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WHAT EXPLAINS THE RECENT GLOBAL COMPETITIVENESS OF THE KOREAN AUTOMOTIVE INDUSTRY?

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Empirical results and the global standing of advanced technology of the Korean automotive industry revealed that the competitiveness of the automotive components suppliers is far behind that of the assembled vehicle manufacturers. The returns to scale (RTS) of the assembled vehicle manufacturers showed strong increasing return to scale (IRS), whereas the automotive components suppliers displayed decreasing return to scale (DRS). The average total factor productivity (TFP) growth of the assembled vehicle manufacturers was ten times greater than that of the automotive components suppliers in the past decade. The technical progress (TP) has been a key contributor to the TFP growth of both sectors, but the strength of the capital-using technical progress (TP) of the automotive components suppliers was less than half of that of the assembled vehicle manufacturers. The paradigm shift of the automotive industry urges persistent, collaborative R&D between the two sectors against expeditious commercialization of Next Generation Vehicles (NGV).

JEL Classification: L62, D24, C23
Keywords: Korean automotive industry, assembled vehicle manufacturers, automotive components suppliers, paradigm shift, total factor productivity, technical progress, technical efficiency, scale components, allocative efficiency

I. INTRODUCTION

Two distinctive trends in the global automotive industry emerged since 1997; one is a paradigm shift under a worldwide trend of strengthening environmental,

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safety, and energy regulations, and the other is the development of a next generation vehicle.

In consequence, the volume of R&D investments and the number of patents definitely determine the global standing of both assembled vehicle manufacturers and automotive components suppliers. Globally, major assembled carmakers are launching ongoing R&D investments for next generation vehicle technology and also their government endeavors to support associated R&D.

Since the automotive industry was one of the target industries for promoting exports to expedite economic growth in the 1970s, it has been successfully designated as a core industry in Korea. After prevalent de-industrialization in Korea in the early 1990s, the automotive industry stood firmly as the key of 1999's export-leading reindustrialization after the 1997 financial crisis. However, enterprises ought to implement strategies of value-creating innovations beyond those of just efficiency promotion in order to promote global competitiveness.

In recent, major carmakers are pushing ahead to develop next generation vehicle (*NGV*) such as hybrid, fuel cell, and intelligent vehicles. Japan is already selling hybrid vehicles and is in the early stage of commercialization for a fuel cell vehicle. Japan and the U.S. are accelerating commercialization for hybrid vehicles such as the second version of Prius and a full size truck. The U.S. is also trying to expedite the commercialization of a hybrid truck and SUV. But, Korea still stays in an infant level of fuel cell vehicle and hybrid vehicle development. For an intelligent vehicle, Japan is developing ASV/ITS and the U.S is pushing forward to develop OnStar, but Korea remains still in an early stage of commercialization.

Thus, it is necessary at this time to examine the global performance of the Korean automotive industry and to find ways to promote potentials for *NGV* and check on productivity of commercial vehicles. The total factor productivity growth of commercial vehicles and preoccupation of advanced *NGV* technology determine a winner in the global automobile market. In fact, the Korean automotive industry is dichotomized into assembled vehicle manufacturers and automotive components suppliers, that are vertically integrated. Several assembled vehicle manufacturers are locked in monopolistic competition, while a number of small and medium-sized automotive components suppliers form competitive market. Therefore, it may be natural that the competitiveness of the assembled vehicle manufacturers arises from that of the automotive components suppliers. The more the automotive components suppliers gain competitiveness, the stronger positive forward-effects the assembled vehicle manufacturers obtain and *vice versa*.

To promote global competitiveness, using micro data,[1] the *TFP* growth of the assembled vehicle manufacturers and the *TFP* growth of the automotive components suppliers are decomposed into technical progress, technical efficiency, economies of scale, and allocative efficiency for commercial vehicles. The empirical results of the present study can suggest appropriate strategies for both the assembled vehicle manufacturers and the automotive components suppliers.

Section Ⅱ shows the technology competitiveness of the Korean automotive industry focusing on R&D activities and Section Ⅲ and Ⅳ present the performance of Korea's automotive industry by decomposition of *TFP* growth into changes in technical progress, technical efficiency, economies of scale, and allocative efficiency. Concluding remarks are presented in Section Ⅴ.

Ⅱ. TECHNOLOGY COMPETITIVENESS OF THE KOREAN AUTOMOTIVE INDUSTRY

1. R&D Investment in the Automotive Sector

Table 1 shows the world's 25 largest R&D investments in the automotive sector for 2003 and 2004, which come from the following headquarter countries: 9 from Japan, 4 from U.S.A., 6 from Germany, 4 from France, 1 from Italy, and 1 from Korea. Out of the 25 top R&D investment companies, the numbers of automotive vehicle companies occupy 15 slots while those of automotive component companies take 10 slots.

Although Hyundai Motors marked a 55 % annual growth rate of R&D investment from 2003, it ranked only 18th with 449.82 £m of R&D investment, and none of the Korean automotive component companies occupied a single slot in 2004. The weak competitiveness of the automotive components suppliers and the lack of collaborative R&D with assembled vehicle manufacturers led assembled vehicle manufacturers to initiate R&D investments in Korea.

With regards to the ratio of R&D to sales, Hyundai Motors ranked in the lowest 2.1% out of 25 companies in 2004, while Toyota and Honda marked 4.3% and 5.5% respectively. Potent competitors of Korean automotive businesses,

[1] Refer to Kim and Han (2001) and Kumbhakar (2000).

Toyota and Honda Motors marked 3,483.99 £m and 2,277.11 £m of R&D investment respectively, which were 5-8 times as large as Hyundai Motor's 449.82 £m.

