
Strategy for Enhancing the Global Competitiveness of the Key Manufacturing Equipment Industry

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1. Introduction

(1) Research background and objectives

Governments of advanced economies worldwide are returning to manufacturing as the trustworthy source of continued economic growth and employment. This has pluralized the structure of competition in the manufacturing equipment sector. China, in the meantime, is rapidly catching up and competing with the strategies of these governments by launching its own Intelligent Production System Development Strategy.

A main objective of this study is to identify and analyze the current issues faced by the major manufacturing equipment industries (MMEIs) in Korea and the demand for their products at home and abroad. To this end, we analyze the competitiveness of Korean MMEIs from various perspectives. We make an objective analysis of the basis of patented technologies for the MMEIs in Korea using

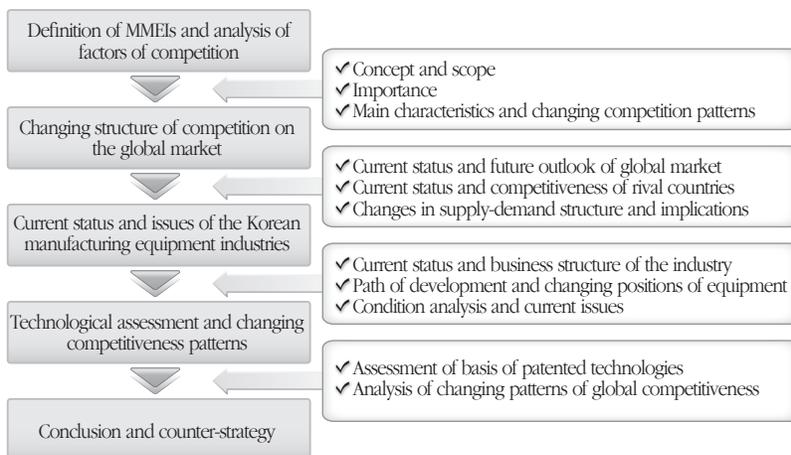
various indicators of reliability, and explore policy implications.

Based on our analysis, we assess the competitiveness of Korean manufacturing equipment on the global market, and identify the tasks that policymakers and businesses need to complete to ensure the future growth of the industry.

(2) Main frame of analysis and methodology

Our analytical framework consists of five dimensions. First, we examine the concept, scope, importance, main characteristics, and changing competition patterns of the Korean MMEIs. Next, we survey the current status and future prospects of global competition. In addition to assessing the Korean MMEIs' competitiveness and status on the global market, we also forecast likely structural supply and demand changes and draw policy implications.

Figure 1. Analysis Frame



This study also assesses and analyzes the current status, the business structure, the path of development, the changing positions of equipment, and current issues of the Korean MMEIs.

Our methodology consists of literature survey, an evaluation of global competitiveness, and diverse quantitative analyses intended to uncover policy implications. In addition to analyzing trade specialization indices (TSIs) and revealed comparative advantages (RCAs) that are commonly used as indicators of competitiveness, we also analyze export similarity indices (ESIs) in order to determine whether the Korean MMEIs are transitioning from a position of price advantage to that of quality/technology advantage.

Furthermore, we measure and compare the MMEIs of diverse countries in terms of their patented technological bases, and explore their implications for the Korean industry. To this end, we analyze the number of patent cooperation treaties (PCTs) filed with the World Intellectual Property Organization (WIPO) (indicative of quantity), the patent citation indices (indicative of quality), and also the patent family sizes that serve as an indicator of the economic power of patented technologies of a given country.

2. Definition and Factors of Competition

(1) Concept and scope of the manufacturing equipment industry

There is a wide range of MMEIs around the world today, including electronic manufacturing equipment, precision processing equipment manufacturing, and plant and energy equipment man-

ufacturing, among others. Our focus is on the manufacturing of equipment that supports the manufacturing of other goods produced by the seven “new growth engine” industries.

In particular, this study concentrates on electronic manufacturing equipment and precision processing equipment manufacturing. Depending on the importance and/or available data, we also analyze specific products. Since bio-medical equipment and broadcasting equipment serve consumers or broadcasters rather than manufacturing firms, they are excluded from the scope of this study.

