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Working Paper

The National Innovation System (NIS) and the automobile industry in South Korea

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The National Innovation System (NIS) and the Automobile Industry in South Korea

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¹ This Paper is the result of an internship at Fraunhofer ISI from May to August 2011.

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1 Introduction

Since Freeman (1988) suggested the concept of National Innovation System (NIS), NIS has provided a foundation for understanding the organizational interactions that engendered innovations in industry. The definition of NIS varies with the context in which innovation activities are performed and evaluated. The multiple definitions of NIS can be classified by their scopes (Chung 2002). In a broad sense, NIS encompasses all the interrelated institutional actors that create, diffuse, and exploit innovations. On the contrary, according to the narrow definition, NIS is a complex of innovation actors that are only directly associated with the generation, diffusion, and appropriation of technological innovation. Research and Development (R&D) departments, universities, and public research institutes can be taken as examples. In this report, primarily the narrow definition of NIS will be adopted, and the role of NIS in the South Korean automotive industry will be accordingly discussed.

The automotive industry is undoubtedly one of the most influential contributors to the entire South Korean economy. The automobile industry has been a major industry sector that sustained the Korean economy for decades and therefore has been proactively supported by the government. Brisk collaboration among government, industry, and academia enabled South Korea to become world's fifth largest manufacturer of automobiles. Indicators such as R&D expenditures suggest that the South Korean automobile industry strives for innovativeness and creativeness. According to Nelson (Nelson 2004), indigenous R&D capabilities are increasingly important for catching-up countries. South Korea, as a late entrant to the world automotive industry, was able to solidify its position in the industry by gradually strengthening independent R&D capabilities. This reinforcement process of the R&D capabilities was effectively carried out under the framework of NIS.

The major focus of this report is on the analysis of the South Korean automobile industry according to the actions taken by innovation actors: innovation efforts of the government and of the industry mainly led by Hyundai-Kia Motors. In this report, I would like to address questions on whether South Korean NIS was practically effective in the industry. In addition, I want to examine the potential shifts that the South Korean NIS is expected to bring about in the industry. Based on this analysis, in the end, I intend to draw a conclusion regarding the influence of NIS on the automobile industry of South Korea.

2 Various Innovation Efforts at the Industry Level

An NIS can be understood as the sum of Sectoral Innovation Systems (SISs) (Chung 1996; 1999; Malerba/Montobbio 2004; Senker 1996). This point of view originates from the inherent nature of national economy: a national economy comprises multiple industrial sectors. Malerba (2002) defined SIS as a set of products and the set of agents performing market and non-market interactions for the creation, production, and sales of those products. Because this paper is focusing on a specific sector of the South Korean economy, the automobile industry, it is cogent to shed light on the concept of SIS. In other words, SIS can serve as a useful tool for understanding innovation activities within the industry. Moreover, the industry appraised within the structure of SIS can also be further understood in the broad context of NIS. To begin with, there will be an in-depth analysis of R&D activities in the automobile sector of South Korea. This will help to determine the influence of the NIS on the automotive industry.

The South Korean automobile industry has put tremendous effort in R&D activities since the industry undertook its first production in the 1970s. As a result, the industry achieved a rapid manufacturing growth over the following decades. According to Lautier (2001), from 1976 to 1996, South Korean automobile production increased by a factor of 76, the total production being 37,000 units in 1976 and 2.8 million units in 1996.

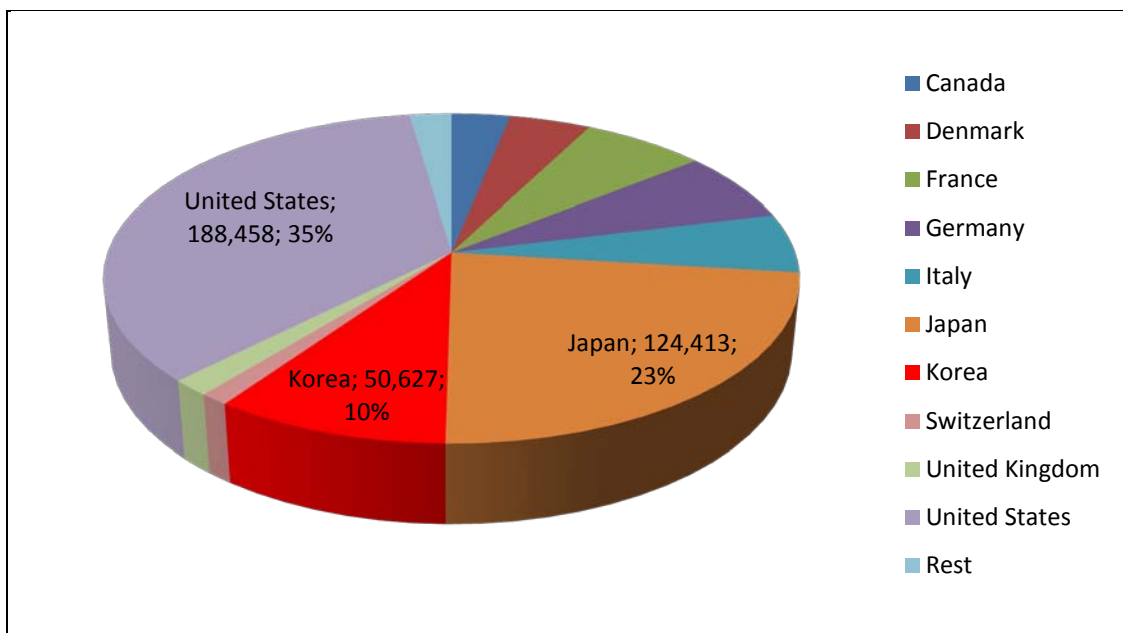
As a late entrant to the world automotive industry, South Korea was in the midst of a catching-up process in the early stage. Throughout the 1990s and 2000s, South Korean automotive industry successfully enhanced its own R&D capabilities in order to stand independently against the frontiers such as Germany, the USA, and Japan. In particular, after President M. Lee announced a government support plan for electric vehicle development in 2009, the industry's R&D efforts were increasingly concentrated towards state-of-the-art electro-mobility applications. Therefore, it is essential to touch on electro-mobility when we discuss South Korean innovation activities at the industry level.

There is no consensus on a single definition of electro-mobility. Similarly to National Innovation System (NIS), electro-mobility too can be defined in either a broad sense or a narrow sense. In a broad sense, electro-mobility is a terminology that encompasses both battery technology and fuel cell technology. According to the German Federal Government (2009), with regard to electro-mobility, battery and fuel cell technologies are mutually complementary paths that need to be pursued together. The European Regions and Municipalities Partnership for Hydrogen and Fuel Cells (HyRaMP) (2011) also defines electro-mobility in this broad sense and understands fuel cells as part of electro-mobility. In a narrow sense, in contrast, electro-mobility includes only battery

technology, leaving out fuel cell technology as a distinct field. In this report, for clear differentiation between the two technologies, the term electro-mobility will follow this narrow definition and represent battery technology.

Electric vehicles can be categorized into three major types, or phases: Hybrid Electric Vehicle (HEV), Electric Vehicle (EV) (100% electric), and Fuel Cell Electric Vehicle (FCEV). A HEV utilizes both an electric motor and an internal combustion engine and is regarded as in the transition phase from a conventional vehicle to a pure EV, which is 100% driven by electricity. The EV uses an electric motor instead of an internal combustion engine, and derives chemical energy from a rechargeable battery. A FCEV takes advantage of a fuel cell that synthesizes hydrogen and oxygen to produce electricity, which generates power for an electric motor. According to Virtanen/Lee (2010), in South Korea HEVs are currently in the commercialization phase. EVs are not yet commercialized in South Korea, but its first full speed EV was launched in 2010. However, FCEVs are the slowest in their rates of progress, and still only in the development phase.