Total sales of Toyota and Honda in 2004 marked 80,800 £m and 41,551 £m respectively, approximately 2~4 times as large as Hyundai's sales volume, 21,842 £m. When it comes to market capitalization, Toyota and Honda Motors were far ahead with 80,174 £m and 26,379 £m respectively, with Korea's sole runner Hyundai Motors showing 5,308 £m.

[Table 1] Top 25 R&D Investments of 2003 / 2004 in the Automotive Sector

Company	1. R&D investment (£m)	2. Growth-Change 1 year (%)	3. R&D/ sales (%)	4. Sales (£m)	5. R&D per employee (£1000)	6. Market cap (£m)
Ford Motor, USA	4,189.71	-3	4.5	92,210	12.8	14,472
Daimler Chrysler, Germany	3,925.45	-8	4.1	96,137	10.6	25,347
Toyota Motor, Japan	3,483.99	13	4.3	80,800	13.2	80,174
General Motors, USA	3,184.18	-2	3.1	103,639	9.8	13,511
Volkswagen, Germany	2,917.14	-5	4.7	62,298	9.3	8,887
Honda Motor, Japan	2,277.11	11	5.5	41,551	17.9	26,379
Robert Bosch, Germany	1,867.25	7	7.3	25,618	8.1	N/a
BMW, Germany	1,803.13	10	6.2	29,259	17.7	16,315
Nissan Motor, Japan	1,565.44	15	4.4	35,593	12.3	26,835
Peugeot (PSA), France	1,478.30	12	3.9	38,217	7.4	7,825
IFI, Italy	1,242.25	0	3.3	37,704	6.5	446
Renault, France	1,223.93	-2	4.6	26,441	9.3	12,538
Delphi, USA	1,117.26	18	7.1	15,695	5.9	2,981
Denso, Japan	953.28	-1	7.8	12,159	10.7	12,033
Visteon, USA	504.44	0	5.1	9,865	7.0	744
Michelin, France	500.62	1	4.6	10,830	3.9	4,447
Mazda Motor, Japan	457.65	-8	3.7	12,325	12.6	2,372
Hyundai Motor, South Korea	**449.82**	**55**	**2.1**	**21,842**	**N/a**	**5,308**
Aisin Seiki, Japan	417.38	18	5.7	7,339	9.5	3,597
Valeo, France	397.41	-2	6.1	6,506	5.8	1,860
Bridgestone, Japan	369.91	4	3.1	12,009	3.4	8,654
ZF, Germany	369.22	-3	5.9	6,291	6.9	N/a
Continental, Germany	351.04	1	4.3	8,127	5.3	3,824
Suzuki Motor, Japan	315.05	34	3.0	10,505	N/a	5,272
Fuji Heavy Industries, Japan (Subaru)	313.32	9	4.4	7,153	11.4	2,362

Source: Department of trade and industry, U.K., 「2004 R&D Scoreboard」.
Note: 1. R&D investment for the latest financial year in £m. 2. Data for an individual company's annual growth change in R&D 3. Total sales in 2004 4. R&D per employee, one measure of knowledge intensity 5. Market capitalization as of July 30th, 2004 and Market Cap is the product of share price and number of shares

2. Patents[2] in the Automotive Sector

Patents protect the successful results of R&D, especially American patents, since the U.S. is the world's leading market for almost all R&D based products. In Table 2, the top 25 businesses are listed by the number of obtained patents as well as the % change in American patents in the last three years, 2001, 2002, and 2003, where 3 Japanese, 2 American, 3 German, 2 French, 1 Italian, and 1 Korean company occupied the top 12 patent acquisitions.

[Table 2] Patents[3] of Automotive Vehicles and Automotive Components

Automotive Vehicles	HQ country	Number of US Patents 2003	Number of US Patents 2002	Number of US Patents 2001	Total US Patents	% Change 2003/2002	% Change 2002/2001	% Change 2003/(2001+2002)/2
Honda Motor	Japan	768	772	660	2,200	-1%	17%	7%
Ford Motor	USA	496	502	492	1,490	-1%	2%	0%
Toyota	Japan	478	392	401	1,271	22%	-2%	21%
Daimler Chrysler	Germany	374	547	739	1,660	-32%	-26%	-42%
General Motors	USA	296	202	187	685	47%	8%	52%
Nissan Motor	Japan	274	275	294	843	0%	-6%	-4%
Hyundai	**Korea**	**105**	**151**	**118**	**374**	**-30%**	**28%**	**-22%**
BMW	Germany	95	86	90	271	10%	-4%	8%
Volkswagen	Germany	70	55	77	202	27%	-29%	6%
Renault	France	12	17	14	43	-29%	21%	-23%
IFI	Italy	10	4	3	17	150%	33%	186%
Peugeot	France	7	9	7	23	-22%	29%	-13%
Automotive Components								
Robert Bosch	Germany	787	722	737	2,246	9%	-2%	8%
Delphi Automotive	USA	650	658	343	1,651	-1%	92%	30%
Denso	Japan	586	512	463	1,561	14%	11%	20%
Goodyear Tire	USA	259	283	228	770	-8%	24%	1%
Visteon	USA	249	198	213	660	26%	-7%	21%
Bridgestone	Japan	174	194	211	579	-10%	-8%	-14%
Valeo	France	160	147	163	470	9%	-10%	3%
ZF Friedrichshafen	Germany	121	88	79	288	38%	11%	45%
Aisin Seiki	Japan	117	142	114	373	-18%	25%	-9%
Michelin	France	109	103	64	276	6%	61%	31%
Continental	Germany	99	123	118	340	-20%	4%	-18%
GKN	UK	69	67	80	216	3%	-16%	-6%
Johnson Controls	USA	52	60	45	157	-13%	33%	-1%

Source: Department of trade and industry, U.K., 「2004 R&D Scoreboard」.

