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Enhancing Productivity through Innovation: Korea's Response to Competitiveness Challenges

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경쟁력 도전에 대한 한국의 대응
-혁신을 통한 생산성 향상-

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ABSTRACT

Korea is far behind other OECD countries in economy-wise productivity: Korea's labor productivity in terms of GDP per hour worked is the lowest among OECD countries. Against the existing productivity gap, there is a worrying sign in Korea's investment trend – rapid fall in machinery and equipment investment with slow increase in R&D investment. The challenge facing Korea is how to transform her economy from catching-up model to a knowledge-based one. The paper shows that, in tandem with the structural changes that today's Korean industries are experiencing, industry's innovation system is also changing. Innovation networks are emerging as the result of economy-wise restructuring since the financial crisis of 1997 and, though still not a dominant force, the newly emerging innovation networks will be the main threads of industry's innovation activities in the future. The changes in industrial innovation system would positively contribute in raising the productivity of the Korean economy. The paper contains a case study on Korea's automobile industry in order to highlight some of main characteristics of the structural changes, in addition to a chapter that gives an overview of the evolutionary paths of the Korea's industrial innovation. The paper assesses that changes can be considered as a positive sign of future growth perspective; but there are further challenges to make the Korea's industrial innovation system effective. The list of such challenges includes strengthening upstream sectors of currently leading industries, expanding the innovation base to SME and promoting technological co-operation between domestic firms and foreign firms.

한국경제는 경제전반의 생산성에 있어서 OECD 국가 중 최하위에 있다. 이러한 생산성 격차와 함께, 한국경제는 구조변화를 경험하고 있다. 설비투자는 급격하게 감소하고 있는 반면, 연구개발투자는 크게 확대되고 있지는 않다. 한국이 당면한 과제는 과거의 추격성장전략에서 지식기반경제로 전환하는 것이다. 이를 위한 과제는 무엇인가? 본 논문은 이 과제를 혁신을 통한 생산성 제고라는 측면에서 검토하고 있다. 외환위기 이후 한국의 산업혁신시스템의 괄목할 만한 변화의 하나는 혁신네트워크가 새롭게 등장하고 있다는 것이다. 이러한 혁신네트워크는 향후 산업혁신시스템의 중핵으로 자리할 것이며, 한국경제의 생산성 제고에 긍정적으로 기여할 것이다. 본 논문은 자동차산업에 대한 사례를 통하여 이러한 변화를 명시적으로 보여준다. 향후 한국 산업혁신시스템의 강화를 위해서는 산업의 상위부문의 강화, 중소기업의 혁신기반 확대 및 국내기업과 외국인기업 사이의 기술협력 촉진이 필요하다.

I. Introduction

The production systems in the East Asia that have prevailed over the past years are dissolving rapidly, and the world economic environment is also changing rapidly. The rapid advances of information technology (IT) are enabling to overcome the limitations of physical distances and thereby to organize the production activities more effectively through the global supply chains. In line with the forces of globalization and IT revolution, the integration of low-cost economies to the world economy raises new challenges to national economies, in particular to Korea, forcing them to move towards knowledge-based economies. It is not sure how long Korea can maintain international competitiveness in her flagship exporting products such as textile, automobile and IT products. We have found that the basis of international competitiveness of the Korean exporting products is not so strong and Korea needs to find out new engines of growth. (KDI, 2003) The challenges faced by today's Korean economy would be termed as, in need of better words, the transition from the catch-up model to an innovation-driven economy. What are the requirements for a successful transition?

As the productivity increase is regarded as crucial factor for long-term economic growth, the process of innovation, a broad concept of productivity increase, not only attracts the attention of academic research but also it becomes recognized as an important policy issue. For instance, comparing the economic performances between Europe and US from a long time-horizon, Gordon (2004) concludes that whether the process of input accumulation comes up with the sustained growth critically depends on the pace of innovation. Productivity increases seem to be closely related to the increases in capital-labor ratio, but capital accumulation without innovation does not end up with economy-wise increases in productivity. More comprehensive research of OECD (2001 and 2003a) on the sources of economic growth also concludes that, in addition to the accumulation of production inputs, differences of economic growth are critically depends upon some institutional and system factors that governs the pace of technological advances. The list of those factors includes not only the quality of production inputs, it also broadly includes such institutional factors as the education system that produces better qualified human resources and the research and development (R&D) system that promotes industrial innovation and diffusion of new technologies.

In terms of economy-wise productivity, Korea is far behind other OECD countries. According to OECD (2003b), controlling the effect of labor utilization, Korea's labor productivity in terms of GDP per hour worked is the lowest among OECD countries. Against the existing productivity gap, we have seen a worrying sign in Korea's investment trend. It is worth reminding that Korea has shown very high machinery and equipment (M&E) investment ratio in the past years, but the trend is reversing recent years. Compared two period between 1993-1997 and 1998-2002, OECD economies on the average has increased M&E investment from 9.4% to 10.8%, in terms of percentage average as of GDP. In contrast, Korea has shown

decreases from 13.8% to 11.2%. Concerning business R&D investment, most of OECD countries have shown an increasing trend and Korea as well but not enough to compensate the decreases in M&E investment.[1]

Does the changes in investment structure outlined above imply only the fact that the Korean economy is being matured? Is there any sign that hints more fundamental changes in industry?

This paper will show that, in tandem with the structural changes that today's Korean industries are experiencing, industry's innovation system is also changing. Innovation networks are emerging as the result of economy-wise restructuring since the financial crisis of 1997 and, though still not a dominant force, the newly emerging innovation networks will be the main threads of industry's innovation activities in the future. The changes in industrial innovation system would positively contribute in raising the productivity of the Korean economy. The paper is organized as follows. Section 2 will summarizes the main features of structural changes in Korean industries as a background for the later sections. This section includes the case of automobile industry in order to highlight some of main characteristics of the structural changes. Section 3 will give an overview of the evolutionary paths of the Korea's industrial innovation. This section would help understand the implications of the newly emerging industrial innovation system, which are documented in section 4. Section 4 focuses on the changes in industrial innovation system with special attention on SMEs and the innovation networks among firms. The section also includes case study on SMEs in automobile industry. The changes can be considered a positive sign of future growth perspective but there are further challenges to make the Korea's industrial innovation system effective. Section 5 concludes the paper by discussing the implications of changes in industrial innovation system.

II. Structural Changes in Korean Industry[2]

The Korean economy has experienced gradual changes in its industrial structure since the 1980s, where, as the industrialization process matured, the share of manufacturing became saturated while service sectors as a whole tended to take more portion in gross economic activities. The manufacturing sector has started to account for smaller shares in the late 1980s. However, its shares have recovered to the previous level after starting to increase in the second half of the 1990s: the manufacturing sector has shown the high growth rate since the mid-1990s. And productivity in the manufacturing sector has been greatly improved; particularly, high productivity increase is found in manufacturing firms that survived the financial crisis with successful restructuring.

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[1] The data in the text are based on two sources: www.sourceoecd.org and OECD *Main Science and Technology Indicators*.

[2] This section reports the findings of KDI project on Korea's industrial competitiveness. For more details, see KDI (2003).

Over the long-term period, the manufacturing sector maintained a stable level, whereas the service sector has been stagnant. Above all, productivity in the service industry is lower than that of manufacturing. In this regard, even though the service industry takes a larger share in terms of employment, its share is constant in terms of added value. This fact implies that enhancing productivity in the service sector is the crux of raising the overall economic growth rate.

Within the manufacturing industry, intervals of business scales widen both in inter- and intra-sectors. Its expanding gaps in inter-sectors are the most evident in inter-sectoral differences in terms of growth rate and total factor productivity (TFP) growth. The electronics and automobile sectors lead a large part of the growth rate of the manufacturing industry and TFP growth. Especially, these growth rates are ascribable to the rapid productivity increase mainly by large conglomerates since the 1990s. Furthermore, according to findings of productivity analysis of manufacturing by sub-sectors and by five groups of firm-scale, the higher growth rates are found in electronics and automobiles, with the larger share led by conglomerates. And these conglomerate firms make a higher contribution to the growth rate of productivity and increasing productivity. These analysis results show that large conglomerates are expected to maintain the leading role in the growth of the manufacturing industry for the time being. In contrast, except for the smallest firm-cohort with less than 10 employees, smaller firms show poor records in productivity growth. The productivity improvement of smaller firms is an important task for sustainable growth and improvement of the competitiveness in manufacturing in general.