Figure 1: R&D Budgets on Fuel Cells Worldwide, in Million USD (PPP), 2007



Source OECD (2011a), IEA Energy Technology R&D Statistics, own computation

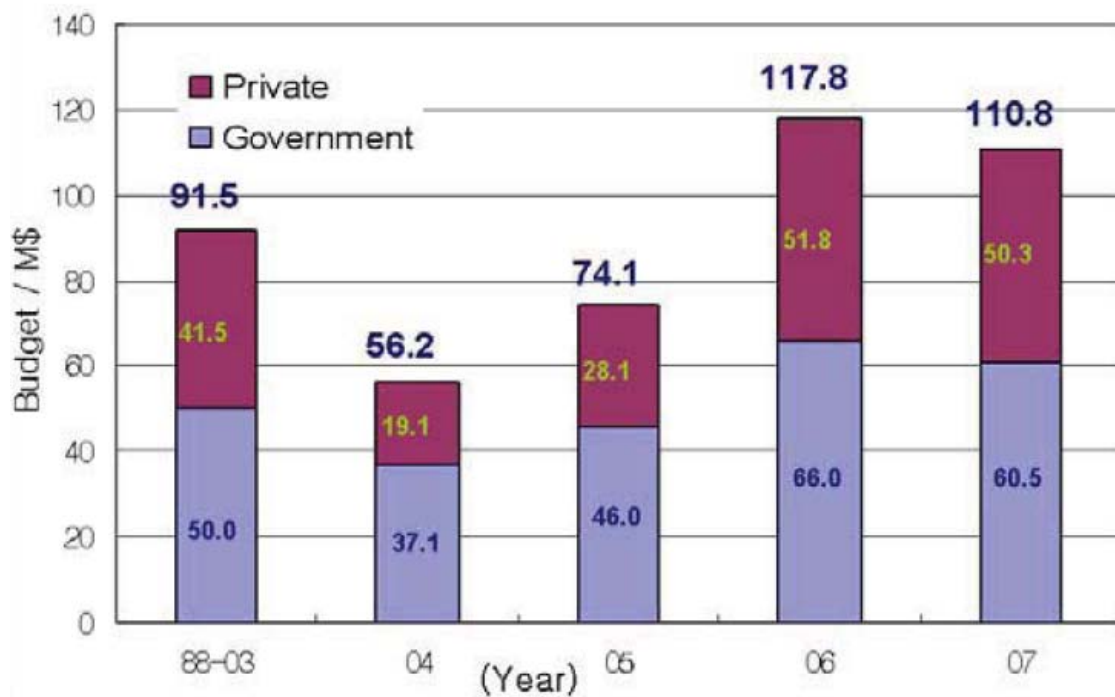
Indeed, the South Korean automobile industry constantly strived to develop and commercialize the new types of vehicles such as HEV, EV, and FCEV. According to Figure 1, the South Korean R&D budget on total fuel cell accounts for 10% of the world's reported total. This share, the 10%, is the third highest in the world following the shares of the

U.S. and Japan. This demonstrates that South Korea is one of the leading nations in the fuel cell research and investing a large amount of resources.

South Korea's intense R&D budget on fuel cell research can be attributed to the government project. According to Korea Economic Institute (2008), in 2005 the South Korean government announced a national long-term plan to build a hydrogen economy by 2040. Fuel cell research is major part of this plan. The government proactively supports the industries' efforts to develop FCEVs, fuel cell portables, and fuel cell power generators. In particular, the development of FCEVs is considered as important, and a significant amount of resources are earmarked for it.

Based on Figure 2, in South Korea the private sector's contribution to the fuel cell research has been as large as that of the government.

Figure 2: Fuel Cell R&D Budget of South Korea, 1988-2007



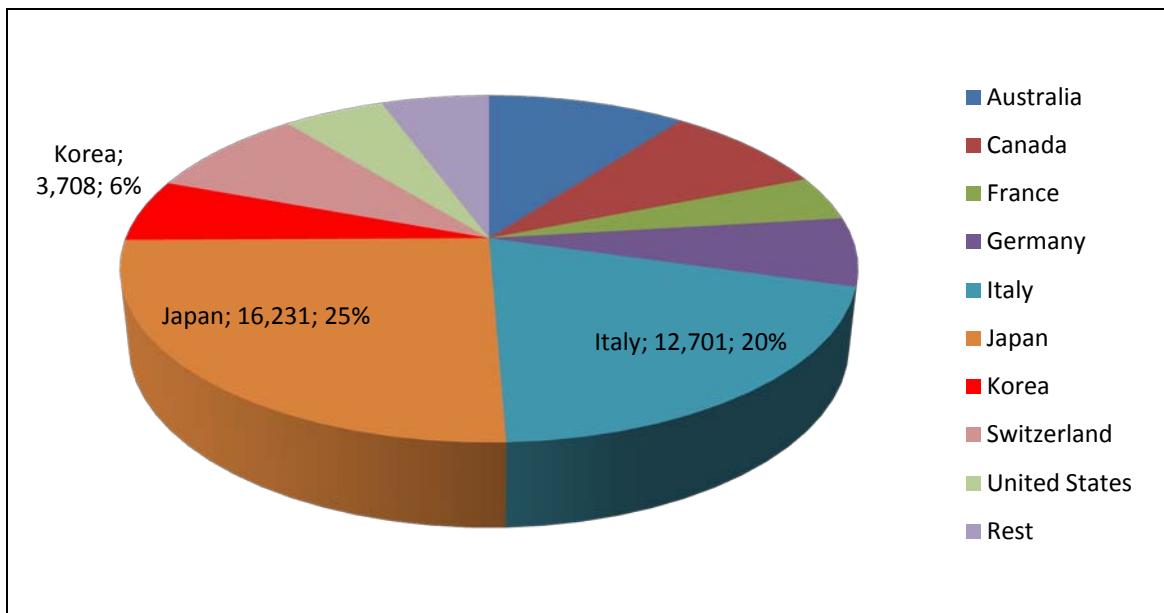
Source: Korea Economic Institute, Hydrogen and Fuel Cell Activities in Korea (2008)

As a matter of fact, the private sector plays an important role in the fuel cell research in South Korea. In response to the active support of the government, private organizations also invest a tremendous amount of resources in the fuel cell research. Hyundai-Kia Motors is a major participant among these private firms that lead the fuel cell research.

According to the Fuel Cell Vehicle Team of Hyundai-Kia Motors (2006), Hyundai-Kia Motors owns the largest fuel cell research facility in South Korea. Hyundai-Kia Motors has developed many types of FCEVs since its first launch of the Santa Fe FCEV in 2000. For the application of FCEVs, based on the Fuel Cell Vehicle Team of Hyundai-Kia Motors (2006), its innovation efforts have been extensively supported by the government: by the Ministry of Commerce, Industry and Energy (MOCIE), the Ministry of Construction and Transportation (MOCT), and the Ministry of Science and Technology (MOST). With the fuel cell application, the South Korean automobile industry tries to cope with the depletion of existent fossil fuels and the intense foreign competition. However, the Fuel Cell Vehicle Team of Hyundai-Kia Motors' study (2006) demonstrates that the commercialization of FCEVs is still subject to the resolution of issues involving cost, durability, and subzero temperature start-up.

In addition to the fuel cell research, the South Korean automobile industry puts substantial efforts into developing EVs, which represent the electro-mobility application in a narrow sense. This is revealed by an increase in the R&D budget on the relevant sector. Here, the energy storage sector is used as an indicator for battery technology. The 2006 OECD statistics for R&D budgets on energy storage is as follows:

Figure 3: R&D Budgets on Energy Storage Worldwide, in Million USD (PPP), 2006

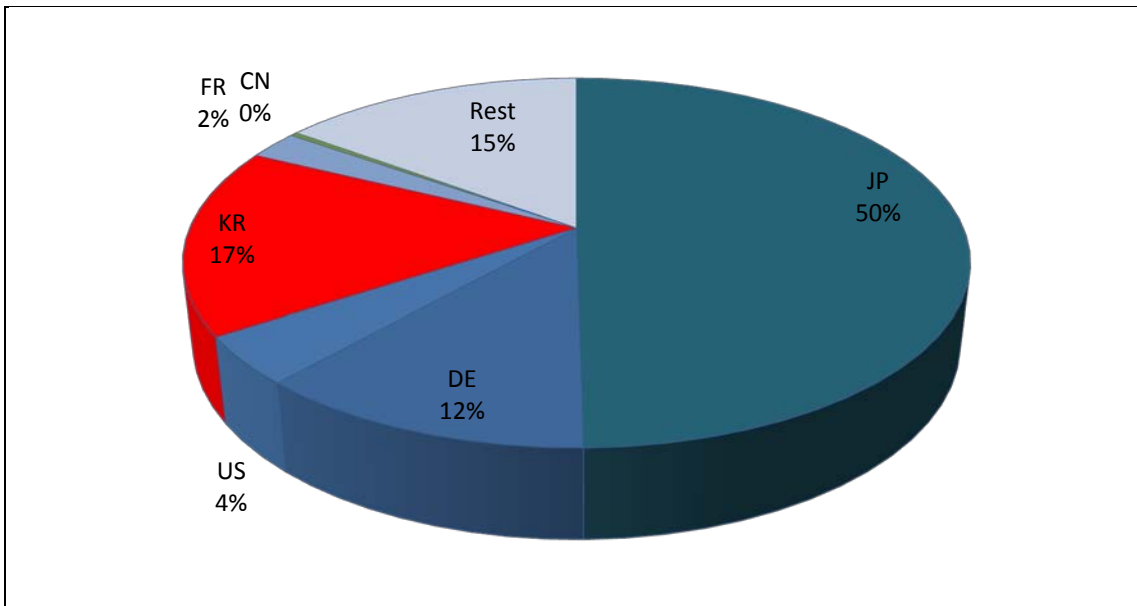


Source: OECD (2011a), IEA Energy Technology R&D Statistics, own computation

Figure 3 shows that South Korea accounts for only a small portion of the world's total R&D budget on energy storage: South Korea held only 6% of the world's R&D budget on energy storage, which is far less than proportions taken by leading nations such as

Japan and Italy². When compared with other leading nations, South Korea does not invest as many resources in the energy storage research as other countries do. In comparison with the South Korean R&D budget on fuel cells, South Korean input in the battery research is substantially small. The very fact that South Korean investment in the fuel cell research surpassed that in the battery research is also significantly reflected in the patent statistics, which are used with publication statistics as a tool for gauging the R&D performance resulting from investments. The following statistics from European Patent office (EPO) show the number of patents for fuel cells and electro-mobility.