(2) Characteristics and changing patterns of competition

The MMEIs are decisive factors of the competitiveness of a national economy, harbor great potentials for future growth, and also contribute significantly to the performance of the manufacturing sector. These industries decide the quality, values-added, and output of products of all manufacturing industries, and thus form the basis of the global competitiveness of any given nation’s manufacturing sector.

With their technological superiority and expertise, Japanese, German, and American equipment manufacturers have long dominated the global market. Yet, international competition is anticipated to become fiercer with the participation of China and other emerging economies.

3. Changing Structure of Competition on the Global Market

(1) Current status and future outlook of the global market for MMEIs

Electronic manufacturing equipment

The global semiconductor equipment market was valued at USD 38 billion as of 2014, having grown since the previous year. Since 2012, Taiwan has been the largest single-country market worldwide for semiconductor equipment, followed by North America and South Korea.

The global semiconductor equipment market is expected to reach USD 43.7 billion in value by 2016. The growing intensity of competition in the back-end process and in the inspection equipment market, which is due to the increased participation by emerging economies and technological saturation, will likely expand the relative share and importance of the front-end process market. Thanks to the progresses being made in the generalization and packaging of 3D devices (to overcome the limits of the miniaturization process) and in stepper exposure-related equipment and technologies, as well as to the growing demand in Asia, the worldwide semiconductor equipment market will likely continue growing for the years to come.

The drastic cuts in investment worldwide led to a significant contraction of the global display equipment market to USD 3.2 billion in 2012. The subsequent recovery in investment levels re-expanded the market to USD 6.9 billion by 2014. As investment is

anticipated to shrink at the beginning in 2015, however, the global display equipment market might shrink again. The main cause is the delay of investment in the production of new products like organic light-emitting diode (OLED) panels. The leadership over the display market growth may have moved from Japan to Korea, but it recently has moved again to China. China is expected to be the source of at least 70 percent of display investment worldwide by 2015.

In the meantime, the global light-emitting diode (LED) equipment market is expected to grow from USD 800 million in 2008 to USD 4.5 billion by 2015. The amount of investment in LED equipment determines the growth of the market. After reaching its peak at USD 2.65 billion in 2011, worldwide LED equipment investment plummeted to between USD 1 billion and 1.5 billion in 2012 due to the continuing economic recession. Nevertheless, the LED equipment market is expected to pick up its pace of growth from 2014 onwards, with the amount of global investment expected to grow to USD 1.19 billion by 2014, up by 17 percent from the previous year. Metal organic chemical vapor deposition (MOCVD) equipment, which are at the core of LED production worldwide, account for around 30 percent of the market. The excess of investment in MOCVD equipment-producing facilities, however, would keep the growth of the market slow for some time to come.

(2) Assessment of the current status and competitiveness of the MMEIs on the global market

1) Electronic manufacturing equipment industry

Exports and imports of electronic manufacturing equipment worldwide

The onset of the global financial crisis in 2008 reduced the amount of worldwide electronic manufacturing equipment exports for several years. However, by 2014, these exports showed signs of full recovery and reached USD 37.9 billion in value.

In particular, semiconductor equipment accounted for 90 percent or USD 35.6 billion of all electronic manufacturing equipment exports in 2014. Exports of display equipment may form only a fraction of worldwide electronic equipment exports, but they are growing much more rapidly than semiconductor equipment exports. Japan, the United States, and the Netherlands are the three top exporters of electronic manufacturing equipment worldwide, together accounting for 65.7 percent of all goods exported as of 2014.

South Korea, China, and the United States are the three leading importers, accounting for 71 percent of all imports as of 2014. China and South Korea, in particular, were racing for the top importer position, until China emerged as the new leader in 2014, having imported USD 11.2 billion-worth of electronic manufacturing equipment (31.7 percent of total imports) that year.

□ Major manufacturers of electronic manufacturing equipment

As the pace of growth of the global electronic manufacturing equipment market has been slowing down, AMAT, ASML, TEL, Ulvac, Lam Research, and other leading manufacturers have been making diverse efforts to enhance their competitiveness, including the developing new technologies and doing mergers and acquisitions (M&A).

American, Japanese, and Dutch companies dominate the global semiconductor equipment market. AMAT and Lam Research of the United States, ASML of the Netherlands, and TEL of Japan are the leading producers of semiconductor equipment traded worldwide. As of 2013, AMAT was the top manufacturer of equipment for both front- and back-end processes, and ASML came in second.