The phenomenon of widening gaps among inter-sectors and inter-firms which we call bifurcation or polarization is also identified in the analysis of financial structure. According to the results analyzing financial stability and profitability from 1990 to 2002, while both total assets and tangible asset investments have been on a downwards trend since the financial crisis, the gaps widen between large conglomerates and SMEs. In addition to this deepening polarization, signs of a decrease in increasing rate of tangible assets give rise to apprehension in light of an expansion of growth potential. However, as KDI study noted in the chapter reviewing R&D activities of firms, we have found a positive sign of the possibility that the Korean economy is in the process of transforming into an innovation-driven economy as the number of technology-intensive SMEs dramatically increases after the financial crisis.

1. Widening Productivity Gaps

We used the plant-level manufacturing survey data for 1984-2001 compiled by the National Statistical Office. The data were re-compiled according to the 29-sector classification system of the KDI Multi-Sector Model, and, for five major industries, the data were rearranged into sub-industries according to the supply chain in each industry. The plants were classified into five categories according to the number of workers, and the analysis was performed for three sub-periods; 1985-89, 1989-97 and 1998-2001. We estimated both single-factor productivity, such

as labor productivity and capital productivity, and total factor productivity (TFP), which was estimated by both the growth accounting method and multi-lateral method.

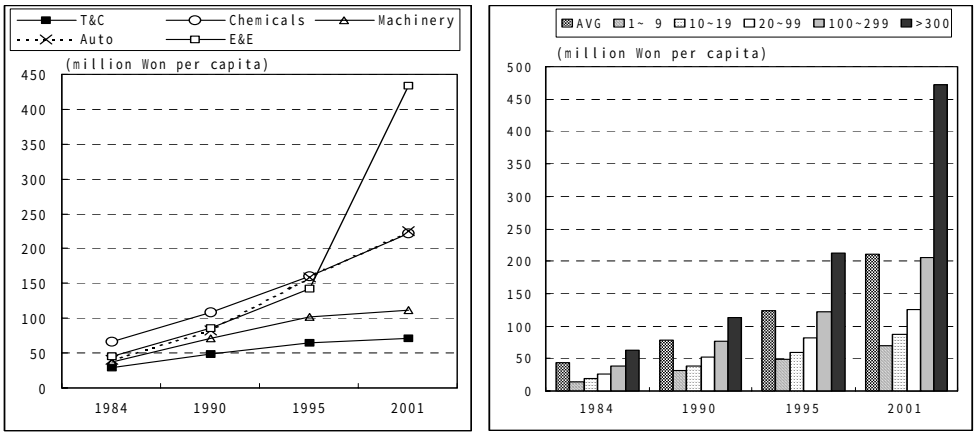
(1) Labor Productivity: Huge gaps of labor productivity were observed among industries and among size groups. The basic metals and electronics industries showed high labor productivity while textiles and garments, metal products, precision instruments industries showed a low level. We could also find that larger plants recorded higher labor productivity for the entire period, and that the gaps are widening. Analysis on the growth rate of labor productivity also showed a similar pattern. Specifically, the electronics industry showed an overwhelmingly high growth rate, and machinery and transportation equipment industries showed comparably high growth rates, while textiles and garments, paper products and publishing, and metal products industries recorded extremely low growth rates. Overall growth rate has persistently risen, with an exceptionally low growth rate right after the economic crisis. Analysis on the growth rate of labor productivity by plant size reveals an important result. We found that, over the entire period, larger plants recorded higher growth rates. However, we found, in addition, that smaller plants showed higher growth rates in the first sub-period (1985-89), that this trend reversed in the second sub-period (1989-97), and that the gaps widened in the third sub-period (1998-2001) when productivity growth was led mostly by large firms.

(2) Capital Productivity: Capital productivity shows a relatively stable time-series, and the gaps among industries and among firm sizes are reducing, except for several industries. Capital productivity by plant size shows an “inverted U” shape, i.e., the plants with medium size show the highest capital productivity.

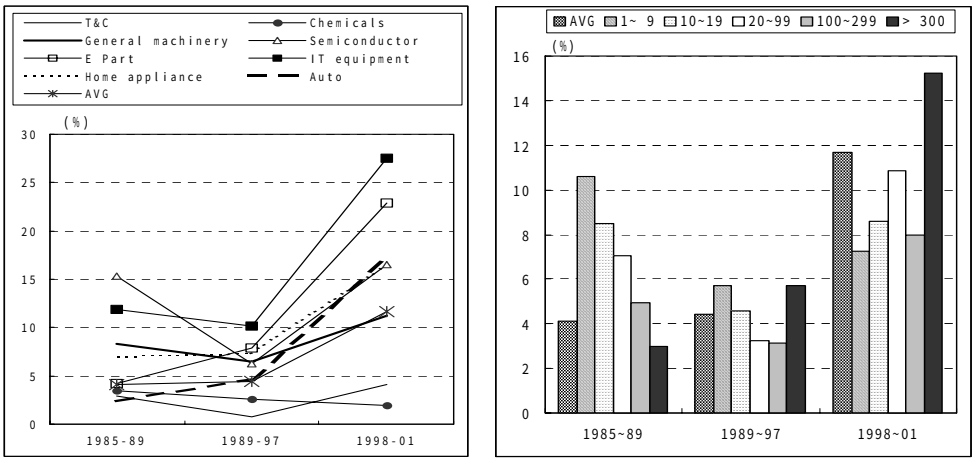
(3) Total Factor Productivity (TFP): Annual average growth rate of TFP for 1985-2001, computed by the growth accounting method, for the entire manufacturing sector was estimated to be 4.33 percent. It was estimated slightly higher than 4 percent until the late 1990s, but rose sharply up to 11.68 percent after the economic crisis. The food and beverage, textiles and garments, and precision instrument industries showed slow TFP growth for the entire period, while the electronics industry showed an extremely high TFP growth rate, high enough to lead the TFP growth of entire manufacturing sector. The machinery and transportation equipment industries, in addition to electronics industry, also recorded high TFP growth rates, and these industries recorded remarkably high TFP growth in late 1990s. Growth pattern of TFP by plant size shows a trend highly similar to that of labor productivity. That is, smaller firms revealed higher TFP growth rates in the first sub-period, but the trend reversed in the second sub-period, and the gaps widened in the third sub-period. Estimation by multilateral index method showed almost the same results.

In conclusion, it can be said that the growth and technological progress of the manufacturing sector has been led by the electronics and automobile industries, and, in particular, by the fast productivity growth of large firms in the 1990s. This can be explained by the fact that the shares of large firms are relatively big in the industries with fast productivity growth. It is expected that the growth of the manufacturing sector led mostly by large firms will persist for the time being. At the same time, however, it is necessary to pay special attention to the increasing

[Figure 1] Labor Productivity by Industry and Firm-size



[Figure 2] Total Factor Productivity Growth by Industry and Firm-size



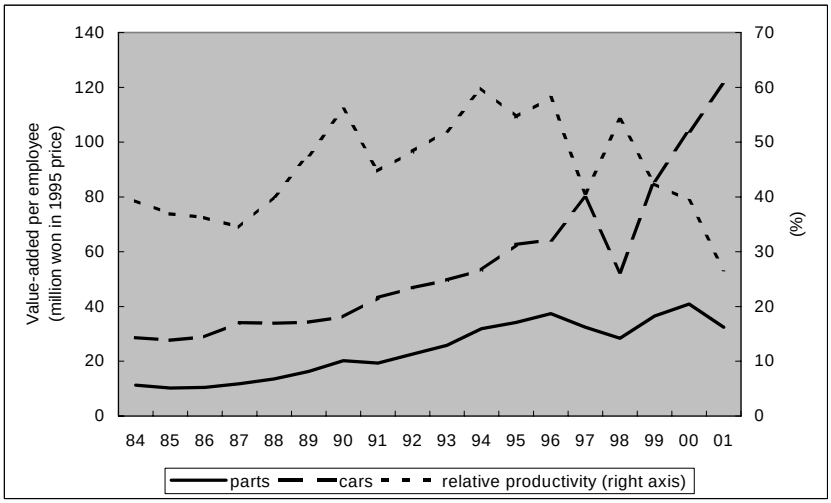
Note: T & C = textile & clothing, E & E = electrical & electronic products.

share of smallest firms and to the slow productivity growth of medium-size firms (with 100 to 300 workers). It would be impossible to sustain a high growth rate and improved competitiveness in the manufacturing sector without sufficient productivity growth of small- and medium-size firms.

