US	US	US
IBM	IP	IP	IP	A	IP	A	NP	NP	NP	NP	IP	US	NP	NP	US
LG Semicon	S	S	US	S	S	US	NP	NP	NP	NP	US	NP	S	A	NP
Matsushita	IP	IP	NP	NP	A	NP	NP	US	NP	NP	A	NP	US	US	NP
Micron	IP	IP	S	IP	IP	S	NP	IP	A	NP	NP	US	NP	NP	NP
Mitsubishi	IP	IP	S	IP	IP	S	NP	A	A	NP	S	A	NP	NP	NP
Mosel Vitelic	IP	S	US	IP	US	US	US	US	NP	US	US	US	NP	NP	NP
Motorola	IP	IP	US	NP	A	US	NP	NP	NP	NP	US	US	NP	US	US
NEC	IP	IP	S	IP	IP	S	NP	NP	NP	NP	IP	US	S	IP	US
Oki	IP	IP	NP	IP	IP	A	A	A	US	NP	S	US	A	A	A
Samsung	IP	IP	IP	IP	IP	IP	NP	NP	NP	NP	IP	USA	US	US	US
Siemens	IP	IP	IP	IP	IP	A	A	A	A	US	US	US	NP	NP	NP
Texas Instruments	IP	IP	S	IP	IP	US	NP	NP	NP	US	IP	US	NP	NP	NP
Toshiba	IP	IP	A	IP	IP	A	NP	NP	NP	NP	IP	A	IP	IP	A

IP = In Production S = Samples A = Announced US = Under Study NP = No Plans

Source: *Electronic Business Asia* 1996.

yields and processing techniques (Miura, 1996). Since 1989, Hitachi has licensed DRAM technology to and purchased memory chips from LG Semiconductor. The relationship between Hitachi and LG Semiconductor also deepened when they agreed in 1996 to build a joint venture fabrication facility in Malaysia to build 16M DRAMs. Ultimately, the venture was canceled due to the deteriorating DRAM market (Mitsusada, 1996: 19).

Little has been written about the organization of production in Korean semiconductor fabrication facilities. The most detailed study available in English is by Brown (1996). Because the study was anonymous, it is difficult to be sure which Korean firms were studied, but the results are extremely interesting. Brown (1996: 219) found that, in Korea, 'operator jobs are strictly segmented from technician jobs. Women, who live and work at the company for only three to five years before quitting to get married, are operators; men, who usually have long careers with the company, are technicians.' Males are the technicians and engineers and usually are long-term employees. Moreover, Rascher and Brown (1996: 106–7) found that activities such as equipment maintenance and statistical process control were confined to equipment and process engineers and operators were not involved. They concluded that the way the Korean DRAM factory in their sample manages to be a high performer is to have a 'high ratio of equipment to process technicians to help the operators at each piece of equipment' (Rascher and Brown, 1996: 109). This labour pattern conforms to the one we described earlier as characteristic of Korean industry. This contrasted with Japanese firms that invested far more actively in upgrading their operators.

Korea did not innovate to enter the semiconductor industry; rather, it joined as a latecomer. Its late arrival meant Korean firms could acquire knowledge from foreign incumbents. In DRAM production there are two difficult tasks: design and manufacturing. Korean firms initially purchased designs from foreign companies aided by the fact that many US companies were abandoning DRAMs production because of Japanese competition and thus were willing to sell technology. For example, when Samsung decided to enter the DRAM business, it purchased designs for its 64K and 256K DRAMs from the then fledgling US firm Micron Technology, and process technologies from a Japanese firm (Y. Choi, 1994: 109). Goldstar and Hyundai also licensed 64K DRAM designs from US firms. According to one estimate, Korean firms signed a total of 53 technology transfer agreements. Forty-eight agreements involved wafer fabrication technologies, 33 with US firms and 13 with Japanese firms (Mathews, 1995: 132–3).