[2] The patents here are subject to a number of caveats.

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Hyundai is positioned 7^{th} with 105 patents among 12 companies of automotive vehicles in 2003, and they obtained 374 patents in the last three years. Honda ranked the top with 768 patents in 2003 and obtained a total of 2,200 US patents in the last three years while Toyota ranked third with 478 patents in 2003 and 1,271 total US patents in last three years. Moreover, the top 4 companies, Honda, Ford, Toyota, and DaimlerChrysler, are prevalent in numbers of U.S. patents with a big gap from the rest of the automotive vehicle companies.

In regards to businesses of automotive components, the number of patents in overall years has been somewhat higher than those of the automotive vehicles companies, where 4 American, 3 Japanese/German, 2 French, and 1 British company are listed in the top 13 USA patent-obtaining companies. The top 3 businesses, Robert Bosch, Delphi Automotive, and Denso swept the patents by a big margin from the rest of the companies in automotive components.

No Korean automotive components business got onto the list of the top 13 businesses of USA patents accumulation that have been outcomes of successful R&D investments from 2001 to 2003. A critical lack of collaborative R&D between automotive components businesses and major vehicle manufacturers in Korea inevitably led to weak technological competitiveness of automotive components and finally lost initiative in their R&D, and that has caused a low level of patents acquisition.

3. R&D Effectiveness in Automotive Sector

The ratio of the number of US patents granted to an R&D- progressive company is an indicator of R&D effectiveness. The numbers in Figure 1 stand for the equivalent numbers in Table 3 where numbers 1 to 12 belong to the automotive vehicles sector and the numbers 13 to 25 belong to the automotive components sector, respectively.

Figure 1 shows that the automotive components sector has a much higher patents-to-R&D ratio than does the automotive vehicle sector. Amongst automotive vehicle makers, Honda motors is exceptional with the highest number of US patents and the highest ratio of patents-to-R&D while Hyundai Motors ranked 12th in patent-to-R&D ratios in 2003.

[Table 3] Effectiveness of R&D Investments in 2003

Unit: ₤ 10m, number of US patents

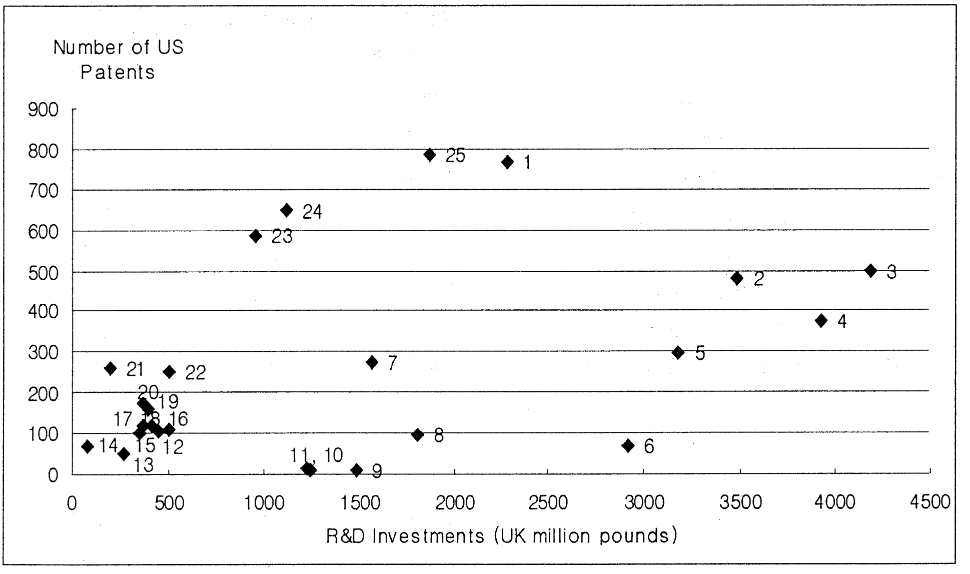
		R&D Investments	Number of US Patents	Number of US Patents/ R&D Investments
1	Honda Motors	227.7	768	3.37
2	Toyota	348.3	478	1.37
3	Ford Motor	418.9	496	1.18
4	Daimler Chrysler	392.5	374	0.95
5	General Motors	318.4	296	0.92
6	Volkswagen	291.7	70	0.23
7	Nissan Motor	156.5	274	1.75
8	Bayerische Motoren Werke (BMW)	180.3	95	0.52
9	Peugeot	147.8	7	0.047
10	Istituto Finanziario Industriale (IFS)	124.2	10	0.08
11	Renault	122.3	12	0.098
12	**Hyundai**	**44.9**	**105**	**2.33**
13	Johnson Controls	27.0	52	1.92
14	GKN	8.1	69	8.11
15	Continental	35.1	99	2.82
16	Michelin	50.0	109	2.18
17	ZF Friedrichshafen	36.9	121	3.27
18	Aisin Seiki	41.7	117	2.80
19	Valeo	39.7	160	4.03
20	Bridgestone	36.9	174	4.71
21	Goodyear Tire	19.5	259	13.28
22	Visteon	50.4	249	4.94
23	Denso	95.3	586	6.14
24	Delphi Automotive	111.7	650	5.81
25	Robert Bosch	186.7	787	4.21

Source: Department of Trade and Industry U.K., 「2004 R&D Scoreboard」.

Note: Numbers 1~12 are the automotive vehicles companies and those 13~25 are the automotive components companies.

Table 4 and Figure 2 together suggest that Hyundai Motors generated about the average *per capita* operation profit but lower *per capita* R&D than the other top 11 ranking automobile businesses. Thus, the above facts confirm that high *per capita* operation profit comes from high *per capita* R&D in the global automotive sector.