2. The Case of Automobile Industry

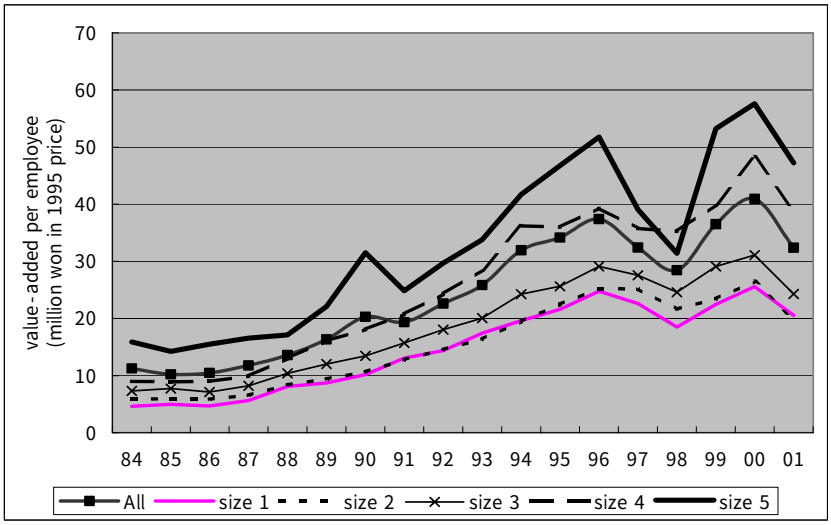
Labor productivity of parts producers has been increasing since 1980s. As is

[Figure 3] Labor Productivity of Automobile and Parts Industry



Note: Relative productivity = parts / cars×100.

[Figure 4] Labor Productivity of Automobile Parts Industry, by Size of Firms



Note: size 1 = 1~9 employees, size 2 = 10~19 employees, size 3 = 20~99 employees, size 4 = 100~299 employees, size 5 = more than 299 employees.

shown in Figure 3, it had peaked at the year of 1996, and decreased for two years from 1997 and 1998. The growing trend seems to be resurrected after the financial crisis, despite a sharp decrease in 2001. Since 1997, labor productivity in the domestic automobile industry has revitalized its growth trend. The labor productivity in the complete cars industry has been increasing rapidly and productivity in the parts industry has been maintaining a steady growth trend. However, the productivity gap between the two sectors is ever increasing. In 2001, the value added per capita in the domestic automobile industry recorded the highest level it has ever been. Despite productivity in the parts industry continually growing, it has not yet recovered to previous levels before the financial crisis. It is interesting to compare the productivity trend between parts producers and carmakers. Compared to carmakers, the parts sector has improve its relative labor productivity until 1990 when it was reached 56% of carmakers. For the 1990s, the parts sector had maintained around 55% of productivity level compared to carmakers, with some fluctuations. The productivity gap has been widened since 1998. Within the parts sector, there are great productivity differences among size-groups of firms. Large firms and medium-sized firms with 100 to 299 employees show more than sector-average productivity levels over the years, with exceptions in the 1980s. In contrast, smaller firms show lower than sector average productivity levels.

The productivity gap between the different size-groups has been maintained with short fluctuations. What are the factors underlying the persistent productivity gap in automobile parts industry? An immediate message is that scale economies are prevailing in the automobile parts industry. We will review several aspects of production activities in two sectors, which shows structural differences between them. And we will investigate the TFP trends in two sectors, which is a source of persistent productivity gap.

TFP level of the complete vehicle manufacturers, by both methods of growth accounts and multilateral index, has been increasing for last 10 years. In case of the parts industry, it experienced a drop during the period 1990-97, and since the crisis, has been on an upward trend. Until the mid 1990s, the TFP level of the vehicle industry was lower than the parts industry's, mainly due to over investments made by many vehicle manufacturers. After the crisis, the vehicle industry's TFP growth has increased rather rapidly, while the parts industry has experienced little change. As a result, the TFP gap between the vehicle and parts industry has widened. According to the analysis by way of the growth accounts method, the TFP growth of large companies has greatly increased almost to the level of 1980s following the crisis, while that of SMEs shows a decreasing trend. However, when applying the multilateral index, excluding small firms with less than 10 employees, the rest of the companies in the industry have shown a growth tendency. The TFP growth of large firms has increased at a fast rate. As a result, the TFP gap between the vehicle and parts industry widened.

Table 2 shows four indicators that characterize the structural differences between parts producers and carmakers. The first indicator is capital-labor ratio, the value of equipment capital per employees[3]. Carmakers are more capital-

[3] Capital-labor ratio can be calculated by using different measures of capital stock, including land, plant and

<Table 1> TFP Growth

(unit: %)

	Growth accounting				Multilateral index approach		
	1985~1989	1989~1997	1998~2001	Whole period	1985~1989	1989~1997	1998~2001
size 1	9.77	7.51	4.76	5.47	1.02	1.18	4.48
size 2	5.62	7.16	-2.41	3.44	-0.57	1.51	-0.90
size 3	2.03	4.91	2.13	2.05	-2.21	0.72	1.60
size 4	5.76	4.00	2.69	3.06	-0.14	1.01	2.69
size 5	11.07	0.53	12.08	2.94	2.83	0.57	1.88
Parts	7.34	2.89	4.75	2.57	1.01	0.74	1.97
Cars	-0.89	4.99	25.99	2.91	-0.96	2.50	6.27

<Table 2> Structural Characteristics

	Capital-labor ratio[1)]		Labor income share to Value-added (%)		Average income per employee[2)]		Share of exports to sales (%)	
	1990	2001	1990	2001	1990	2001	1990	2001
size 1	8.27	18.63	52.69	79.12	8.41	20.00	7.99	2.35
size 2	8.73	18.75	47.41	78.25	7.82	18.28	1.49	6.99
size 3	12.01	23.33	42.26	68.93	8.60	19.86	4.72	9.16
size 4	15.37	43.68	40.99	60.79	11.07	27.89	8.57	21.90
size 5	19.39	66.10	32.15	70.67	15.23	38.85	8.83	26.95
Parts	14.91	36.83	37.15	67.43	11.36	25.73	7.66	18.91
Vehicle	31.51	97.41	43.40	32.22	21.72	46.59	21.94	46.68

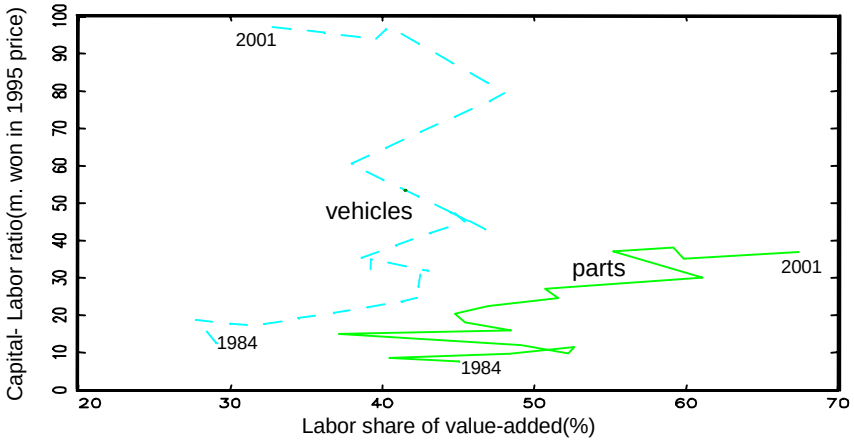
Notes: size 1 = 1~9 employees, size 2 = 10~19 employees, size 3 = 20~99 employees, size 4 = 100~299 employees, size 5 = more than 299 employees.
1) Equipment stock per employee in million won, 1995 constant price.
2) In million won, 1995 constant price.
Source: Calculated from National Statistical Office, Manufacturing Census, each year.