Figure 4: Fuel Cell Patents Worldwide, 1996-2008



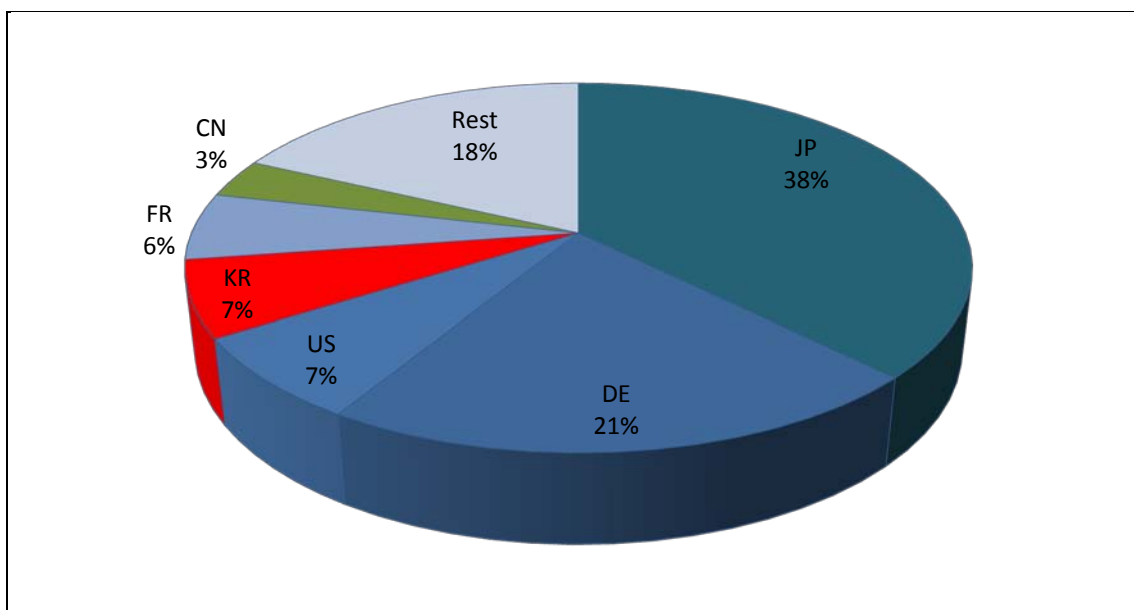
Source: PATSTAT, Fraunhofer ISI

According to Figure 4, South Korea accounts for a fairly large portion of the world's entire fuel cell patents. In contrast, as demonstrated by Figure 5, South Korea does not file as many patents for electro-mobility as for fuel cells, and South Korea's relative position as a registrant of electro-mobility patents is not very solid. Conversely, in contrast to the patent statistics, publication statistics for fuel cells and electro-mobility suggest that electro-mobility R&D outperforms fuel cell R&D in South Korea: 3,991 publica-

² However, OECD (2003) previously noted in the "Energy Policies of IEA Countries: Italy" that a significantly large proportion of Italy's energy R&D is targeting conventional fossil fuels. Hence, in Figure 3, it is recommended to give little attention to Italy holding the second highest R&D budget share. Italy's energy storage R&D share does not closely approximate budgets for battery R&D, or electro-mobility R&D.

tions for electro-mobility and 2,992 publications for fuel cells. The source of these publication data is Scopus³. Evidently, the number of fuel cell publications is far less than that of electro-mobility publications. The corresponding R&D output disparity between the publication statistics and the patent statistics from Figure 4 and Figure 5 becomes even more remarkable when compared with other frontier countries.

Figure 5: Electro-Mobility Patents Worldwide, 1996-2008



Source: PATSTAT, Fraunhofer ISI

For example, Germany has 3,132 publications for fuel cells and 3,046 publications for electro-mobility under the same search strategy. Even though the number of South Korean publications for electro-mobility is greater than that of Germany, South Korean electro-mobility patent share is much less than the German one: 7% for South Korea and 21% for Germany in Figure 5. Furthermore, Figure 4 suggests South Korea registers more fuel cell patents than Germany, while Table 1 shows South Korean publications for fuel cells are fewer than German ones. In fact, there is sufficient rationale for viewing South Korea as a leader in the field of electro-mobility, which might not sound

³ The search strategy used for fuel cells was TITLE-ABS-KEY("fuel cell" or "hydrogen car" or "hydrogen mobility" or "hydrogen vehicle") and AFFILCOUNTRY(Korea) AND SUBJAREA(MULT OR CENG OR CHEM OR COMP OR EART OR ENER OR ENGI OR ENVI OR MATE OR MATH OR PHYS.)

The search strategy for electro-mobility was TITLE-ABS-KEY(battery or batteries or "electric vehicle" or "electric car" or "e-mobility") and AFFILCOUNTRY(Korea) AND SUBJAREA(MULT OR CENG OR CHEM OR COMP OR EART OR ENER OR ENGI OR ENVI OR MATE OR MATH OR PHYS.)

convincing based only on the patent statistics. The publication statistics in Table 1 can serve as a supplement for understanding South Korea's performance in electro-mobility.

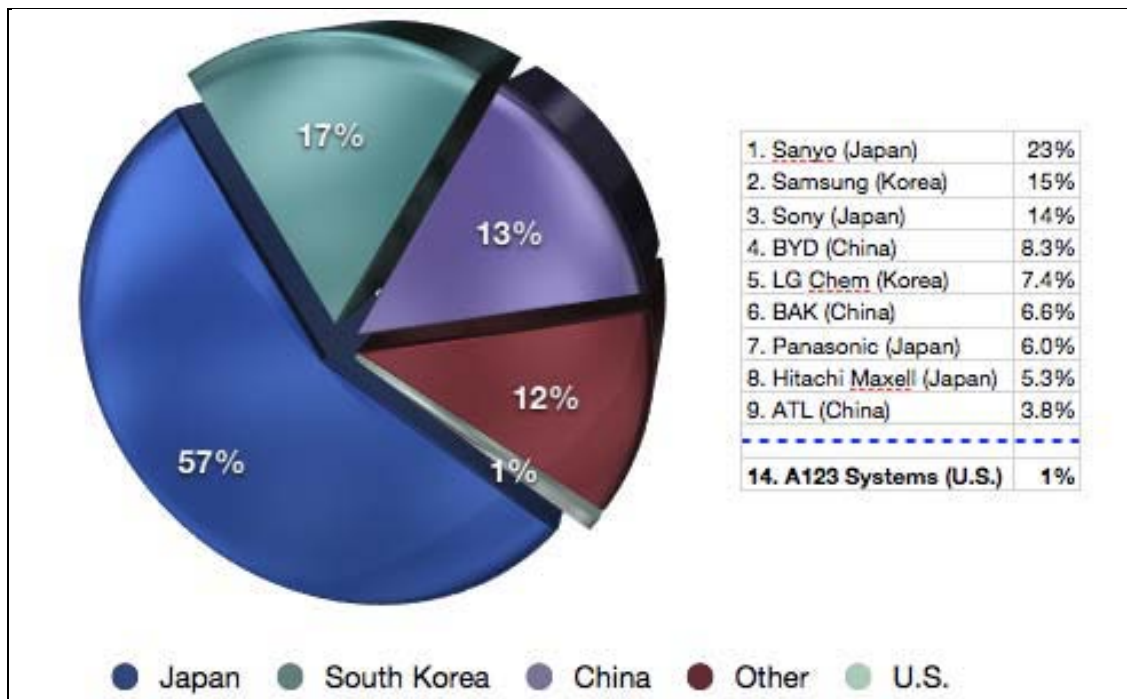
Table 1: Publication Statistics Under the Same Search Strategy, Comparison between South Korea and Germany, 2011

Area	South Korea	Germany
Fuel Cells	2,992 publications	3,132 publications
Electro-mobility	3,991 publications	3,046 publications

Source: Scopus, own computation

Indeed, there exists compelling evidence that South Korea shows a good performance in the electro-mobility field rather than in the fuel cell field. For instance, Hyundai Motors launched its first full speed EV, Blue On in 2010, powered by a lithium-ion battery, while its FCEV still remains in the development phase (Virtanen/Lee 2010). Furthermore, South Korea is rapidly increasing its lithium-ion battery market share, threatening Japan's solid position in the industry (NEDO 2009).