Japanese companies, such as Ulvac, TEL, Nikon, and Canon, lead the global display equipment market with their superior front-end process equipment technology. Cummins, Illinois Tool Works, ITT, KLA-Tencor, and Lam Research are major manufacturers of LED equipment traded worldwide. Most of these companies produce not only LED equipment, but also semiconductor and display equipment.

□ Competitiveness of electronic manufacturing equipment industries worldwide

The global financial crisis that started in 2008 may have set them back, but Japanese and American companies still dominate the electronic manufacturing equipment market worldwide with

unsurpassable competitive edges. Korean electronic equipment manufacturers have been improving their competitiveness, but still lag far behind their counterparts in advanced economies.

It was in 2007 that Japan arose as the world's top exporter of electronic manufacturing equipment, overtaking the United States. Japan managed to increase its share of the international export market to 27.4 percent in 2014. Nevertheless, since reaching its peak at 36 percent in 2010, Japan's share of the global market has been steadily shrinking.

As late as in 2006, the United States was the indomitable top exporter of electronic manufacturing equipment worldwide, holding a market share of more than 50 percent. Since 2010, however, the country's share of the international market has also been shrinking. The Netherlands, on the other hand, has seen its international market share slowly rise since 2009, reaching 15.2 percent in 2014, and marking the country as the third-largest exporter. Germany, which was among the top three exporters until the mid-2000s or so, got down to the seventh place in 2014 with its international market share plummeting to 3.2 percent.

Our TSI analysis shows that the Netherlands and Japan hold especially high degrees of competitiveness over exporting electronic manufacturing equipment. The Dutch TSI has remained at around 0.9 since 2007, close to complete export specialization. Japan's TSI remained as high as 0.66 in 2014, but has actually decreased from the 0.83 level it reached in 2012. The United States' TSI has been declining since the mid-2000s, but rose slightly back in 2011, reaching 0.20 in 2014. Since reaching a peak in 2009, Germany's TSI has been dropping.

Korean and Chinese electronic manufacturing equipment industries, on the other hand, have been showing growing levels of import specialization since the early 2000s. Notwithstanding slight improvements in the recent years, China's average TSI has remained at -0.8 since 2007, on the verge of complete import specialization. Korea also shows a strong tendency toward import specialization, but its TSI has been improving since 2012.

Our RCA analysis reveals that Japan, the Netherlands, the United States, and South Korea are competitive players on the global market, with RCA levels hovering over one as of 2014. China and Germany emerged as less competitive among the countries surveyed.

More specifically, Japan showed the highest RCA with respect to electronic manufacturing equipment, with an indicator remaining constant at 6.77 in 2007 and at 6.79 in 2014. The Netherlands saw its electronic manufacturing equipment RCA improve from 4.08 to 4.49 over the same period of time, while the United States' dropped slightly from 3.71 to 2.42. South Korea's RCA reached 2.25 in 2014, an improvement from its 2007 level.

We also analyzed the ESIs of various countries as part of our analysis on the patterns of competition between Korea and other countries on the global electronic manufacturing equipment market. As of 2014, Korea's biggest rival on this market was Japan, competing over 72.2 percent of all electronic manufacturing equipment exported. The intensity of rivalry between the two countries, however, has been waning since 2010.

Korea and Germany competed over 56.7 percent of their exports as of 2014. The rivalry between Korea and China gained

in intensity from 2007 to 2012, but has since decreased. The two countries competed over 37 percent of exports in 2014.

The intensity of rivalry between Korea and the United States has been fluctuating significantly from year to year since 2007, reaching the lowest level of 0.20 in 2014. While Korea's rivalry with the Netherlands deepened with respect to semiconductor equipment from 2007 to 2012, it has abated in intensity since, with the two countries competing over 24 percent of exports as of 2014.

2) Precision processing equipment industry

Exports and imports of precision processing equipment worldwide

The global financial crisis of 2008 served as a major hindrance to the growth of precision processing equipment exports worldwide until 2010 or so, but the export market soon recovered to its pre-crisis pace of growth, which rose as high as 21.6 percent between 2010 and 2014.