intensive than parts producers - on the average workers in the former has capital equipment around 2.6 times than those in the latter sector, a high increase from 2.1 times in 1990. In terms of capital-labor ratio, the gap is also widening between carmakers and parts producers. The second indicator is labor-income share of value-added, which is measured by dividing labor compensation over value-added[4]. For the parts producers this indicator has increased greatly from 37% in 1990 to 67% in 2001, whereas for the carmakers it has decreased from 43% to 32%. two more indicators average income and exports share, also show differences

transportation equipment. But there is no substantial difference in terms of magnitude and ratio between carmakers and parts producers.

[4] Labor-income share can be calculated by dividing it to total output. But the result shows no difference on the gap between carmakers and parts producers.

[Figure 5] Growth Paths of Carmakers and Parts Producers



between carmakers and parts producers. Average income of employees in parts sector is around 26 million one per year in 2001, which is far lower than that in vehicle sector[5]. The difference between two sectors is also conspicuous in terms of exports share, which shows that carmakers are far more export-oriented than parts producers are. It is also interesting to note that there are great differences among different size-groups of firms within the parts sector: the larger the firm the more capital intensive, highly paid and export-oriented.

Figure 5 shows these two indicators over longer years, comparing carmakers and parts producers. Capital-labor ratio of carmakers has been consistently increased since the 1980s, whereas that of parts producers had slowly increased until the year of financial crisis in 1997 but has remained stagnant afterwards. Instead, parts producers show steady increases in labor share of value-added, which implies that parts producers depends more on labor in their production process. Capital deepening of carmakers and increased dependency on labor by parts producers results in widening gap in labor productivity between carmakers and parts producers.

3. Technology and R&D

The steady increase of automobile and parts exports over the years, as shown in the previous section, indicates that international competitiveness of Korea-made automobiles is also enhancing. What are the factors positively affecting the international competitiveness of Korea cars? One will be the Korean automobile

[5] Hong (2004) points out two factors for the wage difference. First, differences in labor composition – large companies are composed of more skilled workers whereas smaller companies less skilled and women workers. Second, differences in payment capability - large contractor companies have bargaining power over smaller subcontracting companies, which results in lower wages for workers in the latter. Lansbury and Zappala (1990) hint that highly paying exporting firms are subcontracting low-paying smaller firms.

parts. Being suppliers to the carmakers, the technological competence of parts producers are directly affecting the competitiveness of Korea's automobiles. There have been strong concerns over the weaknesses, in particular weak technological competence, of Korea's automobile parts producers that erode the international competitiveness of Korean cars. For example, compared with Japanese competitors, Korea's automobile parts industry as a whole seems weak in their technological capabilities in terms of R&D intensity as in Table 3 below. In contrast, Korean carmakers appear comparable to Japanese ones in terms of R&D intensity, despite the time lag of developing a new car. Considering the fact that Korea's automobile parts imports is negligible and Korean cars are using mostly Korean parts, this concern raises a contradiction. We will show that this concern is misplaced. We contend that automobile parts producers are strengthening their technological activities but there is a notable difference between those very active in R&D activities and those not, and those large companies and smaller companies. It is worth noting that not all the automobile parts producers are in this trend but there is a trend of divergence within the automobile parts industry.

R&D activities of automobile parts industry have been steadily increased from 1995 to 2002, except a sharp decrease in 1998 when the financial crisis overrode the Korean economy. The number of R&D- performing firms is increasing from 152 in 1995 to 223 in 2002. R&D expenditures of industry as a whole have also been increased, roughly two times during the same period. R&D intensity, as the ratio of R&D expenditures to sales, has not increased, compared the periods between pre- and post-crisis years, but it is partly due to the business cycles. Looking at the number of researchers, it is apparent that industry as a whole is strengthening R&D activities: number of researchers and researchers per 100 employees are in an increasing trend. The increasing trend of automobile parts industry is quite contrasting to the stagnant trend of automobile industry. Consequently, the ratios of parts producers to carmakers in terms of R&D expenditures and researchers in 2002 have reached 38% and 84%, respectively.

The following Table 5 groups automobile parts producers into four size cohorts. Average R&D expenditures of four groups increase as the size of the company increases, whereas smaller company groups show higher R&D intensities. The same pattern will be found with respect to researchers: average number of researchers increase according to the firm-size, but smaller group show higher magnitude in the researchers per employee. It is interesting to notice that average R&D expenditures per researcher do not show great differences, though smallest group shows the lowest magnitude. Now, comparing parts producers with carmakers, there are significant differences. The greatest difference is the amount of R&D expenditures and the number of researchers: even the largest group of parts suppliers spends about one-fifth of carmakers, and the number of researchers employed by parts producers are less than half of those of carmakers. It is a well-known fact that the larger the size of the firm, the more likely the firm performs R&D activities, and Korea's automobile parts producers also show the same pattern[6]. All the carmakers are doing R&D activities and it is apparent that the big

[6] According to Suh (2002), only 3.06% of Korean manufacturing firms are performing R&D activities in 2000.

<Table 3> Technology Indicators: Korea vs. Japan

(As of 2000)

		Korea	Japan
The share of R&D personel to employees	Automotive parts producers	1.6%	7.7%
	Carmakers	8.1%	8.7%
Time to develop a new car		50 months	36 months

Source: Korea Auto Industries Cooperation Association, Handbook on Korea's Auto Industry, 2002.

<Table 4> R&D Indicators of Korea's Automobile and Parts Industry

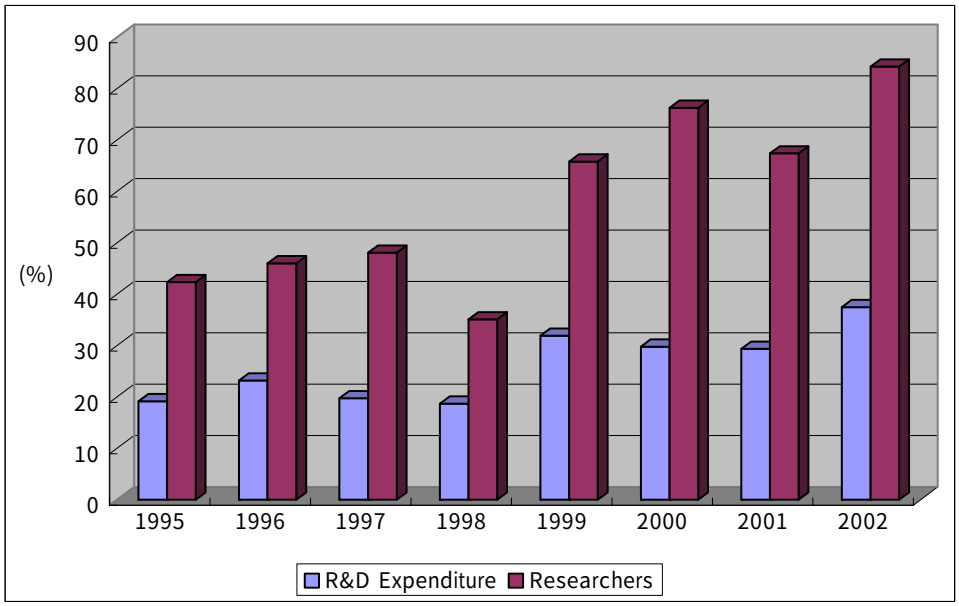
	Number of R&D-performing firms	R&D Expenditure		Researchers	
		Amount of investment (billion won)	As of sales (%)	Number of persons	Per 100 employees
Automobile parts industry					
1995	152	236.16	2.41	3074	3.97
1996	168	346.71	3.02	3700	4.96
1997	156	324.71	2.76	3746	5.46
1998	119	231.32	2.95	2772	5.62
1999	140	272.02	2.13	4001	6.94
2000	167	330.08	1.64	3998	6.11
2001	193	320.49	1.91	3818	6.20
2002	223	447.61	2.07	4748	7.16
Automobile industry					
1995	15	1230.70	4.91	7261	5.69
1996	17	1494.88	5.17	8047	6.15
1997	14	1644.84	5.69	7793	7.71
1998	11	1237.68	7.83	7897	9.51
1999	12	852.17	2.90	6079	5.27
2000	12	1108.28	3.02	5241	5.42
2001	24	1091.07	2.51	5665	3.68
2002	19	1194.37	2.44	5633	5.53