Figure 6: Lithium-Ion Battery Market Shares Worldwide, 2007



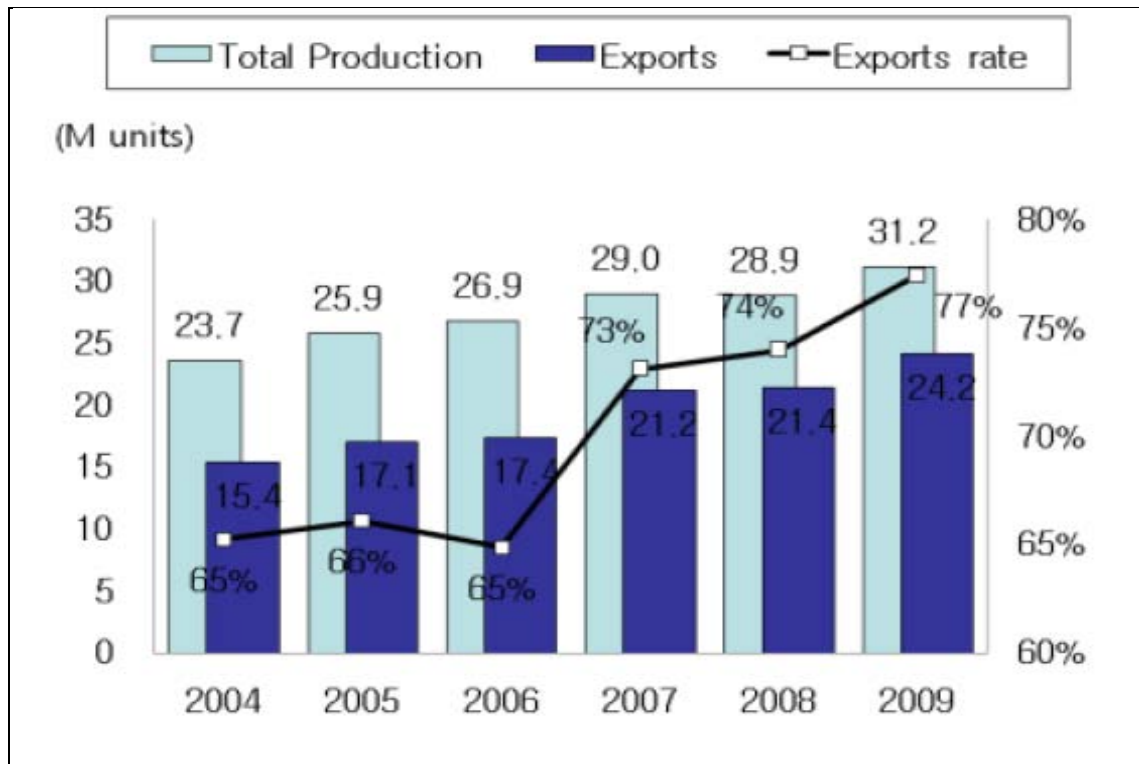
Source: Lowe et al. (2010)

Based on Figure 6, South Korea held a 17% lithium-ion battery market share in 2007. According to the Ministry of Economy, Trade, and Industry of Japan (METI 2010), there

was a remarkable increase in South Korean lithium-ion battery market share. In the year 2000, South Korea held only a 2% share in world's lithium ion battery market. As empirically shown by the market share statistics, South Korea is currently one of the major lithium-ion battery manufacturers in the world. Those lithium-ion batteries produced by South Korean manufacturers are extensively utilized for HEV and EV applications (Lowe et al. 2010).

Up to the year 2009, South Korean exports of rechargeable battery, which is essential in EV applications, steadily increased, based on Figure 7. Figure 7 also displays that the total production, exports, and export rate all went up consistently in recent years. This, in addition to the lithium-ion battery market share, indicates the competence of South Korea in the electro-mobility field.

Figure 7: South Korea's Rechargeable Battery Exports, 2004-2009



Source: Electric Vehicles South Korea, Virtanen and Lee (2010),

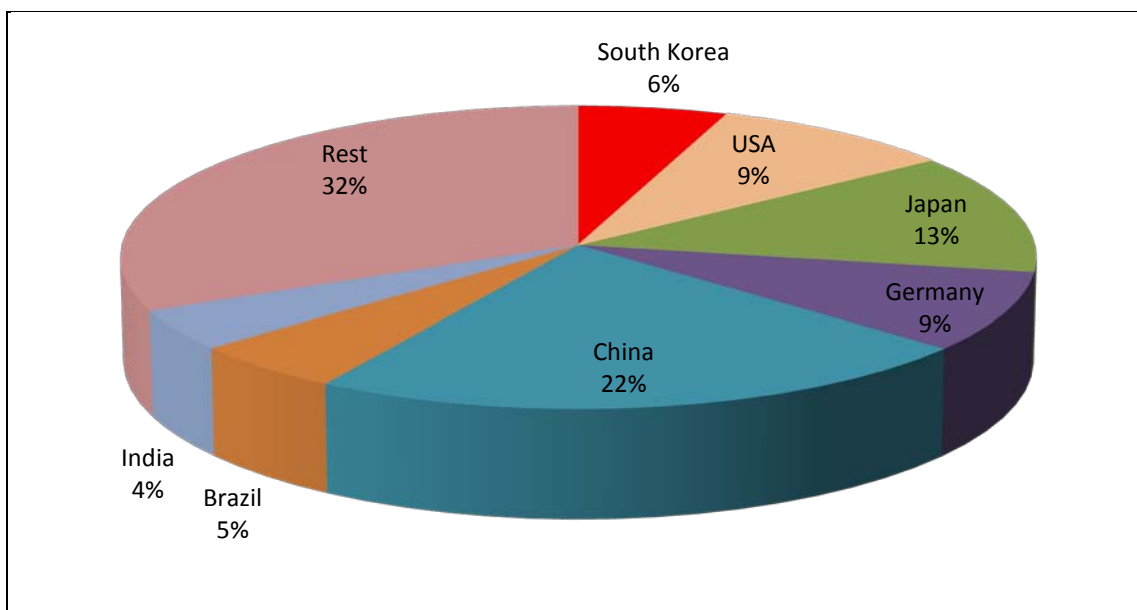
In summary, currently the South Korean automotive industry's innovation efforts are largely devoted to FCEVs and EVs. The industry especially concentrates on the development and commercialization of EVs under the government's support. Macro-level evidences such as R&D budgets, patents, and publications in the relevant fields delineate the innovation activities in the automotive industry. The R&D budget statistics show that South Korea invests more intensely in fuel cell research than in electro-

mobility research. This is highly consistent with an R&D performance indicator, namely patent statistics. However, another indicator, publication statistics, reconciles the R&D input and the empirical R&D output that has been observed. The publication statistics implies that South Korea is one of the frontiers in electro-mobility, which is also empirically demonstrated by the current EV development phase and the competent battery industry.

3 The Significance of the South Korean Automobile Industry

South Korea is currently world's fifth largest automobile manufacturer. According to Figure 8, South Korea manufactured approximately 6% of the total world automobiles produced in 2009. In 2009, the number of vehicles produced by Hyundai-Kia Motors of South Korea was over 3.5 million. This is among the largest automobile countries in the world following China 22%; Japan 13%; the U.S. 9%; and Germany 9%.

Figure 8: Automobile Production Worldwide, 2009

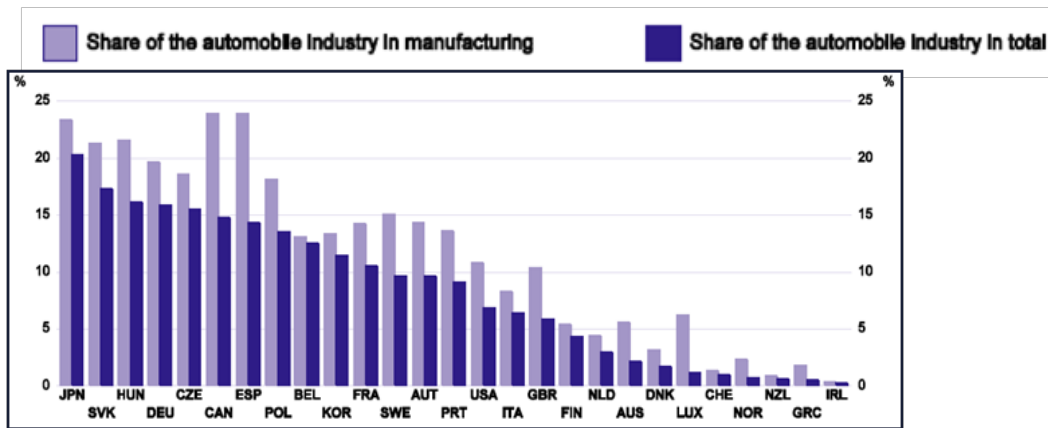


Source: OICA (2011), <http://oica.net/category/production-statistics/2009-statistics/>, own computation

Moreover, based on Figure 9, the share of the automobile industry in total South Korean exports equals 12%. It is a considerable ratio given that South Korean economy is strategically based mostly on a great deal of exports. Hence, as shown by Figure 9, the automobile industry can be understood as a key sector of South Korean economy. This gives some insight into the topic's relevance to SIS. Since the automobile industry is a major sector of the entire economy, the industry assessed in the context of SIS will help us to determine the broad scheme of NIS's influence on the industry.