[Figure 1] Number of US Patents vs R&D Investment for the Automotive Sector in 2003



Source: Department of Trade and Industry U.K., 「2004 R&D Scoreboard」.
Note: Numbers 1~12 belong to the automotive vehicles sector and numbers 13~25 belong to the automotive components sector in Table 3.

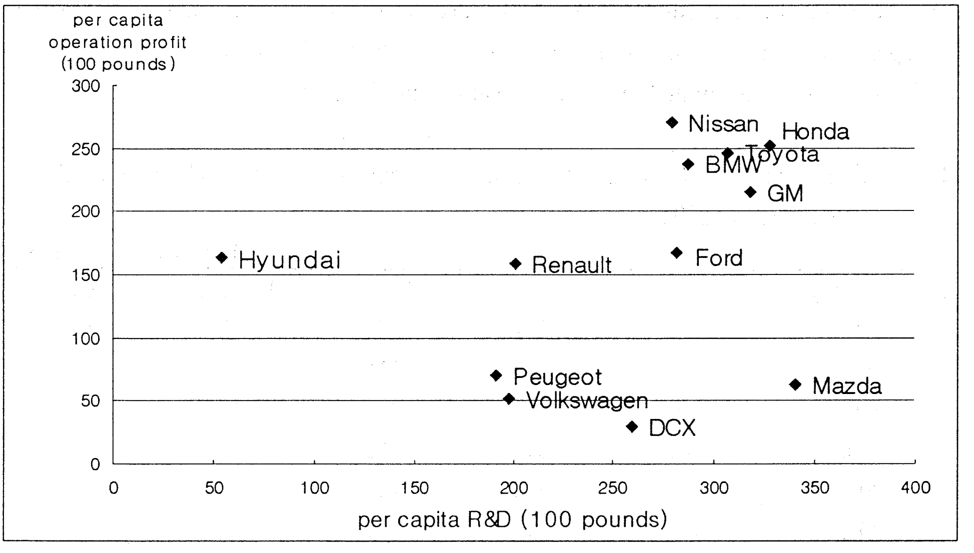
[Table 4] Top Ranking 12 *per capita* operation profit and *per capita* R&D

Unit: 100 £

	BMW	DCX	Ford	GM	Honda	Hyundai
per capita operation profit	236.9	29.4	166.9	214.6	252.4	164.1
per capita R&D	286.6	259.3	281.5	317.9	327.4	54.4
	Mazda	Nissan	Peugeot	Renault	Toyota	Volkswagen
per capita operation profit	62.2	271.1	70.6	159	246.3	51.3
per capita R&D	340.6	278.9	191.2	201.3	306	198

Source: Department of Trade and Industry U.K., 「2004 R&D Scoreboard」 and Hyundai Motors Inc.

[Figure 2] Top Ranking 12 Companies' *per capita* operation profit and *per capita* R&D



4. Technology-led Transformation in the Automotive Industry

Among the top 100 private sector patent recipients in 2002, none of the Korean automotive companies is included whereas four Japan, six American, and two German automotive businesses are listed.

[Table 5] Ranks of Automotive Sectors in Top 100 Private Sector Patent Recipients in 2002

Rank	Company (HQ Country)	Number of patents granted in 2002
22	Robert Bosch (Germany)	679
25	Honda Motor (Japan)	653
26	Delphi Technologies (USA)	640
34	Denso Corp. (Japan)	482
45	Ford Global Technologies (USA)	389
58	Daimler Chrysler (Germany)	304
59	Toyota (Japan)	296
69	Nissan Motor (Japan)	249
78	TRW (USA)	227
88	Goodyear Tire & Rubber (USA)	192
90	General Motors (USA)	190
95	Visteon Global Technologies (USA)	185

Source: US Patent and Trademark Office TAF database

The technology development gap between the automotive parts & components companies of Korea and Japan is larger than that of the assembled vehicle manufacturers. In particular, Denso, the largest automotive components company in Japan, has recently surpassed Toyota in numbers of patent applications as a result of continuous annual growth, as shown in Table 6.

[Table 6] Korean and Japanese Automotive Companies' Patents Granted in the US: 1997~2002

Unit: number of patents

Year \ Company	Honda	Toyota	Denso	Hyundai	Kia
1997	340	211	7	72	10
1998	386	386	124	92	42
1999	452	402	303	93	7
2000	445	342	366	60	1
2001	547	328	423	99	7
2002	632	294	465	145	10
Total	2,802	1,963	1,688	561	77

Source: US Patent and Trademark Office TAF database.

Toyota's recent slump in numbers of U.S. patent applications is mainly due to its own strategies of technology protection against leakage of advanced technology in the U.S. market during the due process. The numbers of patents related to energy efficiency and pro-environmental applications create the competitiveness of advanced technology of Korea and Japan, as shown in the Tables 8 and 9. It is likely that in the next decade, more energy efficient and cleaner vehicles will create competitiveness, and conventional gasoline internal combustion engine (ICE) vehicles will no longer be competitive in the global market.

Korea is far behind Japan in the eleven advanced automotive technology categories for hybrid electric and fuel cell vehicles, as indicated by the patenting activity and patent citation for each technological category from 1996 to 2001 as in Table 7. Japan already hit the top level of eleven advanced technologies for hybrid and fuel cell vehicles which are expected to be in commercialization by 2010. Korea is approximately 10 years behind Japan in *NGV* such as clean diesel, hybrid electric, and fuel cell vehicles for commercialization. In fact, the recent high oil prices have also led to a rapid increase in demand for the hybrid electric vehicles developed by Honda and Toyota.