Source: Author's calculation from the raw data from Ministry of Science and Technology, *Report on the Survey of Research and Development in Science and Technology*, each year.

size of carmakers gives an advantage of mobilizing R&D resources, compared to smaller parts producers.

The size distribution is as follows: 1.9% for firms with less than 100 employees, 25.6% for those with 100-299 employees, 64.2% for those with 300-999 employees and 94.8% for firms with 1,000 or more employees.

[Figure 6] The Ratio of Automobile Parts Industry to Automobile Industry



<Table 5> R&D Activity by Firm-size

	Automobile parts producers (By size of employee)					Carmakers
	Less than 100	100 to 299	300 to 999	1000 and more	All	
Number of firms	54	75	57	9	194	18
Average R&D expenditure (million won)	359.9	969.2	2647.7	13,668.8	1886.9	62,846.9
Ratio to sales (%)	2.63	3.81	2.30	1.78	1.68	1.88
Average number of researchers	5.8	10.9	30.3	147.0	21.5	306.2
Researchers per 100 employees	11.2	5.9	5.9	7.2	6.5	4.7
R&D exp. per researcher (million won)	62.0	88.3	87.3	93.0	87.4	205.2

Note: Three-year average from 2000 to 2002.

Source: Author's compilation from raw data from MOST.

III. Korea's Innovation System: Catching-up Model in Brief

Although Korea, as a late-industrializing country, has depended heavily on foreign technologies, Korea has also made concerted efforts to accumulate technological capabilities. When beginning to launch economy-wide economic development plan, Korea was poorly endowed with necessary factors for industrialisation except plenty of labour force. Further, technological competence of Korean firms was far below from world standard. Consequently, it was inevitable or natural to seek for foreign sources of technologies. After the industrialisation process launched in 1962, imports of foreign technologies grew remarkably. The process of technological capability building in Korea is characterised as a dynamic process of the interplay between imported technologies and indigenous R&D efforts. Reviewing the process of industrialization since the 1960's, there appears a general pattern of technological development across industries with some industry-specific variations. Table 6 presents the pattern in Korea's machinery industry. The Table shows that technology transfer and in-house R&D are two principal modes of building technological capability in machinery sector and other industries in general.

<Table 6> The Process of Technological Capability Building in Korea's Machinery Industry

	The process of development	Technology imports	Production and R&D
1960s – 1970s	Policy goal: establishment of production base Characteristics: heavy dependence on imported technologies	Packaged technology: turn-key based plants Assembling technology	Knock-down type Production system OEM-dominated Almost no in-house R&D
Early 1980s	Policy goal: promotion of self-reliance Characteristics: Import-substitution, localisation of parts/components production	Unpackaged technology: parts/components-related technology Operation technology	OEM/own brand: High ratio Product development In-house R&D starts
Late 1980s – 1990s	Policy goal: export-promotion by means of expansion of domestic market Characteristics: beginning of plant exports, learning advanced and core technologies	Materials-related technology Control technology Design technology High-quality product tech.	OEM/own brand: low ratio Product innovation Process improvement

Source: Suh(2000).

During the early stages of industrialization, technologies are imported in packaged forms. Turnkey-based plant imports were most common during those years. And assembling technologies were imported for the purpose of knocked-down assembly and/or OEM-based production. Then, afterwards, self-sufficiency of technology was enthusiastically pursued, although it was not achieved in a short period. Localization of some technologies was one of the main goals both for government and the private firms. In this period imported technologies changed to unpackaged ones and the importation of operation technology increased in order to enhance the productivity. After achieving, in some extent, the goal to promote self-reliant technologies, the next step is to let Korean products enter into world markets. In doing this, expansion of domestic markets was necessitated. In this period, imported technologies are relatively more sophisticated and advanced, and material-related technologies and control and design technologies were imported. Throughout whole periods the ratio of OEM to own brand name (OBN) has steadily decreased.

The pattern of technology transfer differs slightly across industries, particularly in the early years. Unit production industries, such as shipbuilding and machinery, mainly relied on formal transfer in the form of licensing and consultancy for the initial erection of production facilities and design of products. Mass production industries, such as electronics and automobiles, also depended on formal transfer but to lesser extent. Instead, more emphasis was placed on engineering efforts for implementation. Continuous process industries, such as chemicals, cement, paper, and steel, were established on a turn-key basis. Since then and throughout the 1970s and 1980s, technology imports prevailed, and it is still an important tool for technological innovation. Recently, however, the outsourcing of foreign technologies has become more sophisticated, and the modes of technology transfer have tended to be diversified and complex. Exchanges or alliances, for the mutual benefit of both parties, are beginning to take the place of unilateral technology imports. Further, interest in foreign technologies is shifting towards more high-tech areas and/or design technologies, and the scope of foreign partners has widened considerably.

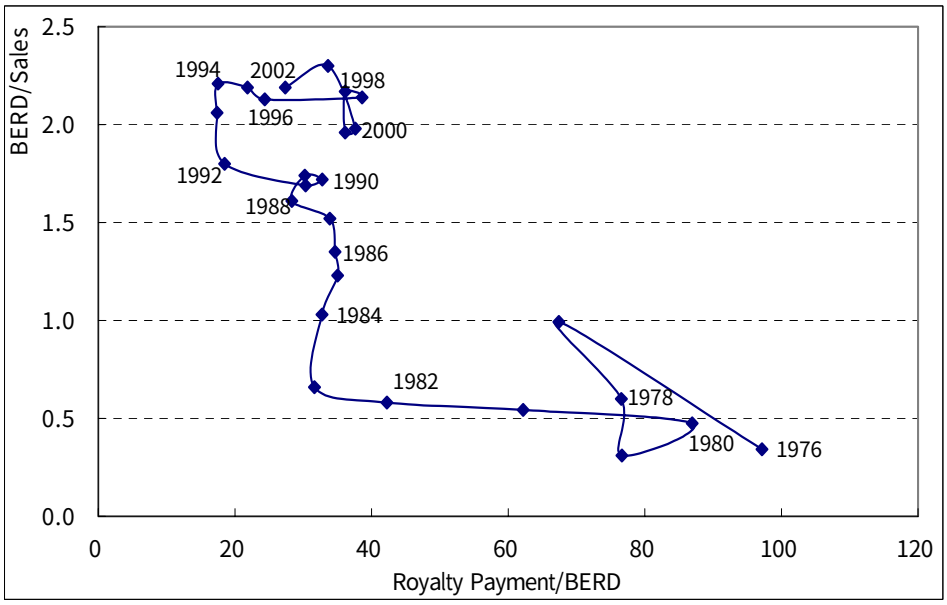
The growth pattern of private sector's R&D activities also shows a similar pattern outlined above. During the earlier period of industrialization, systematic in-house R&D efforts were hard to find out. It was not until the 1980's that Korean firms endeavoured to make efforts to build in-house technological capability via institutionalising the R&D activities. In the early 1980's R&D activities of private firms were closely related to adaptation and assimilation of imported technologies. Product development was main features of R&D in those years. Afterwards, based on accumulated experiences and knowledge, a number of firms in some specific industries have been able to make some innovations in product. In these years, efforts to improve production process have been continued.