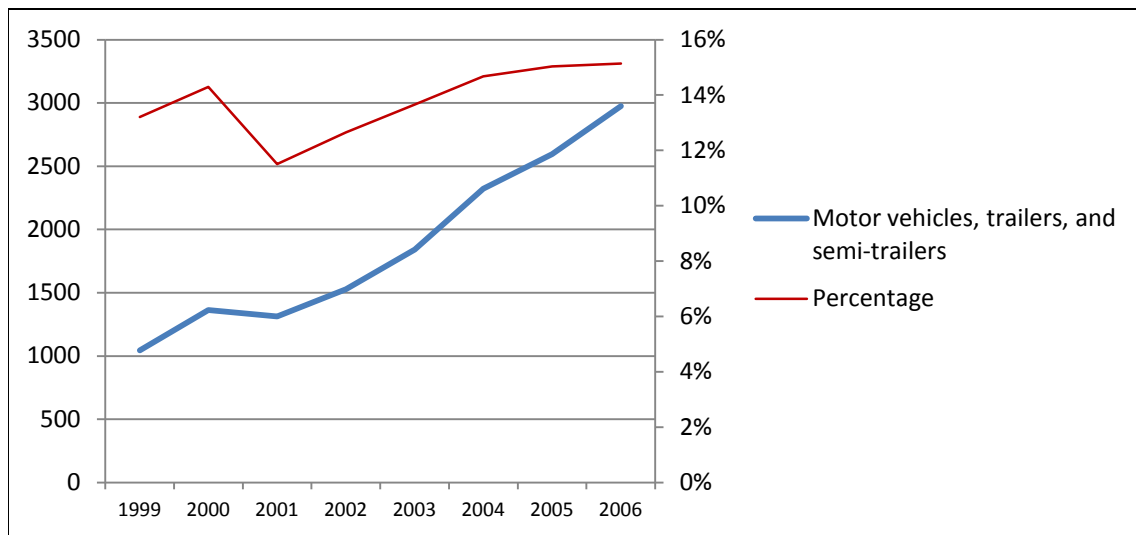
In order to appraise the automotive industry's current phase, it is also necessary to examine relevant R&D statistics within South Korea. The business enterprise R&D expenditures of South Korea reveal that the automobile industry has accounted for a moderately large proportion of the entire South Korean economy throughout several recent years. This reflects the strength and stability of the automobile industry.

Figure 9: Export Share of the Automobile Industry Worldwide, 2007



Source: OECD (2009), The automobile industry in and beyond the crisis

Figure 10: Business Enterprise R&D Expenditure of South Korea, in million USD, 1999-2006



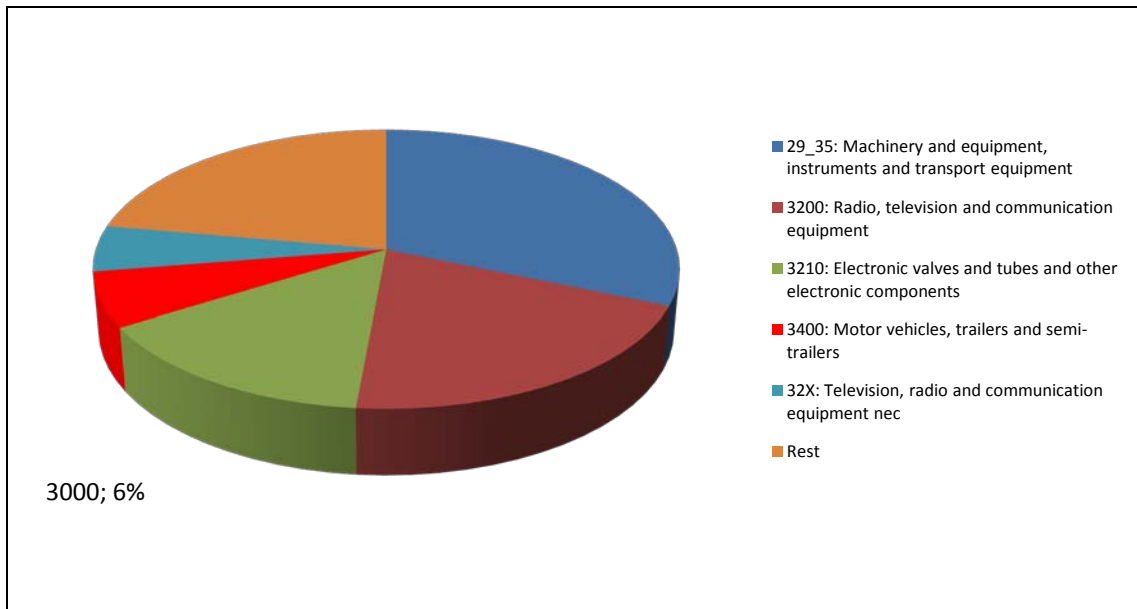
Source: OECD (2011b), Science Technology and R&D Statistics, own computation

According to Figure 10, the R&D expenditures on the automobile industry increased rapidly in the 2000s. In particular, the proportion of the R&D expenditures spent on the automotive industry against those spent on all of the industries steadily went up from 2000. As Figure 10 clearly displays, there was a drastic proportion decrease in the beginning of the decade, but the subsequent proportion increase throughout the rest of the decade is noteworthy. This demonstrates that South Korea has made consistent efforts in supporting its automobile industry.

Furthermore, Figure 11 displays that R&D expenditure in the automobile sector takes the fourth largest proportion of the total manufacturing R&D expenditures after the ma-

chinery and equipment industry, etc. In South Korea 6% of the total R&D expenditures were invested by the automobile industry.

Figure 11: Business Enterprise R&D Expenditure by Industry, in million USD, 2006



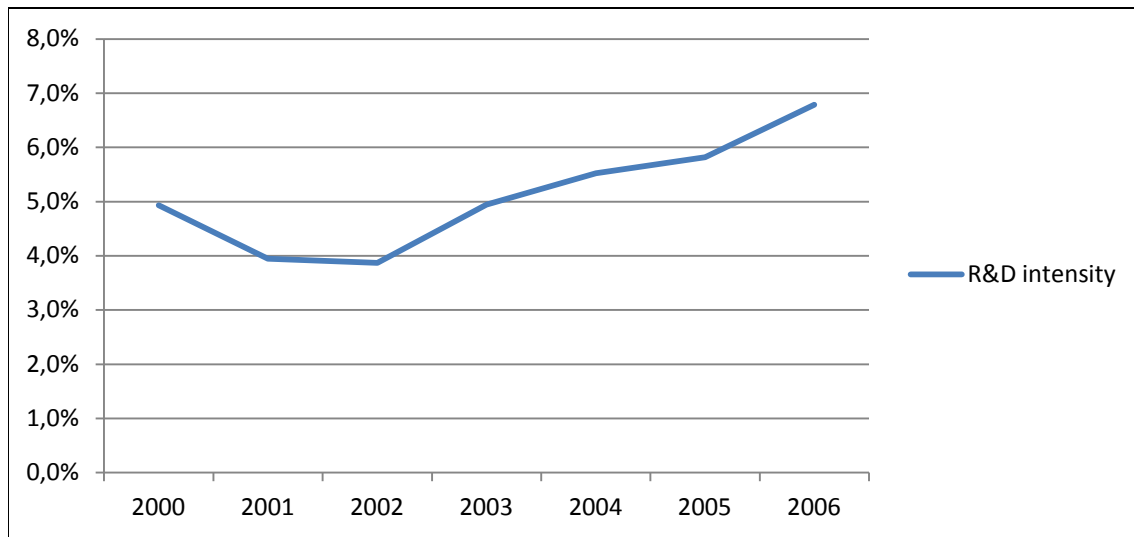
Source: OECD (2011b), Science Technology and R&D Statistics, own computation

According to Figure 12, in the 2000s there was a significant steady increase in the R&D intensity⁴ of the South Korean automotive industry. This indicates that more and more dollars obtained from vehicle sales are going towards R&D activities. As at 2006, a year with the highest R&D intensity, approximately 6.8 percent of the automobile sales were devoted to generating R&D activities. The general trend of R&D intensity curve is substantially comparable to the proportion of R&D expenditures spent on the automobile industry in Figure 10. In the early 2000s, there was a temporary decrease in R&D intensity as the proportion of R&D expenditures went down. However, in the following years, both R&D intensity and R&D expenditure percentage increased rapidly but in a consistent manner. This is highly congruent with the fact that in the 2000s South Korea, as a late entrant to the automobile industry, intensely strived for achieving independent R&D capabilities against frontier countries such as Germany, the U.S. and Japan.