[Table 7] Korean and Japanese Levels in Eleven Advanced Automotive Technology Categories (hybrid electric vehicles / fuel cell vehicles)

Unit: number of patents

Technology Categories	Country	1996~98	1999-2001	Total	Number of companies
Automotive Fuel Cells	Japan	29	66.2	95.2	12
	Korea	0	2	2	1
Hydrogen Storage	Japan	n.a	n.a	13.5	5
	Korea	n.a	n.a	2	1
Advanced Batteries	Japan	104.5	183.5	288	34
	Korea	5	24	29	4
Hybrid Electric Vehicles	Japan	72	191	263	12
	Korea	0	0	0	0
Lightweight Materials	Japan	119.8	123.6	243.4	34
	Korea	2	1	3	1
Ultracapacitors	Japan	15.7	71	86.7	12
	Korea	0	0	0	0
Other Power Electrons	Japan	62	77.7	139.9	13
(excluding Ultracapacitors)	Korea	8	15	23	4
Direct Injection Combustion	Japan	67.5	148.1	215.6	14
	Korea	3	2	5	1
Emissions Control	Japan	375.6	379.8	755.4	14
	Korea	0	0	0	0
New Combustion Regimes	Japan	14	7	21	4
	Korea	2	0	2	1
Hydrogen Internal Combustion	Japan	n.a	n.a	4.5	1
Engines (Hydrogen ICE)	Korea	0	0	0	0

Source: CHI Research, The U.S. Competitive Position in Advanced Automotive Technologies, 2003

Ⅲ. TFP GROWTH OF THE KOREAN AUTOMOTIVE INDUSTRY

1. Decomposition of *TFP* Growth[4]

Let a frontier production function be defined as

$$y_{it} = f(x_{it}, t)\exp(-u_{it}), \quad i = 1, \dots N, \quad t = 1, \dots T., \tag{1}$$

where y_{it} is the output of the *ith* establishment in the *tth time period*; $f(x_{it}, t)$

[4] Refer to Kim and Han (2001).

is the production frontier; x is an input vector, t is a time trend index that practically act as a proxy for technical change; and $u \geq 0$ is the output-oriented technical inefficiency random disturbance and varies over time.

The production frontier $f(x_{it}, t)$ is totally differentiated with respect to time to get

$$\frac{d\ln f(x,t)}{dt} = \frac{\partial \ln f(x,t)}{\partial t} + \sum_j \frac{\partial \ln f(x,t)}{\partial x_j}\frac{dx_j}{dt}. \tag{2}$$

The change in frontier output generated by Technical Progress (TP) is measured by $\frac{\partial \ln f(x,t)}{\partial t}$ and by change in volume of input is measured by $\sum_j \frac{\partial \ln f(x,t)}{\partial x_j}\frac{dx_j}{dt}$.

$$\frac{d\ln f(x,t)}{dt} = TP + \sum_j \varepsilon_j \dot{x}_j \tag{3}$$

where the output elasticity of input j, $\varepsilon_j = \frac{\partial \ln f(x_j,t)}{\partial \ln x_j}$ and $\dot{x}_j$[5] denotes $\frac{d\ln x_j}{dt} = \frac{1}{x_j}\frac{dx_j}{dt}$.

Thus, equation (3) indicates that change in frontier output is composed of technical progress and change in input use.

The logarithm of y in equation (1) is totally differentiated with respect to time, t and using equation (3),

$$\frac{d\ln y}{dt} = \dot{y} = \frac{d\ln f(x,t)}{dt} - \frac{du}{dt} = TP + \sum_j \varepsilon_j \dot{x}_j - \frac{du}{dt} \tag{4}$$

Therefore, the overall output change comes from TP, changes in input use, and changes in technical inefficiency.

TP is positive (negative) if exogenous technical changes such as technological innovation raises (lowers) the production frontier for a given level of inputs. If $\frac{du}{dt}$ is negative, then TE improves over time and vice versa.

Next, the effect of TP and a change in efficiency on TFP growth ($\dot{TFP}$) is derived as output growth unexplained by input growth.

[5] A dot over a variable implies its rate of change.

$$\varepsilon_L = \partial \ln f(x, t)/\partial \ln x_L = \alpha_L + \beta_{LK}\ln x_K + \beta_{LL}\ln x_L + \beta_{TL}t \tag{10}$$

$$\varepsilon_K = \partial \ln f(x, t)/\partial \ln x_K = \alpha_K + \beta_{KL}\ln x_L + \beta_{KK}\ln x_K + \beta_{TK}t \tag{11}$$

$$RTS = \varepsilon_L + \varepsilon_K \tag{12}$$

The TP rate in this model is defined by

$$TP = \partial \ln f(x, t)/\partial t = \alpha_T + \beta_{TT}t + \beta_{TL}\ln x_L + \beta_{TK}\ln x_K \tag{13}$$

In equations (10)~(13), ln x_L and ln x_K are the sample means of the input levels in the estimation of SFPF in equation (1). The type of technical progress for the specified stochastic frontier model allows for non-neutral TP.[7] TP is labor using (saving) if β_{TL} is positive (negative), TP is capital using (saving) if β_{TK} is positive (negative), and TP is neutral if both β_{TL} and β_{TK} are equal to zero. Finally, TFP growth is decomposed into Technical Progress, changes in Technical Efficiency, Scale Component, and Allocative Efficiency as follows.