Korean firms pay more than ten per cent of the total value of their chip production in royalties to US companies, and another two per cent to Japanese companies (Byun, 1994: 120). Perhaps the longest running and most expensive patent-related relationship has been Samsung's licensing of Texas Instruments (TI) patents. In 1990, Samsung signed a five-year licensing agreement with TI. In early 1996, after the 1990 agreement expired, Samsung refused to renew its licenses, but by November an agreement had been reached committing Samsung to approximately $1 billion in royalty payments for the next decade. Samsung also had to pay $105 million for the three quarters of 1996. This is an improvement because, in 1995, it was estimated that Samsung paid TI between $300 and 350 million (Electronics News, 1996). Samsung's success in lowering its licensing and royalty costs are a measure of its growing research and manufacturing muscle.

The most important source of knowledge for the development of a DRAM industry was a set of listening posts and laboratories Korean firms established in the Silicon Valley (Y-S. Kim, 1995; L. Kim, 1996; Kirk, 1994). These institutions performed a variety of functions: they provided Korean firms a presence in the leading semiconductor production region in the world and they allowed the recruitment of personnel not only for the Silicon Valley facility, but also for the Korean operations.

Korean firms borrowed extant knowledge quite freely with little regard to intellectual property laws. Often, they had only two choices: use the intellectual property and pay the penalties if shown to be guilty, or bargain with companies that did not wish to license. Generally speaking, they simply used the technology. The result was Korean firms lost court cases or settled by paying significant royalties and licensing fees. For example, American Micro Devices (AMD) and Hyundai recently settled litigation regarding Hyundai's hiring a dozen AMD employees from its flash memory division that were alleged to have taken trade secrets with them (Hardie, 1996). The Korean strategy of hiring personnel to get access to their expertise led to situations in which it was difficult to distinguish the employee's trade secrets from the employee's expertise, so when hiring skilled engineers it was quite possible to transgress laws on intellectual property.

The final important method of acquiring semiconductor industry knowledge is to purchase it embedded in production equipment. Semiconductor production requires sophisticated equipment developed through intense communication between the users and equipment makers – in other words, these producer goods have much knowledge embedded in them. A knowledge transfer occurs when Korean firms purchase equipment from overseas vendors and the vendors' engineers and technicians install it in Korea. This provides Korean engineers with an opportunity to learn from the vendors, whose equipment already operates in state-of-the-art factories. In the late 1980s, a number of US start-up companies such as Synopsys and Cadence Design began selling semiconductor design automation tools, providing yet more tools and another source of knowledge. Korean firms, especially Samsung, were desirable customers because they paid top prices for the best equipment and software (Y. Choi, 1994).

With the collapse of the Korean economy and especially the won, this strategy of moving to the leading edge by importing knowledge embedded in foreign equipment looks less brilliant than it did in 1994 and 1995. The difficulty Korean semiconductor makers face in 1998 is that according to some estimates only about 15 per cent of the cost of manufacturing a DRAM comes from Korean labour and supplies. The rest is expensive manufacturing equipment and other costs paid in foreign currencies. Today, the Korean firms can export, but because of the price collapse they may not recover the cost of their capital equipment. This means they will have great difficulty buying new equipment, which must be paid for in yen or dollars (Wade, 1997: 44). And, it is unlikely that either the US or Japan will be willing to rescue the Korean firms they blame for the current over-capacity in several industrial sectors including electronics.

To enter the semiconductor industry, the *chaebol* were willing to invest without regard to initial losses. The deep pockets of the *chaebol* enabled them to bear huge losses and continue investing. An example of the magnitude of these losses is the $345 million Hyundai lost on its initial attempt to enter the memory business through an investment in a Silicon Valley fabrication facility in the early 1980s (Perry, 1987: 36). Similarly, Samsung invested billions before it became profitable. LG also lost significant sums. Hyundai and LG have recently admitted the difficulty of continuing separately in the semiconductor industry and agreed to merge their operations. Korean firms saw losses as necessary to enter the industry and accumulate knowledge. They did accumulate knowledge and were able to capture a leadership role in DRAMs just as the market collapsed. The Korean strategy was successful, but at what cost?