The pattern outlined above can be clearly illustrated by Figure 7. It plots the trend of the relationship between technology imports (TI) noted as payment for foreign technology licensing fees and indigenous R&D efforts noted in terms of R&D expenditure over industrial production from 1973 to 2002. Over the years the trend changed substantially. Until the early 1980s, indigenous R&D efforts had

remained at an insignificant level; but afterwards R&D intensities have increased considerably. Consequently, the overall relationships between imported technologies and indigenous R&D effort changes from the previously substituting to complementing ones. The Figure shows that the trend of relationship changed around the year of 1982. The turning is not accidental: this year marks the launch of NRDP and since this year private enterprises have begun to establish in-house R&D laboratories.

The changing relationship between TI and R&D can be originated mainly from two sources: private enterprise's increased R&D efforts and government's policy changes. Throughout the 1980's TI increased steadily and maintained its pace. But in-house systematic R&D efforts by private sector have begun to prevail since the early 1980's. Underlying this change, three driving forces, inter alia, have been into action. First, as Korean economy moved to technology-intensive industries, foreign sourcing of technology could not meet the required technological standards. And as foreign firms tend to be more reluctant to release their technologies, it becomes harder to acquire advanced technologies solely by depending on conventional means of technology imports. Lastly, the cost advantage originated from cheap and skilled labour came to be exhausted after the early 1980's. Therefore, Korean firms tend to feel the necessity to develop their own technological capabilities.

[Figure 7] Changing Relationship between Royalty Payment and R&D (1976-2002)



Source: Author's compilation.

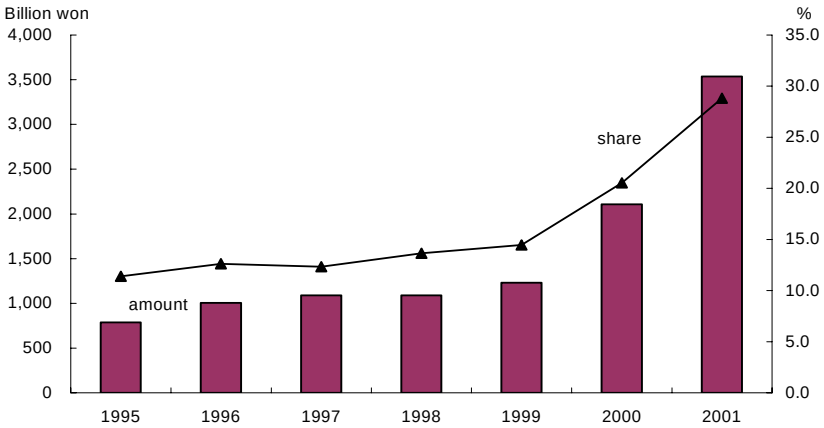
IV. The Changes in Business R&D Activities[7]

1. SMEs in transition

In the past years, large firms played a leading role in industrial R&D activities. Since the early 1980s, private enterprises began to establish in-house R&D centers, and large firms established most of them at that time. For example, the *Directory of Korean Technology Centers* published by Korea Industrial Research Institutes in 1985 listed 141 industrial R&D centers, out of which only 15 centers belonged to SMEs. Another characteristic of industrial R&D activities in past years is their mostly adaptive nature. This was mainly because R&D activities were to assist the production of mature products. Technologies invented elsewhere were transferred by licensing contracts or other means of technology transfer, and adapting those transferred technologies to the requirements of the production process was the major goal of industrial R&D activities.

The trend has changed, particularly since the financial crisis in 1997. As shown in Figure 8 although SMEs are still responsible than less than one third of total R&D expenditures, their spending is increasing more rapidly than that of large enterprises (LEs), which results in an increase in SMEs' share. During the period 1995 and 2001, SMEs' share of total industrial R&D expenditures has been doubled. Do the increased R&D spending by SMEs and their increased R&D share imply that SMEs' role in industrial innovation activities is also increasing?

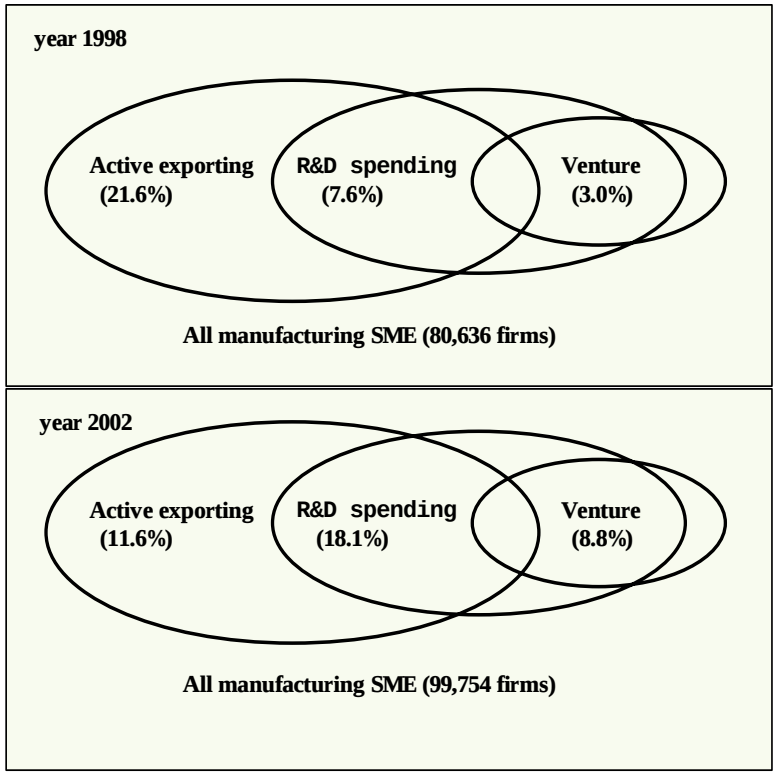
[Figure 8] R&D Expenditure by SMEs and its Share of Total R&D Expenditure



Source: Ministry of Science & Technology, *Report on the Survey of Research and Development in Science and Technology*, each year.

[7] This section is based on Suh (2003).

[Figure 9] Classification of SME by Activities



Source: Korea Federation of Small and Medium Business.

Today's SME in Korea face a challenge to strengthen their technological capabilities and thereby to move up to higher ladder of value chains. Unlike the new technology-based firms (NTBF) or those small numbers of firms that can make partnership relations with chaebols or other firms, however, the prospect for the rest of SME is not necessarily positive.

Figure 9 below[8] gives a snapshot on the current status of manufacturing SME in Korea. The figure classifies manufacturing SME into three: those that are actively exporting, those that are spending money for R&D, and those are certified as "venture". Exporting can be interpreted as a measure to indicate firm's overall competitiveness; R&D spending as a measure of firm's technological capability; and venture certification as an entrepreneurial capability to enter into a new business. Intuitive conclusions can be drawn from the figure. Most of Korean SME are home market-oriented that only about 12% manufacturing SME are actively engaged in exporting, which might imply that they are vulnerable to market opening. In terms of technological capability, about 18% SME have ever spent

[8] The data are from Korea Federation of Small and Medium Business. "Active exporting" firms are those that exporting more than 30% of total sales.

money for R&D purpose – an increase by 10 percentage point from 1998. This implies that majorities of SMEs are weak in their technological capabilities; but there is a positive sign of increase. In contrast, the fact that 9 % of manufacturing SME get the certification of "venture"- a significant increase from 3% in 1998 - might be a promising indicator for the prospect of Korea's SME in the future[9]. It is interesting to see that the share of those SMEs in active exporting category decreased by 10 percentage-point from 1998 to 2002. One possible explanation is that as more foreign firms are entering into Korea, SME are directly supplying their products to multinationals in Korea.[10] The study in the following section will give substantive evidence on the changes that Korean SMEs have experienced.