$$TFP = TP + (TE - TE_{-1}) + SC + AE \tag{14}$$

3. Data Description

For the assembled vehicle manufacturers, the unbalanced panel of annual time-series micro-data of the *Manufacture of Motor Vehicles* (KSIC 3412) from the Report on *Mining and Manufacturing Survey* of Korea for the years 1992~2003 is used. Additionally, for the automotive components suppliers, the unbalanced panels of annual time-series micro-data of the *Parts for Motor Vehicles and Engines* (KSIC 343), *Manufacture of Motor Vehicle Bodies* (KSIC 34201), and *Trailers and Semitrailers Manufacturing* (KSIC 34202) from the *Report on Mining and Manufacturing Survey* of Korea for the years 1992~ 2003 are used. To estimate the SFPF and the decomposition of TFP growth thereafter, the real amount of tangible fixed assets is used for the capital stock (K), the number of workers is used as proxy for labor input (L), and real value added is used for output. Labor costs (C_L) are measured by employee remuneration,

[7] See Kim and Han (2001).

including wages, retirement compensation and welfare costs, and capital costs (C_K) are calculated as the sum of rents and depreciation costs. Total costs are calculated as the total sum of these two factor costs ($C = C_L + C_K$), and the factor shares of labor and capital in total costs ($S_L = C_L/C, S_K = C_K/C$) are calculated as the factor's share out of the total costs. The Summary Statistics are as follows.

[Table 8] Summary Statistics for variables in the stochastic frontier production functions for Assembled Vehicle manufacturers in Korea

Year	Number of Observations	Labor	Capital	Value Added	Labor Share	Capital Share
1992	22	5.675 (2.698)	9.294 (3.258)	9.722 (3.017)	0.695	0.304
1993	23	5.629 (2.651)	9.113 (3.607)	9.462 (3.064)	0.671	0.328
1994	42	4.430 (2.293)	6.592 (3.811)	7.937 (2.701)	0.699	0.300
1995	48	4.501 (2.448)	7.842 (3.627)	8.428 (2.977)	0.675	0.324
1996	30	5.563 (2.601)	9.754 (3.164)	9.766 (2.975)	0.705	0.294
1997	47	4.957 (2.390)	9.010 (3.264)	8.971 (2.961)	0.618	0.381
1998	59	4.401 (2.413)	7.936 (3.873)	8.106 (2.857)	0.601	0.398
1999	61	4.182 (2.359)	7.367 (4.046)	7.871 (2.862)	0.649	0.350
2000	59	4.550 (2.166)	6.904 (4.356)	8.209 (2.879)	0.678	0.321
2001	20	6.379 (2.616)	11.057 (3.898)	10.847 (3.525)	0.705	0.294
2002	21	6.560 (2.510)	11.584 (3.319)	11.316 (3.193)	0.746	0.253
2003	23	6.374 (2.665)	11.248 (3.586)	11.064 (3.373)	0.795	0.204
1992~2003 Total number of Observations	455					
1992~2003 Total number of Firms	177					

Note: Labor, Capital, and Value Added are all logarithmic values as used in actual estimation of SFPF and standard deviations are in parentheses.

[Table 9] Summary Statistics for variables in the stochastic frontier production functions for Automotive Components Suppliers in Korea

Year	Number of Observations	Labor	Capital	Value Added	Labor Share	Capital Share
1992	2,307	2.994 (1.064)	5.726 (1.630)	6.171 (1.345)	0.758	0.241
1993	2,470	2.966 (1.075)	5.739 (1.735)	6.199 (1.360)	0.733	0.266
1994	2,070	2.936 (1.075)	5.833 (1.739)	6.208 (1.375)	0.759	0.240
1995	2,842	2.915 (1.083)	5.928 (1.746)	6.248 (1.389)	0.749	0.250
1996	3,217	2.876 (1.064)	5.996 (1.735)	6.303 (1.345)	0.749	0.250
1997	2,949	2.896 (1.098)	6.170 (1.774)	6.338 (1.411)	0.716	0.283
1998	2,449	2.915 (1.051)	6.224 (1.823)	6.250 (1.403)	0.674	0.325
1999	2,855	2.932 (1.048)	6.153 (1.810)	6.349 (1.416)	0.673	0.326
2000	3,090	2.932 (1.062)	6.124 (1.840)	6.460 (1.398)	0.701	0.298
2001	3,358	2.907 (1.052)	6.231 (1.827)	6.400 (1.398)	0.711	0.288
2002	3427	2.949 (1.042)	6.334 (1.853)	6.513 (1.413)	0.726	0.273
2003	3,508	2.964 (1.059)	6.364 (1.890)	6.574 (1.405)	0.715	0.284
1992~2003 Total number of Observations	34,542					
1992~2003 Total number of Firms	13,038					

Note: Labor, Capital, and Value Added are all logarithmic values as used in actual estimation of SFPF and standard deviations are in parentheses.

Ⅳ. ESTIMATION RESULTS

1. Decomposition of Total Factor Productivity Growth of the Assembled Vehicle Manufacturers in Korea

While the output elasticity of labor (ε_L) decreased steadily from 1.291 in

1992 to 1.276 in 2003, the output elasticity of capital (ε_K) increased steadily from 0.337 in 1992 to 0.397 in 2003.

[Table 10] Output Elasticity of Labor (ε_L), Output Elasticity of Capital (ε_K), and Returns to Scale (RTS) for the Assembled Vehicle Manufacturers in Korea: 1992~2003

year \	ε_L	ε_K	$RTS=\varepsilon_L+\varepsilon_K$
1992	1.291	0.337	1.628
1993	1.290	0.342	1.632
1994	1.288	0.348	1.637
1995	1.287	0.353	1.641
1996	1.286	0.359	1.645
1997	1.284	0.364	1.649
1998	1.283	0.370	1.653
1999	1.282	0.375	1.657
2000	1.280	0.381	1.662
2001	1.279	0.386	1.666
2002	1.278	0.392	1.670
2003	1.276	0.397	1.674
1992~2003 average	1.284	0.367	1.651

Combining the output elasticity of labor (ε_L) and the output elasticity of capital (ε_K) together, the returns to scale (RTS) has persistently increased from 1.628 in 1993 to 1.674 in 2002, indicating high increasing returns to scale (IRS).