Discussion

The lesson that most observers take from the Korean experience (and the lesson most Koreans believed until the catastrophic meltdown at the end of 1997) is that government policy made a crucial difference. There is, however, another lesson that may be even more important: namely, there must be a market for the entrepreneur's products, and entrepreneurs must be able to see that it is possible to succeed. The US provided Korea with the market, Japan provided the example, and both were crucial sources of expertise. Korean firms have proven capable of rapid absorption of knowledge from overseas and shown an ability to join the global front-runners. The next objective is to take the knowledge created in DRAMs and broaden it to other classes of integrated circuits. Saving Korean assembly-based consumer electronics operations may be more difficult, as worker involvement in quality control and process improvement continues to be weak and their design capabilities are limited.

The reasons for greater Korean success in semiconductors than in televisions were multifaceted. As a consumer product television sales were influenced by brand name and design; even in 1998, the quality and design of Korean televisions remained marginal when compared to Japanese televisions. As a result, Korean firms were forced into OEM relationships at the low-end of the marker and cannot secure shelf space with retailers. Also, they could not build strong distribution channels. In contrast, a DRAM chip is a commodity where brand is irrelevant and marketing channels are far easier to penetrate.

In a curious way, though DRAM technology is far more complex, the value-chain is easier to master. Much of the production knowledge is embedded in equipment and the inputs are basic materials. Relationships to suppliers are important, but nearly all the suppliers are large multinationals. In the case of televisions, there are more components and concomitantly more SMEs involved. Proximity to highly capable suppliers is an advantage. Here, Korea's weak small and medium-sized enterprises (SMEs) are a handicap. In contrast, Japanese SMEs developed deep pools of expertise, much of which is tacit, enabling them to produce cutting-edge electronics components of the highest quality. The long-term co-operative relationships with Japanese assemblers mean that they receive first access to new developments.

In television and semiconductor production continuous improvement activities are important. However, because of the capital intensity of semiconductor production, engineers can be used for these activities. Also, chip design is extremely important, so Korea was able to utilize its excellent élite engineers. In a television assembly facility it is simply uneconomical to have such intensive use of highly paid personnel. Here, the Korean labour relations system is a significant handicap in products requiring relatively complicated assembly lines because workers are not contributing suggestions for improvement.[15]

Still, by all measures, Korea has successfully entered the first rank of global electronics producers. Korean electronics firms used a wide variety of technology transfer methods to accelerate their learning. In co-operation with the Korean government, this learning was concentrated in the largest *chaebol* firms. This concentrated capability, combined with the immense capital resources of the *chaebol*, enabled Korea to create some peaks of excellence. One result of the current economic crisis is that the brute-force strategy of enticing markets at any cost will never again be viable. New strategies for learning are now necessary.

The knowledge and learning congealed in Korean institutions also conceals some significant weaknesses. The *chaebol*-related companies centralized nearly all the Korean capital, resources and knowledge. Moreover, within the firms, knowledge and power was concentrated at the top. This means that the *chaebol* can mobilize the resources to enter capital-intensive new businesses. The converse is equally true. The smaller firms and suppliers are dependent and, in global terms, significantly less capable. The imponderable question is whether the future of the global economy belongs to huge centralized juggernauts or more nimble competitors. The 1998 price drop in DRAM chips followed by a collapse of the financial system has exposed the weakness of the Korean strategy based on massive borrowing to enter extremely price competitive commodity markets.

In the firm, the knowledge-generation capability seems to be similarly concentrated in higher-level management and the significant investment in formal R&D. Workers, though well educated, generally received little training (the exception being senior supervisors). Their upward mobility was capped by their educational attainment and not ability – a sure guarantee that shop-floor knowledge will be truncated. Combined with the hierarchical autocratic management system this means that an entire sector of the Korean work force is not mobilized to participate in the knowledge economy.