⁴ The following formula was used in calculation:

$$\text{R\&D intensity} = (\text{R\&D expenditures}) / (\text{sales in dollars})$$

Figure 12: Business Enterprise R&D Intensity in South Korean Automobile Industry, 2000-2006



Source: OECD & Financial statements of Hyundai-Kia Motors, own computation

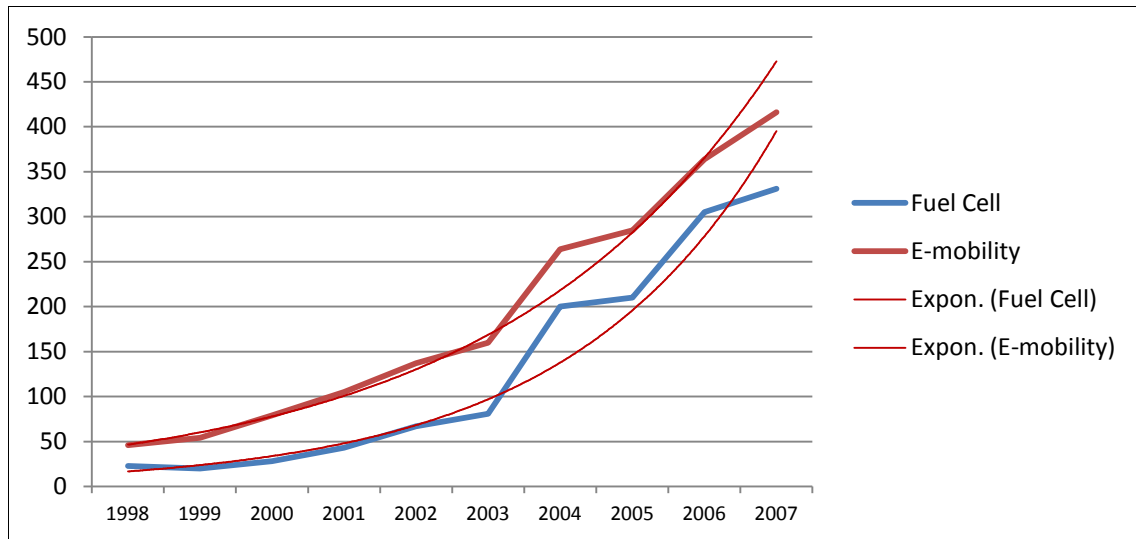
In fact, it is visible that South Korea's strategy changed in the early 2000s. As a result of the industry's high R&D expenditure proportion and R&D intensity, the number of publications⁵ in the relevant disciplines, fuel cells and electro-mobility, increased accordingly (see Figure 13). Furthermore, the rate of their increase became much greater than before. The increase in publications implies enhanced independent R&D activities. Figure 10, Figure 12 and Figure 13 all point out that 2001-2003 was a notable transition period for the industry's R&D activities: the industry's R&D input and output all underwent a drastic increase. This confirms the structural transition from an imitation-based industry to an innovation-based industry. The industry's achievement over a short period of time, displayed by its currently stable position in world market competition, was possible under the reinforcement of autonomous innovation efforts. This completely supports Nelson's (2004) point of view that indigenous R&D capabilities are essential for catching-up countries. With regard to automobile industry, South Korea exemplifies a catching-up country that succeeded by means of independent innovativeness and creativeness.

In contrast to these positive indications about the South Korean automobile industry, its actual performance in foreign competition does not appear to be as positive. In other words, South Korea's consistent R&D investment in the automobile industry did not necessarily result in a good performance when compared with other nations' automobile industries. It is plausible that a variety of existing external factors intervene in the

5 With regard to the search strategy, please refer to footnote 3.

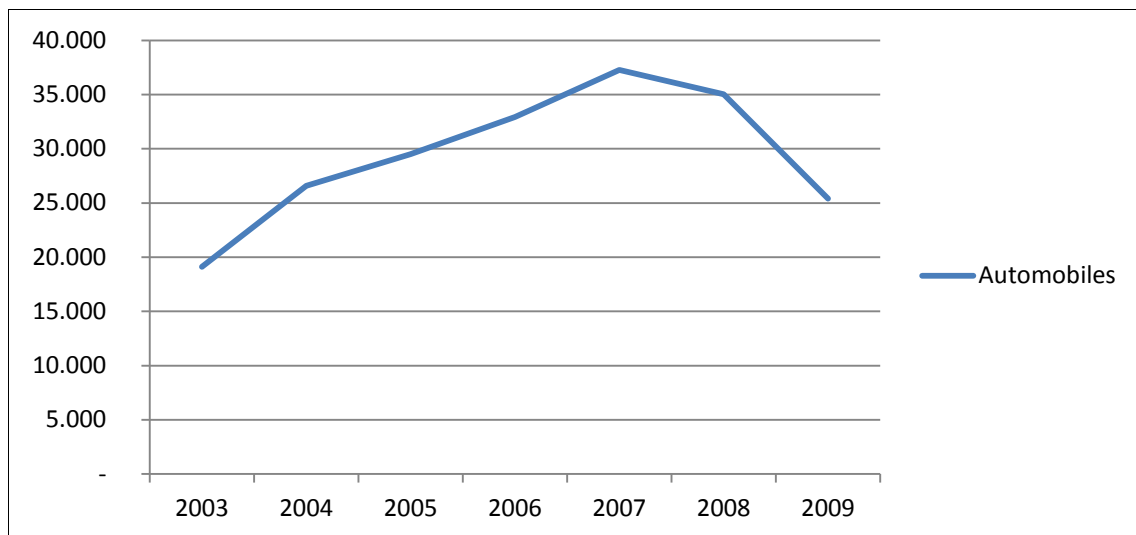
industry's performance, counteracting the positive influence of the massive R&D input. This point is in part demonstrated by Figure 14 about automobile exports of South Korea.

Figure 13 The Number of South Korean Publications by the Field, 1998-2007



Source: Scopus, own computation

Figure 14: Automobile Exports of South Korea, in Million USD, 2003-2009

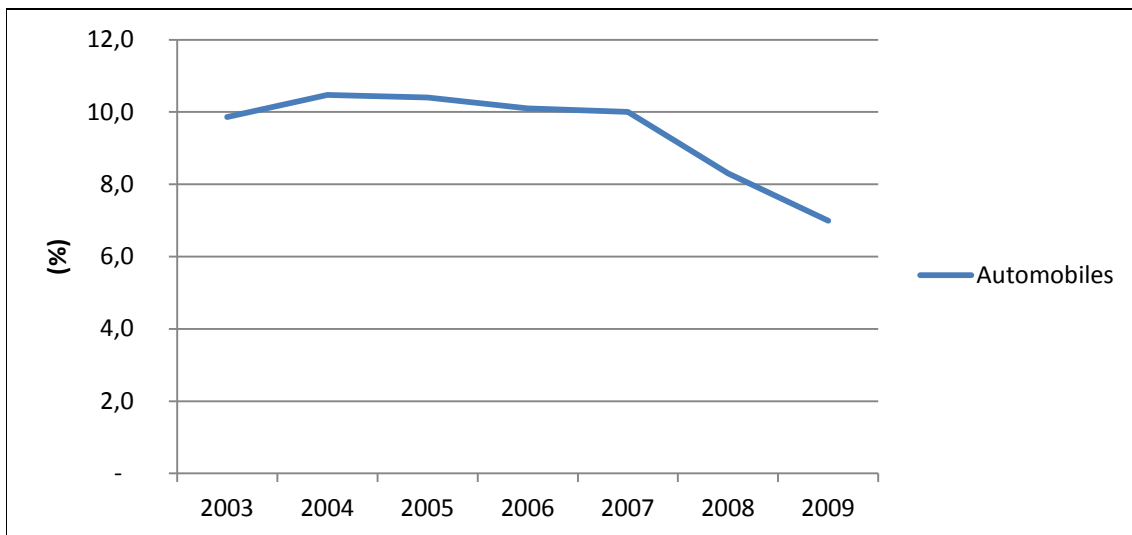


Source: The Ministry of Knowledge and Economy of South Korea (2009), own computation, http://english.mke.go.kr/language/eng/economic/key_view.jsp?seq=21&srchType=1&srchWord=&ctx=Trade&pageNo=1

According to Figure 14, South Korean automobile exports considerably diminished in recent years. This contrasts with South Korea's continuous R&D efforts in the automo-

bile industry. The decrease in South Korea's automobile exports could be possibly attributed to the severe recession recently experienced by the U.S., whose market is of extreme importance to the South Korean automobile industry. Even though automobile exports dropped recently, it might have been possible that the automobile industry did not fall behind other industries in regard to the exports. However, Figure 15 shows that there was a substantial decrease in the ratio of the automobile exports to the total exports. However, the ratio of the automobile exports to the total exports indicates that the speculation is invalid: the proportion of automobile exports to the total exports diminished substantially. Figure 15 suggests there was a tremendous downturn in the automobile exports especially from the year 2007. The automobile industry did not do well on exports in comparison with the other industries.