The demand for imports of precision processing equipment has similarly been growing significantly worldwide at 20.7 percent since 2010. This is so notwithstanding the slowdown of China's economic growth.

Since 2005, the top five exporters of precision processing equipment on the global market have been Japan, the United States, Germany, Italy, and China.

Competitiveness of precision processing equipment industries worldwide

The rankings of the top producers of precision processing equipment on the global market have changed frequently since the global financial crisis, but Germany is still recognized as the most competitive source of such equipment. Korea has been improving its competitiveness, but still lags behind other advanced economies.

Japan's RCA was the highest, at 3.35, in 2014. Germany, perhaps the most competitive producer of precision processing equipment in the world, also retained a high RCA of 2.16 in 2014. Korea's RCA, on the other hand, was 0.94, indicating that the country still has a long way to go until its precision processing equipment industry becomes as competitive as its counterparts in other advanced economies.

(3) Changes in the supply-demand structure and implications

Changing structure of the global electronic manufacturing equipment market

Major semiconductor equipment manufacturers worldwide have been striving to ensure their survival through M&A amid the ongoing international recession and the rising intensity of the chicken game on the global semiconductor market. Semiconductor producers have opted for cooperation over competition as the global semiconductor market continues to shrink.

In October 2015, Lam Research, the fourth-largest producer of semiconductor equipment in the world, merged with KLA-Tenko, the fifth-largest. AMAT of the United States, the world's largest producer, sought to merge with TEL of Japan, the world's third-largest, in April 2015. The proposed M&A never materialized due to objection from other manufacturers and countries concerned with possible monopolization of the global market.

M&A nevertheless is emerging as a dominant trend on the global equipment market due to the miniaturization of semiconductor devices and companies' desire to achieve greater economies of scale. The larger a company, the better it is able to invest money and time in developing 10-Nano-grade miniaturization technology.

JAS Tech, a Korean manufacturer of semiconductor equipment, announced in October 2015 its plan to merge with Sungjin Hi-Mech, a Korean display inspection equipment producer. JAS Tech is expected to diversify its business portfolio, enhance the competitiveness of its products, and strengthen its position as a Samsung supplier through the M&A deal.

A number of other Korean companies followed suit, announcing plan after plan for M&A. These include the M&A between Wonik IPS and Tera Semicon, between AP System and DE&T, between SF and STS Semiconductor, and between HB Technology and K-Mac. Semiconductor equipment manufacturers have begun to recognize the limit to the growth of their existing business portfolios, and thus have begun to actively pursue M&A in order to secure their future prospects.

Strategic alliances and M&A with partner companies capable of maximizing the synergy effect also allow these semiconductor

equipment manufacturers to minimize their cost. These companies are bracing themselves for the next rise in the silicon cycle through ongoing restructuring and increasing investment in research and development (R&D).

The abrupt fall in global demand for the DTV, however, has brought down the demand for large flat panel display (FPD) devices along with it, causing a series of delays in investment by manufacturers. The display manufacturing equipment market is rapidly shrinking as a result.

The display panel demand cycle has turned vicious, with the saturation of the DTV market, as the major source of demand, leaving no option for manufacturers but to rely solely on the demand for replacement display panels, and the deterioration of display manufacturers' payability causing them to halt investment in production facilities and equipment. This, in turn, has required the manufacturing equipment industries to aggressively streamline and restructure their activities. Manufacturers of smartphones, tablet PCs, and other such small devices can produce their own small display panels, without generating much demand for equipment manufacturers.

With strong backing from the Chinese state, Chinese display industries have begun expanding their panel production capacity, particularly by setting up additional assembly lines for small-to-medium and high-precision display panels. The series of massive investments made by Chinese panel makers in manufacturing facilities and equipment has turned China into an emerging hotbed of competition among all global equipment manufacturers.

The days of high and fast growth may have come to an end,

but Korean manufacturing equipment companies should hold onto, and strategically realize, their hopes for the expanding in the Chinese display panel market. Korean companies need to form strategic alliances with one another to maintain the technological superiority and distinction of their products, while also boosting industry-wide R&D and reducing the cost.