The TFP growth ($\dot{TFP}$) is decomposed into the rate of Technical Progress (TP), Changes in Technical Efficiency (dTE), Changes in Scale Component (SC), and Changes in Allocative Efficiency (AE) from 1993 to 2003, as drawn from Kumbhakar (2000). First, the $\dot{TFP}$ was increased sharply until 1995 by the strong SC effect, but since then fell deeply until 1998 just after the 1997 financial crisis occurred. However, the $\dot{TFP}$ increased rapidly up until 2003 since reindustrialization in 1999, except for a single downturn in 2001 caused by the strong negative SC.

Second, AE exerted a mostly negative effect on the $\dot{TFP}$ during a decade that resulted from factor prices not being equivalent to their value of marginal product.

[Table 11] Technical Progress (TP), Technical Efficiency Change (dTE), Scale Component change (SC), Allocative Efficiency change (AE), and Total Factor Productivity Growth ($T\dot{F}P$) for the Assembled Vehicle Manufacturers in Korea: 1992~2003

	TP	TE	$dTE = TE - TE_{-1}$	SC	AE	$T\dot{F}P$
1992		0.734				
1993	-0.021	0.687	0.046	0.038	-0.020	0.043
1994	-0.005	0.661	0.026	0.065	-0.013	0.072
1995	0.010	0.618	0.042	0.086	-0.013	0.125
1996	0.025	0.577	0.040	0.039	-0.004	0.100
1997	0.041	0.526	0.050	0.015	-0.035	0.072
1998	0.057	0.476	0.050	-0.020	-0.039	0.047
1999	0.072	0.423	0.053	-0.030	-0.019	0.076
2000	0.088	0.377	0.045	-0.012	0.003	0.125
2001	0.104	0.323	0.053	-0.054	-0.009	0.093
2002	0.120	0.289	0.033	0.039	0.001	0.194
2003	0.135	0.241	0.048	0.029	0.001	0.214
1993~2003 average	0.057	0.494	0.044	0.017	-0.013	0.106

Third, SC was a fairly positive contributor to the $T\dot{F}P$ except during the industrial restructuring period 1997~2001 that was triggered by the 1997 financial crisis. Fourth, dTE consistently made a substantial contribution to the $T\dot{F}P$ in the past decade.

Lastly, TP has been a key contributor to the $T\dot{F}P$ that is more capital-using than labor-using because β_{TK} is bigger than the β_{TL} ($\beta_{TK}=0.0055$ and $\beta_{TL}=-0.0013$).

In average, $T\dot{F}P$ in the past decade is 0.106 where the TP, dTE, SC, and AE contributed 43.51%, 33.58%, 12.97%, and - 9.92% respectively.

2. Decomposition of Total Factor Productivity Growth of the Automotive Components Suppliers in Korea

Table 12 shows that the output elasticity of labor (ε_L) increased gradually from 0.825 in 1992 to 0.839 in 2003 and also that the output elasticity of capital (ε_K) increased steadily from 0.124 in 1993 to 0.143 in 2003. As a result, returns to scale (RTS) increased from 0.949 in 1993 to 0.982 in 2003, which definitely reveals a decreasing return to scale (DRS).

[Table 12] Output Elasticity of Labor (ε_L), Output Elasticity of Capital (ε_K), and Returns to Scale (RTS) for the Automotive Components Suppliers in Korea: 1992~2003

year \	ε_L	ε_K	$RTS=\varepsilon_L+\varepsilon_K$
1992	0.825	0.124	0.949
1993	0.826	0.126	0.952
1994	0.828	0.127	0.955
1995	0.829	0.129	0.958
1996	0.830	0.131	0.961
1997	0.831	0.133	0.964
1998	0.833	0.134	0.967
1999	0.834	0.136	0.970
2000	0.835	0.138	0.973
2001	0.836	0.140	0.976
2002	0.838	0.141	0.979
2003	0.839	0.143	0.982
1992~2003 average	0.832	0.133	0.966

[Table 13] Technical Progress (TP), Technical Efficiency Change(dTE), Scale Component (SC), Allocative Efficiency (AE), and Total Factor Productivity Growth ($T\dot{F}P$) of the Korean Automotive Components Suppliers: 1992~2003

	TP	TE	$dTE= TE- TE$	SC	AE	$T\dot{F}P$
1992	0.024	0.749				
1993	0.024	0.748	-0.0014	-0.003	-0.016	0.003
1994	0.024	0.743	-0.0046	0.010	-0.008	0.022
1995	0.024	0.745	0.0014	-0.011	-0.009	0.005
1996	0.024	0.745	0.0008	-0.002	-0.015	0.007
1997	0.024	0.738	-0.0069	0.001	-0.014	0.004
1998	0.025	0.731	-0.0073	0.007	-0.051	-0.026
1999	0.025	0.731	-0.0004	-0.003	0.011	0.032
2000	0.025	0.735	0.0039	-0.002	0.001	0.027
2001	0.025	0.730	-0.0042	-0.001	-0.014	0.005
2002	0.025	0.734	0.0035	-0.001	-0.006	0.021
2003	0.025	0.733	-0.0006	-0.0006	-0.001	0.022
1993~2003 average	0.025	0.739	-0.0014	-0.0007	-0.0114	0.0114