Figure 15: Share of Automobile Exports in Total Manufacturing of South Korea, 2003-2009



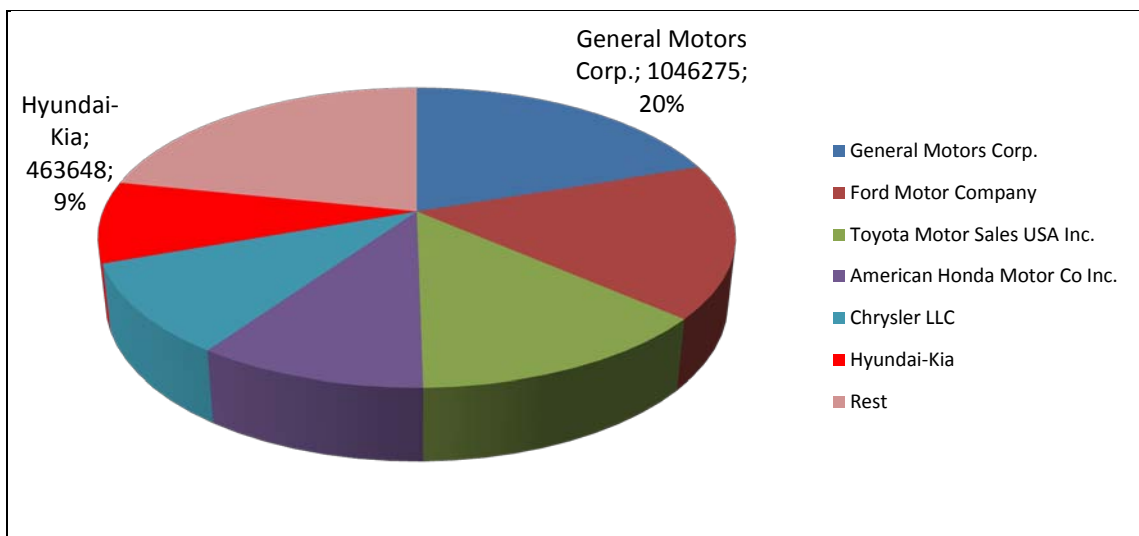
Source: The Ministry of Knowledge and Economy of South Korea (2009), own computation, http://english.mke.go.kr/language/eng/economic/key_view.jsp?seq=21&srchType=1&srchWord=&ctx=Trade&pageNo=1

According to the market share statistics from the Wall Street Journal (2011), South Korean automobiles became more and more popular in the U.S. Figure 16 shows the year 2011 automobile market share in the U.S. by manufacturer. This data is based on the automobile sales. The Hyundai-Kia Motors accounts for 9% of the total U.S. market in 2011, which is higher than 7.4% from 2010.

Based on Figure 17, in the European automobile market, Hyundai-Kia Motors has a market share of 4.6%, which is less than half its U.S. market share of 9%. Two explanations for this observation can be given. A simple conjecture for the cause could be that there is an inherent factor that intervenes in global competition. Certainly, Euro-

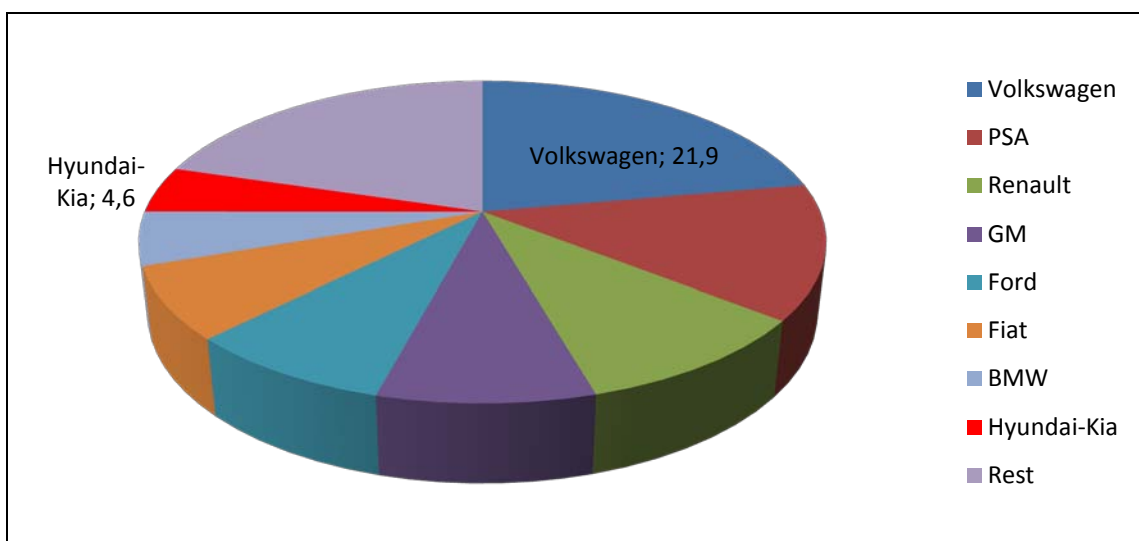
pean automobile manufacturers maintain strong positions particularly in the European market; for example, Volkswagen has a market share of 21.9% in Europe but only 2.4% in the U.S. market. It is intrinsically convincing that local manufacturers are more welcomed and demanded than foreign manufacturers. The fact that there exist a greater number of local manufacturers in Europe than in the United States would explain the reason South Korean automobiles have a smaller market share in Europe than they do in the United States.

Figure 16: Year-To-Date Automobile Market Shares in the U.S., 2011



Source: Wall Street Journal (2011), own computation, http://online.wsj.com/mdc/public/page/2_3022-autosales.html

Figure 17: Automobile Market Shares in Europe, 2011



Source: Utelio (2011), <http://www.utelio.it/market-share-auto.php>, own computation

The other speculation is that the South Korean automobile industry strategically focused on the North American market in the early phase of catch-up. This is clearly shown in the corporate histories of the two major manufacturers, Hyundai Motor and Kia Motors, from South Korea. In order to expand their business overseas, they founded Hyundai Motor America and Kia Motor America in 1985 and in 1992 respectively. This was earlier than when they established own European branches: Hyundai Motor Europe founded in 2000 and Kia Motor Europe in 1995. The two South Korean automobile manufacturers found it more advantageous to target the U.S. market rather than the European market. For example, the U.S. market was inherently integrated, while the European market consisting of multiple national markets was fragmented. Moreover, in the U.S., where English is officially spoken, the language barrier was minimal. Also, when compared with European countries, the U.S. household's Average Propensity to Consume (APC) was high enough to assure the South Korean manufacturers of potentially positive profits: the manufacturers assumed Americans would be more willing to spend money on their products than Europeans would.

Even though their market share is small, South Korean automobiles' performance in the European market is consistently maintained as indicated by its share of 4.5% in 2010, which is not very different than 4.6% in 2011.

4 Various Innovation Efforts of Government

The South Korean government showed consistent commitment to the automobile industry. It is incontrovertible that the South Korean government played a tremendous role in sustaining the automobile industry. The government backed up the automotive industry with a variety of Science and Technology (S&T) policies, which laid foundations for collaboration among innovation actors. In fact, the splendid success that the South Korean automobile industry, as a world's late entrant, achieved over the past decades was possible under the brisk cooperation among government, industry, and academia. This cooperative relationship is also unmistakably demonstrated by recent government initiatives.

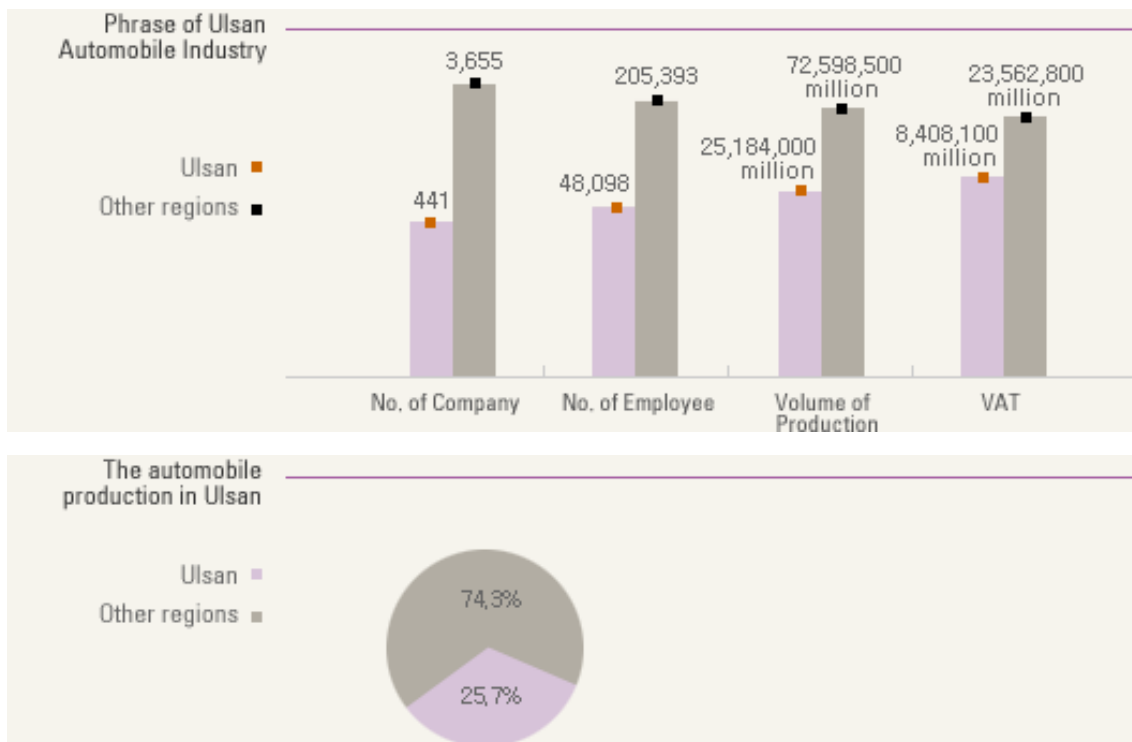
For instance, the South Korean government invested 400 million USD in the Ulsan Auto Valley Project (Prativedwannakij 2009). Under this project, the Ulsan Metropolitan City continuously supported Hyundai-Kia Motors as a production base, which reflects the close relationship between government and industry. With regard to academia, moreover, a major plan of the Ulsan Auto Valley Project was to establish the Graduate School of Automotive Technology, which is expected to help the industry in many ways. According to Figure 18, the Ulsan city currently accounts for 74.3% of the total automobile production in South Korea. The proportion of 74.3% clearly shows what meaning the Ulsan city has for the entire South Korean automobile industry.