Structural changes in the precision processing equipment industry and implications

The most noteworthy trend in the precision processing equipment industry today is the increase and intensification of global intra-industry division of labor. Yamazaki Mazak, for instance, opened its second plant in China in March 2013, and succeeded in reducing its production cost by 10 percent by relocating the production of major items, such as CNC racks and machining centers, to China. Okuma has launched a similar strategy of dividing its production between its headquarters in Japan and a foreign base. DMG MORI, the industry-shaping multinational corporation with an expanding supply chain, has been enlarging and reforming its organization since the historic M&A between the German and Japanese companies.

DMG MORI set up its two corporate headquarters in Tokyo and Zurich in 2014, and followed them up with the creation of the Solution Centers at the headquarters to provide worldwide network services. The company also provides a wide range of training programs, including the 5-Axis Machining School.

4. Current Status and Issues of Korean MMEIs

(1) Current industrial and business structures

Electronic manufacturing equipment industry

The Korean electronic manufacturing equipment industry made up only 0.3 percent of the total manufacturing output of the country in 2013, but the figure represents a steady improvement from the 0.1 percent the industry recorded in 2001. The amount of the values-added from the industry also multiplied from KRW 570 billion in 2001 to KRW 4.2 trillion in 2013, or from 0.6 percent of the total manufacturing values-added to 2.3 percent. The output of the industry has been growing at a remarkable 20.6 percent from year to year since 2001, amounting to KRW 11.352 trillion as of 2013. The steady growth of the semiconductor and display markets worldwide is expected to increase the industry's output and exports consistently in the coming years.

The electronic manufacturing equipment industry's amount of exports has multiplied by hundredfold since 1995. In particular, exports of semiconductor equipment have been growing at 22.1 percent a year since 2005, except for brief setbacks in 2008-2009 and 2012 under the influence of the global financial crisis. The Korean semiconductor equipment industry is expected to grow even further in 2015, thanks to the increases in facility investment and exports. China is the largest importer of Korean-made semiconductor equipment, accounting for 42.3 percent of all exports as of 2014. Following are the United States (24.9 percent), Taiwan (11.5

percent), and Japan (6.5 percent).

The pace of growth in display equipment exports may have slowed down in the recent period, but the industry's exports kept growing at 20.8 percent a year from 2007 to 2014, exceeding USD 1 billion in 2014. The explosive growth in China's demand for display equipment enabled the industry's exports to multiply by 199.2 percent in just a year from 2012 to 2013. The industry's exports still managed to grow by 7.3 percent in 2014 thanks to China.

Much of the Korean electronic manufacturing equipment is made of small and medium enterprises (SMEs). The number of businesses in the industry reached 1,375 in 2013, 1,277 or 92.9 percent of which were semiconductor equipment producers. Except for the few well-known producers, such as Semes, Wonik IPS, and Ulvac Korea, 99 percent of these businesses are SMEs. Korea lacks a world-class corporation specializing in electronic manufacturing equipment.

The Korean semiconductor industry shows a vertical division of labor between electronic manufacturers and equipment manufacturers. The vertical division of labor provides the benefit of captive markets that generate steady revenues. But it also enables client companies to exert undue pressure on lowering prices, reduces R&D incentives through cross sales, and generally serves to block the emergence of independent brands and pioneering new overseas markets.

A number of already established semiconductor and display equipment businesses in Korea made their headway into the LED field in the late 2000s in response to the increasing investment by Korean conglomerates in LED production. Korean LED manufac-

turers are perceived as less competitive than their counterparts abroad, despite the relatively strong sales records Korean companies have on back-end process and packaging equipment. In 2014, Top Engineering became the first company to succeed in striking a MOCVD equipment sales deal with a large Korean conglomerate and Genicom.

□ Precision processing equipment industry

As of 2014, the Korean precision processing equipment industry received orders totaling to KRW 3.6861 trillion in total, which was a 0.3 percent dip from the previous year's record. Yet the industry's output managed to grow by 7.9 percent to KRW 3.36 trillion, and amount of goods released from warehouse also reached KRW 3.5012 trillion, 0.9 percent up from 2013.

The industry's exports amounted to USD 2.2 billion in 2014, 0.9 percent up from 2013. The worldwide slowdown in economic growth may have shrunken the emerging markets in Asia as well as North America, but the South American and European markets kept growing.