Korea has definitely and powerfully mobilized for knowledge importation, absorption and, most recently, with the beginning of indigenous R&D, the creation of new knowledge. When this article was initially submitted in April 1997, I argued that Korea had a most difficult problem, namely changing a successful system. With the crisis that began in late 1997, the system has been shown to have reached its limits (for an early and brilliant exposition of this conclusion, see Ernst, 1994). To become a stable economy, Korea will need to broaden its technological base to encompass smaller firms. The long record of government failure in 'assisting' smaller firms and suppliers argues for a more general deregulation and removal of the state from decisively biasing economic activity toward the *chaebol* and central family-based control. In the labour arena, the state must encourage business and labour to develop the compromises necessary to establish a less confrontational environment. Korean militaristic centralism may have been the basis of success, but it also has led to nepotism, the encouragement of centralized learning for managers (while discouraging learning among workers and SMEs), and an unhealthy secrecy.

Beyond the crisis, there is the possibility that the developing networked information economy will force changes upon Korea. This has already occurred in the US as companies have moved to empower manufacturing workers. Similarly, Japanese companies are being forced to become more transparent and the *keiretsu* system continues to decline in importance. The centralization of Korean firms and their intra-*chaebol* links that previously were integuments of strength were by 1998 the bonds of inflexibility. In a certain manner, the pervasive secrecy in Korean society and the division between North and South Korea are typical of the divisions and boundaries characterizing Korean industry – such as the divisions between factory and white-collar workers, *chaebol* assemblers and suppliers, and the various *chaebol*. During the last four decades, Korea has had repeated inflection points where it has had to change direction to continue its development process. In each case, Korea has successfully managed the transition. The challenge is to do it again.

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NOTES

1. The fundamental statement on evolutionary economics is Nelson and Winter (1982).
2. Porter (1990) captures this in his 'diamond' structure for explaining the competitiveness of national industries.
3. It is not within the purview of this paper to discuss the limited nature of this borrowing. In fields such as industrial relations and supplier relations the borrowing was far more limited. Also, because of the different environment, even where institutional forms were borrowed, the actual routines inside the forms mutated quite dramatically. Where forms were borrowed, their content was dramatically different.
4. For a discussion of the nature and organization of the *chaebol*, see Amsden, 1989; Janelli, 1993; Soon, 1993. The *chaebol* are highly diversified, though the member firms are controlled from a central office. The *chaebol* practice what Hamilton and Biggart (1988), among others, have called 'one-setism', meaning that the *chaebol* aim to develop a presence in as many businesses as possible.
5. For an excellent general discussion of the *chaebol*, see Kang (1996).
6. Of course, the credit crunch of 1997–8 is caused by the debt the *chaebol* amassed due to reckless borrowing and over-investing even when there was no prospect of profit.
7. I thank Haeran Lim for making this point.
8. According to Westphal *et al.* (1979), for 1967–76 Korea received less investment than did Taiwan, Brazil and Mexico.
9. Some Korean managers who started in the foreign firms left and joined Korean firms, 'bringing their technical skills with them' (International Labour Organization, 1988: 141–2).
10. Often, where Korean electronics brand names are known, their reputation for quality is insufficient to warrant high prices. In the world's largest electronics market, the US, Korean brands do not have strong positive images, despite the fact that Korean components and even OEM products are sold under the labels of US and Japanese firms with their strong brand images.
11. Kenney and Florida (1988) discuss the manner by which the Japanese management system emerged out of the chaos and confrontation in early post-war Japan.
12. Korea entered the transistor radio business but was not a leader, being beaten by Hong Kong and, to a lesser degree, Taiwan.
13. The 1978 US ITC ruling limiting imports of televisions and knock-down television kits forced the Korean and Taiwanese industry to reorient production to computer monitors (US ITC, 1984), a commodity in which the two countries continue to be the leaders.
14. All calculations were made at $1=800 won.
15. The current difficulty of the Korean automobile industry is instructive, because it is an even more complicated assembly process.

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