The South Korean government invested a significant amount of resources in the Ulsan city, enabling the city to become a strategic automobile cluster. The Ulsan Auto Valley Project mentioned in the previous paragraph was a noteworthy governmental plan that reinforced the automotive industry. The major contents of this project are as follows: provide auto-parts at low prices by building an industrial complex near automobile plants; strengthen R&D and innovation capacities of local companies by establishing an auto-parts innovation center (Ulsan Metropolitan City 2011). In particular, the Auto-Parts Innovation Center was immensely funded by the Ministry of Commerce, Industry, and Energy (MOCIE) and the Ulsan Metropolitan City. As a result of the government's intensive investment, Ulsan became extremely essential in the South Korean automobile industry.

Aside from the Ulsan Auto Valley Project, the South Korean government implemented many other policies for bolstering the automotive industry. Some policies were geared towards sustaining the industry in rather a conventional manner, not necessarily aimed at technological innovations in the industry. For example, the government provides financial support for auto parts suppliers and car loan/finance industry; which comprises a temporary 30% reduction in individual consumption tax up to the second half of

the year 2009 (Agustin 2009). In addition, the government reviewed granting subsidies to car owners if they switch to smaller cars. The primary goal of these policies is to invigorate the automotive industry by inducing favorable shifts in auto-related consumption. Because consumption is directly related with production, the policies will also positively influence the innovation efforts of the industry.

Figure 18: Comparison of the Ulsan Auto Cluster and Other Regions in South Korea



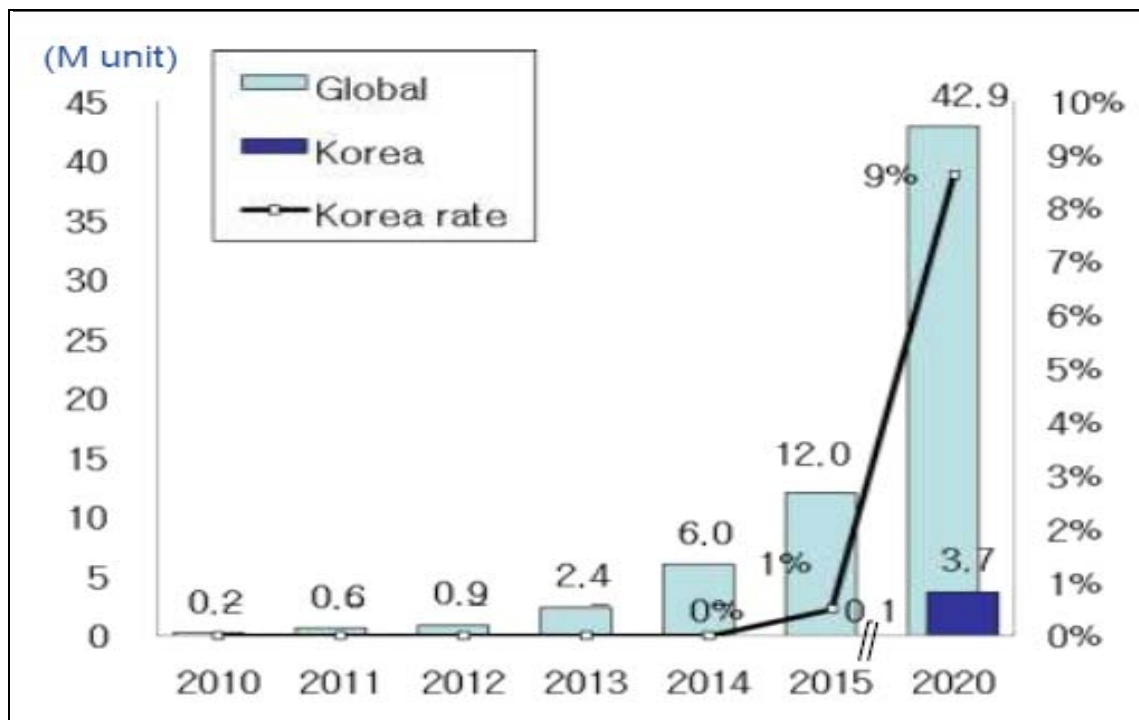
Source: The Ulsan Metropolitan City (2011), http://www.ikjournal.com/InvestKoreaWar/work/reg/eng/co/index.jsp?1_unit=90202&...

There are many policies directly enticing technological innovations in the automobile industry. The hybrid vehicle tax incentives can be taken as an example. Under this policy, the South Korean government provides the maximum tax credit of 2,000 USD per HEV (Agustin 2009). In addition to this initiative, the government also encourages the usage of bio-fuel driven vehicles. Likewise, many policies are implemented in order to foment the development of eco-friendly vehicles that are also fuel efficient. For instance, the government intensely supported the production of EVs, aiming at securing 10% of the global EV market by 2015. To enable this, according to the Ministry of Knowledge Economy (2009), the government will invest the total of 341 million USD up to 2014 in the development of high-performance batteries and other related systems. The Seoul Metropolitan Government (2010) announced that the half of all public transport vehicles will be electric by 2020. In fact, the city government is planning to in-

crease the number of EVs within Seoul up to 120,000 by 2020. All of these innovation efforts at the national level suggest that the South Korean government puts equal emphasis on both the development of technology and the application of it.

In addition, the South Korean government designed a variety of new supporting measures for reinforcing innovation efforts in the automotive industry. According to Virtanen and Lee (2010) the South Korean government plans to subsidize public organizations purchasing electric vehicles the maximum of 20 million KRW to until 2012. This amount is approximately the half of the conventional gasoline vehicles' prices. Virtanen and Lee (2010) also suggest that electric vehicle users will receive further benefits of tax reduction, free parking, and other bonus systems based on greenhouse gas emission level. Moreover, the government also plans to establish a sustainable charging infrastructure for electric vehicles. The government will invest 111 million EUR in building the charging infrastructures by 2020 (Virtanen/Lee 2010). These policy measures recently coordinated demonstrates that the government as a public actor plays an essential role in bolstering the automobile industry.

Figure 19: Anticipation over the Global Electric Vehicle Market



Source: Virtanen and Lee (2010), Electric Vehicles South Korea

In particular, the current South Korean government is claimed to have made brisk innovation efforts for boosting economy. President M. Lee often proclaims the necessity of technological advancement in electro-mobility. Green growth is one of President Lee's

major interests, and electro-mobility is certainly an important topic of his policies. In 2009 he announced that the government will offer full support to help South Korean companies in order to secure 10% of the global electric car market by 2015 (Agence France-Presse 2009). Based on Figure 19, South Korea will actually be able to take the market share of 9% in the year 2020 unless the current innovation efforts significantly abate in the future. The prospective 9% market share corresponds to 3.7 million EVs in 2020.

5 Conclusion

In summary, the South Korean automobile industry, as a late entrant to the world automotive industry, succeeded in strengthening its position in the market. This was possible through extensive R&D activities in the process of catch-up. The industry's recent innovation activities in fuel cells and in electro-mobility were described in detail. South Korea's R&D intensity within the industry went up significantly. Furthermore, the industry's export-orientation strategy was effective and helpful for its expansion. Market share statistics previously suggested that South Korean automobiles gained more and more popularity overseas throughout decades. These R&D activities and exports were largely supported by the government, which devised and implemented many policies conducive to stimulating the automotive industry. This interrelationship between the industry and the government is a major component of the NIS structure.

The growth of the South Korean automobile industry can be explained in the context of NIS. In the process of catch-up, South Korea strategically took a highly systematic approach. Various innovation efforts at an industry level and at nation level were discussed. The government determined the direction of resource allocation as a central authority, or a participant. Private companies in the industry were extensively supported and strived for innovative applications in close collaboration with the government. Fuel cell and electro-mobility applications are considered as key innovation targets in the industry. Academia's role was considered not as significant as the government and the industry. Nonetheless, academia supplied highly qualified R&D personnel to the industry. It is after 1990s when the automotive industry realized the importance of academia, as the government's S&T policies started aiming at promoting the competitiveness of universities. In recognition of the academia's value to the industry, the Ulsan Metropolitan City government recently established the Graduate School of Automotive Technology.

All of the three innovation actors, government; industry; academia, view future-orientation as a requirement and come up with various creative initiatives for supporting automobile industry. The automotive industry is allocated the fourth largest amount of the total manufacturing R&D investments, implying the automotive industry is a target industry of South Korea. Especially, innovation efforts towards EV and FCEV become intense in competition with foreign automotive industries. As a result of the vigorous cooperation among the actors, South Korea had its first full speed EV launched in 2010 and is anticipating 120,000 EVs will be on the road within Seoul by 2020. Cooperation as a driving force has always been fundamental for the advancement in the automobile industry, which is in part reflected by the increasing demand for and supply of South Korean automobiles. In response to the issue of energy depletion and foreign competition, through the structured NIS, South Korea continually peruses and cements innovation initiatives for its automotive industry.

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