The industry has been a steady trade surplus producer for a decade since 2005. Having reached a peak of USD 1.59 billion in 2012, however, the amount of trade surpluses produced by the industry has now remained below USD 1-billion for two years in a row.

(2) Paths of development and the changing presence of major products

Electronic manufacturing equipment industry

Although Korea is a world-renowned stronghold of semiconductor and display technologies, the Korean electronic manufacturing equipment industry remains in a marginal position on the global market today. The Korean government has actively fostered the semiconductor and display equipment industries for over a decade at both public and private levels. Yet these industries remain largely focused on catering to the domestic market. At the same time, these industries have failed to localize key technologies and production facilities, and rely much on imported parts and materials that are regarded as more reliable than Korean-produced ones. The rate of display equipment localization may be on rise, but Korean manufacturers still much prefer importing core equipment, particularly for high-value-added front-end processing.

The Korean electronic manufacturing equipment industry has thus been a chronic source of trade deficits. About the only sign of hope is the fact that the amount of the semiconductor equipment industry's trade deficits reached its peak at USD 79 billion in 2010, and has been on decline ever since. The display equipment industry similarly struggled with chronic deficits until 2012, but generated a surplus of USD 100 million in 2013 thanks to Chinese demand.

Notwithstanding its marginal presence on the global market, the electronic manufacturing equipment industry of Korea has

been seeing steady increases in the number of businesses and output since 2000. The industry may not be a huge exporter yet, but it managed to increase its share of the global market from less than one percent in 2000 to 7.6 percent by 2014. With the government's continued support, the industry will continue to grow and expand.

The electronic manufacturing equipment industry is one of the hottest emerging fields of new economic growth worldwide. The industry presents a very high technological barrier, but also a very attractive blue ocean with potential for almost unlimited values-added. Japan, the United States, and Europe are already leading the international market, while China has also embarked upon the course of making aggressive investment in future-oriented R&D.

The Korean electronic manufacturing equipment enjoys the advantages of well-established infrastructure for semiconductor, display, and LED production, a prosperous domestic market, and proximity to the world's best producers of semiconductor and display products.

Yet it is still plagued by the extremely low rate of technology and production localization. The majority of businesses that makes up the industry is also excessively dependent on a few large Korean conglomerates as clients, and lacks the capability to independently survive and expand globally. The little brand value of domestically produced equipment and the much greater preference for proven foreign-brand goods continue to inhibit the growth of the Korean industry. All these weaknesses point to the need for Korean electronic manufacturing equipment producers to develop and adopt a systematic and comprehensive growth strategy, particularly aimed

at enhancing their independence and global competitiveness.

Precision processing equipment industry

Mazak and DMG MORI have succeeded in developing complex processors using their accelerated complex processing system technologies. MAG of Germany and Makino and Okuma of Japan have developed solutions for processing difficult-to-cut materials using their highly efficient processing technologies, and durable equipment and tools.

Moore Tools and Precitech of the United States, Nachi-Hujikoshi, Toshiba, and Nagase of Japan, and Kugler of Germany are also developing solutions that can process increasingly larger and heavier materials and add super-precision to the processed results.

(3) Analysis of current conditions and issues

Our survey shows that, of the 49 companies that participated, 46 were SMEs and three were middle-sized corporations. The middle-sized corporations together had only a six-percent market share, most likely because their clients much prefer to import the manufacturing equipment they need to organize their assembly lines, thus giving few opportunities for the growth of the domestic equipment manufacturing industries.

The surveyed companies listed the enormity of the cost of setting up production facilities, the excess competition among the businesses and the saturation of the domestic market, and the invasion of low-priced products from overseas as major obstacles to

their business.

In the meantime, 67 percent of respondents named R&D funding, subsidization of facility and operation costs, and other types of policy financing as the policy support measures they most needed.

5. Technological Assessment and Changing Patterns of Global Competitiveness

(1) Assessment of the patented technology basis of the MMEIs

We analyzed the correlation between patent records and export records of the seven core MMEIs in Korea, and discovered that the patent records (quantitative indicator) showed a relatively high degree of correlation to the recent increases in exports and global market shares. The number of patents, in other words, forms the R&D investment stock that contributes to the growing exports of the Korean MMEIs. It is therefore important to keep increasing the number of patents held by the Korean MMEIs today.