2. The Case of SMEs in Automobile Parts Industry

SMEs in automobile parts industry have usually grown as subcontractors to domestic automobile companies or domestic large automobile parts companies. The existence of automobile companies affords small and medium sized automobile parts companies, whether they are first or lower tier subcontractors, the leverage to secure home market for growth. And large automobile and parts companies had lead industry's technology development activities so that smaller parts companies had made more efforts for producing cost-effective products meeting the requirements set by the contractors. The stable relationships between parts suppliers and large companies in the automobile industry began to be dissolved even before the financial crisis. The growth of domestic automobile market had been saturated since the early 1990s when domestic demand for automobile did no longer grow as fast as the previous years. It was the automobile companies to breach the limitations of domestic market size by increasing exports; but most of smaller subcontractors had still remained inactive in exporting.

Along with market and demand conditions already in change, the financial crisis accelerated the changes and smashed the existing business relationships in automobile and parts industry. There has been a structural change in global automobile industry. Fierce competition among automobile manufacturers in the world and the changes in the way to produce automobile and to procure parts are the basic forces behind the structural changes in the world automobile industry. Korea's automobile and parts companies have sensed the changing business environment for years. It is fair to say that the financial crisis would have accelerated the restructuring in the Korea's automobile and parts companies.

First, restructuring of automobile manufacturers. The history of Korea's automobile manufacturers coincides with that of Chaebols. Backed up by the expansion strategies of Chaebols, automobile business was considered as having a strategic value for the rapid growth of Chaebols. But the aggressive expansion strategy coupled with the financial crisis placed most of automobile companies

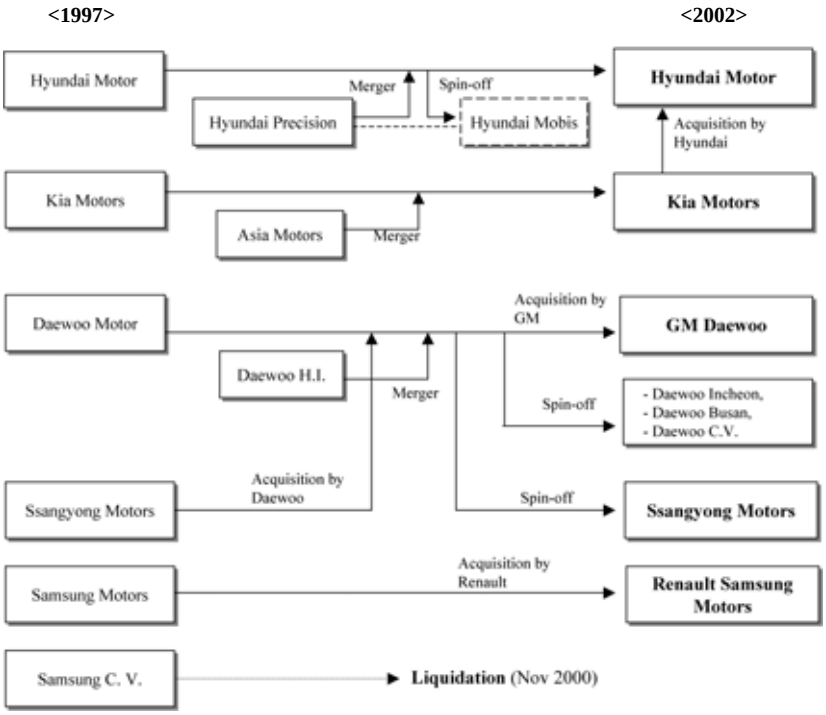
[9] Despite the debate on the nature of "venture" in Korea, it is evident that venture activities in Korea are very active. An indicator is the investment in venture capital as a percentage of GDP. OECD (2003) shows that Korea is one of countries above OECD average.

[10] This needs further study afterwards.

into financial difficulty that led to changes in ownership. Daewoo Group acquired Ssangyong Motor Company in 1998. But Daewoo Group went bankrupt only 2 years after taking over Ssangyong Motor Company, putting Ssangyong's fate in question. Samsung Motor Company, which was established in 1997, could not go through the travails of the financial crisis, and it was finally taken over by Renault in 2000. Kia Motor Company was taken over by Hyundai Motor Company in 2000, and GM finally decided to take over Daewoo Motor Company in 2002.

Second, merger and acquisition of insolvent or bankrupt automobile parts companies by foreign companies. Many parts companies that had financial problems were handed over to the foreign companies. Mando, the largest automobile parts company in Korea, is a good example. Mando had been affiliated with Halla Group, one of the leading Chaebols. Because of Halla's insolvency, Mando, despite its high productivity and relatively sound financial status, was split; and, several production plants were sold out to foreign companies including Valeo, Visteon, Autoliv and Gibbs. In addition to these foreign companies, several other foreign companies such as Delphi, Robert Bosch, VDO, BorgWarner, Siemens, TRW, and Denso have enterted into the Korean market by M&A or joint ventures

[Figure 10] Restructuring of Korea's Automobile Industry



Source: Adapted from Kyeong-won Kim (2003) and KAICA (2004).

<Table 7> Major FDI after the Financial Crisis of 1997

Investor	Name of Korean company	Amount (1,000 $)	Share (%)	Year
Delphi (USA)	Korea Delphi	58,201	50	2000
Delphi (USA)	Delphi A. S. Sungwoo	60,135	100	2000
TRW (USA)	TRW Steering Korea	13,959	71	2000
Tower Automotive (USA)	SeoJin Ind.	42,383	82	1999
Visteon (USA)	DuckYang Ind.	24,112	51	2001
Siemens Automotive (GER)	Korea EMS	40,682	51	2001
Valeo (FRA)	Valeo Mando	140,043	100	1999
Visteon (USA)	Halla Climate Control Co	110,000	70	2000
SUN Sage (NED)	Mando	150,873	83	1999
Nippon Denso (JAP)	Denso Poongsung	1,936	51	2001

Source: Compiled from MOCIE D/B on FDI in Korea, 2002.

with the Korean companies.

In the process of restructuring of automobile and parts industry, the existing relationships between automobile assemblers and parts suppliers began to be dissolved. Conventionally, the automobile parts suppliers, whether they are subsidiary or independent company, were as subcontractors hierarchically organized by automobile assemblers, and the hierarchical relationships was determined according to Chaebol grouping. The restructuring of Chaebols and their automobile companies caused this hierarchical relationships to change, even though it is prevailing until now. Further, the existence of foreign companies offers a new opportunity to parts suppliers. As foreign contractors do not need stick to the existing relationships, so domestic suppliers would have better leverage than the past.

Since the restructuring process is still undergoing, it is too early to presuppose any uniform pattern in business relationships and networks in Korea's automobile and parts industry. But it is clear that the conventional business relationships based on Chaebol grouping will be no longer as dominant as in the past years. And both smaller and lager firms should be more global in their business strategies and practices.

3. The Emergence of Innovation Networks

Based on cross-shareholding, subsidiary companies in a Chaebol are mostly vertically integrated. Vertical integration can be seen in that subsidiary companies in a Chaebol take part in various stages of a supply chain. Diversified business structures of Chaebols might allow to developing horizontal division of labor among subsidiary companies of a Chaebol; but, horizontal relationships between

Chaebols or subsidiary companies of different Chaebols are less prevalent. The expansion strategy of Chaebols, which aims to widen business areas as possible, results in more diversified business structures for Chaebols; but, it obstructs the development of horizontal relationships between companies, in particular those between Chaebols and SMEs.

The business relationships that were prevalent in the past years have been changing after the financial crisis. Chaebols could no more pursue as aggressively as in the past the expansion strategy based on debt financing and cross-shareholding. Instead, they had to substantially lower their debt-ratios and to rationalize their diversified business structures. The new strategy was to concentrate on core businesses and to sell out or spin off unprofitable businesses. As is shown in the Table 8, 442 business branches that had employed 67,863 people had been spun off to independent companies. Samsung has rendered 161 spin-off companies, followed by Hyundai with 98 companies, LG with 94 companies and SK with 45 companies. Spinn-off companies from these four Chaebols account for 398 companies, more than 90 % out of total. The number of spin-off companies peaked at the year of 1998, when the repercussions of the financial crisis on the corporate restructuring were also at its highest.