Table 13 presents the decomposition of TFP growth ($\dot{TFP}$) of the automotive components suppliers according to the rate of technical progress (TP), Changes in Technical Efficiency (dTE), Changes in Scale Component (SC), and Changes in Allocative Efficiency (AE) from 1993 to 2002. First, the sharp jump of $\dot{TFP}$ in 1994 was boosted by TP and SC but the negative $\dot{TFP}$ in 1998 was triggered by the negative AE and dTE when industrial restructuring was underway after the 1997 financial crisis. The sudden drop of $\dot{TFP}$ in 1998 generated the rapid $\dot{TFP}$ by TP and AE in 1999, but the $\dot{TFP}$ went into a downturn again but has again soared since 2002. In average, the $\dot{TFP}$ of the automotive components suppliers was barely one tenth of that of the assembled vehicle manufacturers. Second, in the past decade, TP also has been a key contributor to $\dot{TFP}$ that has been more capital-using than labor-using because β_{TK} is bigger than the β_{TL}($\beta_{TK}=0.0017$ and $\beta_{TL}=0.0012$) although the strength of capital-using TP is less than the half of that of the assembled vehicle manufacturers. Third, dTE and SC made negative contributions to $\dot{TFP}$, whereas those of the assembled vehicle manufacturers made positive contributions to the $\dot{TFP}$ in the past decade.

In average, TP, dTE, SC, and AE contributed to the $\dot{TFP}$ of 0.0114 by 64.93%, -3.63%, -1.81%, and -29.61%, respectively, in the past decade.

V. CONCLUSIONS

The empirical results of the present study explain the current global standing of the Korean automotive industry and the weaker competitiveness of the automotive components suppliers compared to that of the assembled vehicle manufacturers. First, returns to scale (RTS) of the assembled vehicle manufacturers showed strong increasing return to scale (IRS), whereas the automotive components suppliers evidenced decreasing return to scale (DRS). Second, the average total factor productivity growth ($\dot{TFP}$) of the assembled vehicle manufacturers marked ten times as big as that of the automotive components suppliers in the past decade. Third, technical progress (TP) has been a key contributor to the $\dot{TFP}$ of both sectors, but the strength of the capital-using TP of the automotive components suppliers is less than the half of that of the assembled vehicle manufacturers. Fourth, the changes in technical efficiency (dTE) and scale component(SC) made negative contributions to the

$T\dot{F}P$ of the automotive components suppliers whereas those of the assembled vehicle manufacturers made positive contributions to the $T\dot{F}P$ in the past decade. Lastly, the allocative efficiency (AE) in the market exerted mostly negative effect to the $T\dot{F}P$ for both sectors in a decade resulting from factor prices not being equivalent to their value of marginal product. Thus, it is concluded that resource allocation should be improved in the market to raise the TFP growth ($T\dot{F}P$) of the Korean automotive industry.

Furthermore, the paradigm shift rendered the automotive industry high technology-expresslt-intensive since 1997, which urges Korean automotive businesses to develop the Next Generation Vehicles (NGV). Among the NGV, the Korean automotive industry has comparative advantages in developing intelligent vehicles with e-transformation and telematics through its advanced IT technology. In fact, total sales of commercial vehicles in 2005 marked its highest for the entire assembled vehicle manufacturers-Hyundai, Kia, Renault, and GM-notwithstanding relatively low labor productivity.

In conclusion, the weak competitiveness and low level of R&D investments of the automotive components suppliers undermine the competitiveness of the assembled vehicle manufacturers due to vertically integrated structure of both and finally compromise the competitiveness of Korean automotive industry. Therefore, it is strongly recommend that assembled vehicle manufacturers facilitate persistent collaboration schemes with the automotive component suppliers for the R&D of advanced technology for the NGV as well as commercial vehicles.

APPENDIX

Hypothesis Testing

The likelihood ratio test statistic of the null hypothesis (H_0: $\gamma=\mu=\eta=0$) is $\lambda=-2[L(H_0)-L(H_1)]$ where the $L(H_0)$ is the value of the log-likelihood function under the setup of the null hypothesis and the $L(H_1)$ is the value of the log-likelihood function under the setup of the alternative hypothesis. If the null hypothesis is true, then λ has approximately a Chi-square distribution with degrees of freedom equal to the number of restrictions and if $\gamma=0$ is incorporated in the null hypothesis then the asymptotic distribution would be a mixed Chi-square distribution by Coelli and Battese (1996).

The result of hypothesis testing for time-varying stochastic translog production frontier with the assumption of the more general truncated normal distribution for the inefficiency effects among firms with unbalanced panel data is presented in table 14.

[Table 14] Statistics of hypotheses tests of SFPF with time varying truncated normal distribution for assembled vehicle manufacturers' sector and automotive components suppliers' sector

Assembled vehicle manufacturers' sector				
Null Hypothesis	Log-Likelihood Function	Test Statistics (λ)	Critical Value	Decision
H_0: $\gamma=\mu=\eta=0$	-478.62	54.64	10.50*	Reject H_0
Automotive components suppliers' sector				
Null Hypothesis	Log-Likelihood Function	Test Statistics (λ)	Critical Value	Decision
H_0: $\gamma=\mu=\eta=0$	- 25646.56	3654.03	10.50*	Reject H_0

Note: Refer to Coelli, T. J. (1996) and Kim and Han (2001).

The estimated parameters for the assembled vehicle manufacturers' sector are $\gamma=0.6686$; $\mu=1.7231$; and $\eta=-0.1518$, and the estimated parameters for the automotive components suppliers' sector are $\gamma=0.8230$; $\mu=-1.9107$; and $\eta=0.0006$, respectively.

The results clearly show that the null hypothesis is rejected at the 1% of significance level, where according to the null hypothesis there is no technical inefficiency effect. If there are no frontier parameters in the regression equation then the estimation leads to an ordinary least square estimation. The present results imply that the average production function is an improper specification of the Korean automotive industry by underestimating the actual frontier due to technical inefficiency effects.

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