The increasing tendency of large enterprises to make strategic alliances with venture companies is another new trend that has occurred since the financial crisis.

<Table 8> Spin-offs from Chaebols

	No. of mother co.	No. of spin-off companies						No. of employees
		1997	1998	1999	2000	2001	Total	
Samsung	16	0	115	29	5	12	161	17,235
Hyundai	12	36	27	18	8	9	98	16,937
LG	15	5	18	51	14	6	94	21,443
SK	11	3	11	11	13	7	45	3,650
Hanjin	5	0	0	4	1	0	5	2,866
POSCO	1	0	0	0	1	0	1	40
Hanwha	2	0	0	4	0	0	4	2,636
Doosan	1	0	0	0	3	1	4	103
Ssangyong	1	0	0	0	2	0	2	880
Dongbu	1	2	5	1	1	0	9	144
Dongyang	2	0	0	2	1	0	3	227
Hyosung	1	0	2	0	0	0	2	52
CJ	3	1	0	0	1	4	6	643
Kolon	3	0	0	0	3	0	3	289
Hyundai Dept.	1	0	0	0	0	1	1	658
Daewoo E.	1	0	0	4	0	0	4	60
Total	76	47	178	124	53	40	442	67,863
		(10.6)	(40.3)	(28.1)	(12.0)	(9.0)	(100.0)	

Note: Spin-off is confined to the cases of MBO (management buy-out) and EBO (employee buy-out).
Source: Federation of Korean Industry, 2001.

strategic alliances had been more prevalent between large enterprises; but it was hard to find those between large enterprises and SMEs before the financial crisis. Two factors, among others, are worth to note. First, backed by the expansion strategy, large enterprises, particularly Chaebols, usually set up their own business branches or subsidiaries when new opportunities arose or found. In other words, large enterprises preferred to internalize new business opportunities rather than to externalize them. The second factor was that since the number of technologically advanced SMEs had been few, the number of partners for alliances with LEs was also few. Under these circumstances, strategic alliances between firms, particularly between LEs and SMEs, will not be well developed.

The situations described above have also been changed since the financial crisis. Because of the more stringent financial constraint, LEs should concentrate on core businesses. Spinning-off, as is explained above, is other side of the concentration. And there come a large number of technologically agile smaller companies. These changes have rendered a new trend of increasing strategic alliances between LEs and SMEs.

Table 9 shows some examples of strategic alliances between LEs and new technology based firms, or venture companies in the Korean parlance. Samsung Electronics' strategic alliances with about 100 venture companies focus on non-memory chips where it has the strong necessity to enter into and needs business partners. LG Electronics runs what they call LG Venture Club composed of venture companies founded by retirees from LG Electronics or other LG companies. (See below for details on LG Venture Club.) LG Chemical has made strategic alliance with four venture companies and plans to increase the number of partners. SK and CJ are collaborating with venture companies for R&D projects for entering into new businesses where they do not have competence.

Although there is no complete information on the new business relationships between LEs and SMEs such as in Table 9, we can further assume that strategic alliances and other kinds of business relationships between LEs and SMEs are rapidly increasing. There are, at least, two grounds for the assumption. First, the necessity of strategic alliances is stronger than before the financial crisis. When LEs

[Table 9] Strategic Alliances between LE and Venture Company

Samsung Electronics	Strategic alliance with about 100 venture companies. Focusing on non-memory chips
LG Electronics	LG Venture Club
LG Chemical	Made alliances with 2 domestic and 2 overseas venture companies
SK	Project for developing pharmaceutical products with 11 venture companies
CJ	Project for developing pharmaceutical products with 2 venture companies. Plan to make alliances with 20 venture companies

Source: Dong-A Ilbo, March 27, 2002.

need to enter into new businesses, partnership with NTBF(new technology-based firms) will be less costly and risky than total internalization. Second, smaller NTBF will have an incentive to make alliances with LEs that have advantages of scale economies. Partnership with LEs will allow NTBF to safeguard their growth by utilizing LEs', for example, capital and marketing advantages.

V. Conclusion

The paper showed that industrial innovation system after the financial crisis is changing, in a positive direction. The financial crisis and subsequent restructuring have rendered new constraints and incentives for firms, particularly in their inter-firm relations. As North (1990) notes, institutions structure incentives in economic action. Apparently, the financial crisis has rendered an institutional change that gives different incentives to economic agent and, consequently, results in different modes of inter-firm relations. The process of structural change is still on the way, and it will take further times for the new modes to be settled down. But we can make a conjecture on the future patterns of inter-firm relations and linkages. Orru et al (1996) had compared organizational patters of three East Asian economies, benchmarked with three European economies. Despite the danger of over-simplification, they placed Korea as the prototypical case of the dirigiste capitalism. Under dirigiste capitalism where the state wields authoritative leadership and large corporations dominant in the national economic activities, autonomous conglomerates are modal means of organization, firms are vertically integrated, and horizontal linkages among firms are not well developed. The changes proceeding in Korea's industrial innovation system show that, although it is too premature to generalize, more horizontal inter-firm relations are being developed in the Korean industries. The inter-firm relations or networking between firms would proceed in various ways, but the paper showed that the emerging pattern is different from the past one, and some industries such as automobile parts industry show that the changes are fundamental. Further, we can predict that the development of horizontal inter-firm relations and innovation networks will contribute to enhancing productivity economy as a whole. It is not yet possible to have comprehensive evidence but it is clear that R&D networking between firms have been rapidly risen recent years. The emerging new trend will enable firms to do R&D activities more efficiently by utilizing external R&D sources through innovation networks.

The Korean economy is facing a new environment. As economic activities are becoming more knowledge-intensive, so the transition to the knowledge-based economy requires significant changes in work and production organizations. That the Korean economy has matured and developed at a level comparable to advanced economies implies that the available stock of technologies drawn on through conventional technology transfer is exhausted. The trend toward globalization emphasizes the importance of the global integration of national

economic activities. How well is the Korean firm responding to these changes? Can the Korean economy achieve sustainable economic growth in the future? Under the new economic setting, the conventional ways of technological development will not be as effective as they have been in the past. Standing at the crossroads, private enterprises need a new strategy. Korea's industrial innovation system faces further challenges ahead including the following.

First, the industrial structure shows the weakness of upstream sectors, particularly in the capital goods industry. This weakness is closely related to the predominance of large firms, notably Chaebols, and the government's industrial policy. In accordance with the aggressive export-promotion policy that complements the limited domestic market, the imported technologies are both mature in life cycle and of kind being able to render economies of scale in production. The production structure has centred on end products, and ignoring support firms and industries has resulted in heavy dependence on the foreign sources of materials, parts, and components. This chronic phenomenon renders the Korean economy vulnerable to external changes in the foreign market. Accordingly, strengthening upstream industrial linkages is one of the most urgent tasks for the Korean economy.

Second, related to the first issue, a small number of Chaebols are still dominating industrial innovation activities. The dominance of Chaebols, per se, is not an evil. The problem lies in the diffusion of innovation. The internal diffusion of technological innovation is not so active in Korea. The lack of domestic diffusion among firms is well demonstrated by the fact that repetitive importation of foreign technologies is common. Furthermore, the diffusion from research institutions to private firms is not as effective as expected. More organic co-operation between domestic firms, particularly between large firms and SMEs, and more active collaboration between research institutions and private firms are imminent. In this regard, we have observed a positive sign of change, for example, the emergence of innovation networks between conglomerates and SME. It is needed to sustain this trend.

Third, technological co-operation between domestic firms and foreign firms should be promoted. In the past, the Korean economy has benefited from the inflow of advanced foreign technologies. Now, new modes of co-operation such as cross-licensing and strategic alliances need to be utilised more. Facing rapid changes in technological opportunities and the expansion of globalisation, private enterprises need to strengthen the development of human resources and international R&D networks.

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