However, the Korean precision processing equipment, electronic manufacturing equipment, and other core industries fall significant behind the average scores of their counterparts in the top 10 leading countries in terms of qualitative indicators. This indicates the critical need for Korean businesses to enhance the qualitative aspects of their technology if their goals are to overcome competition from other latecomers and to ensure sustainable future growth.

In the meantime, we found no significant correlations between

the market reach of the patents of the seven core industries, on the one hand, and the rates of increases in these industries' exports and market shares, on the other. Most of the seven core industries had shorter market reaches than the average of their counterparts in the top 10 leading countries. As the market reach index represents the future economic value of patents, the seven core industries need urgently to research and develop better-patented technologies with greater market potentials.

(2) Changes in the patterns of global competitiveness of the MMEIs

Of the seven core industries analyzed in terms of global competitiveness, the precision processing equipment industry emerged as the one with the highest ratio of Type-4 (technologically inferior) products, at 33.4 percent, in 2004. By 2014, however, the industry had managed to increase the ratio of its Type-1 (technologically superior) products by 28.7 percentage points from 15.0 percent to 43.7 percent, indicating that it made technological progresses over the last decade.

In the meantime, the ratio of Type-1 products in Germany's precision processing equipment industry increased from 42.0 percent to 80.5 percent. Germany boasts an unsurpassable capability for technological innovation and progress, which bears great implications for Korea.

6. Conclusion and Counter-Strategy

(1) Implications of the global competitiveness analysis

The Korean precision processing equipment industry has been growing at a remarkable speed thanks to the growth of Korea's manufacturing sector as well as the increasing demand in China, but the majority of its products are still competitive in terms of prices only. The cutting machine parts, which form a major product group for the industry, are consistently seen as structurally inferior, and continue to dampen the profitability of the industry as a whole.

The Korean electronic manufacturing equipment industry may have increased its exports to China and elsewhere dramatically, but is still seen as structurally inferior. The front-end process section, with its high technology barrier and low localization rate, keeps producing chronic trade deficits, and reaps income that is only 27 percent of the manufacturing exports average. Businesses in these industries must increase investment to enhance the competitiveness of their front-end process equipment and parts, while also developing common technological bases for semiconductors, display devices, LED products, and photovoltaic solutions.

(2) Strategic enhancement of global competitiveness

The Korean smartphone industry has growing need for large-scale precision processing equipment to handle the processing of metallic smartphone cases. Seeing the inability of the Korean in-

dustry to cater to this demand, however, Korean manufacturers have imported equipment from Japan instead. Korean companies invest increasingly in their facilities for producing semiconductor devices, display devices, secondary cells, and LED products in China, but by equipping those facilities with manufacturing equipment imported from the United States, Japan, and Europe instead of Korea.

The Korean MMEIs need to enhance their infrastructure and capability, as urgently as possible, for producing the high-end manufacturing equipment in demand from semiconductor, display, and smartphone companies. This will require a close public-private partnership and a clear policy strategy, as well as effective concentration and investment of available resources.

Manufacturing equipment forms one of the four core elements of manufacturing (parts and materials, processes, equipment, and manpower), and the basis for the quality, productivity, and values-added of all manufactured products. It is impossible for semiconductor, display, smartphone, LED, battery, and other IT producers to maintain their competitiveness without the innovation of manufacturing equipment. For the core technology of IT products is built into the equipment that is used to manufacture them. The competitiveness of manufacturing equipment is thus directly translated into the competitiveness of finished products.

The imbalance in the value chain of the MMEIs in Korea, with their clients mostly resorting to imported equipment rather than domestically produced ones, should be overcome at all possible costs. In the early stage of industrial development, increasing R&D investment may be the only key to technological diffusion. In the

Table 1. Main Policy Issues in Improving the Korean MMEIs

Major issue	Description
Insufficiency of R&D support for manufacturing equipment producers	<ul style="list-style-type: none"> - The insufficiency and compartmentalization of R&D investment hinders the emergence of a comprehensive fostering strategy - The manufacturing equipment subsidization policy subsidizes equipment costs of only certain industries, failing to provide support for the development of innovative equipment
Shortage of original technologies and human resources	<ul style="list-style-type: none"> - Highly skilled workforces continue to migrate to other industries, while businesses struggle with absolute shortages of original technologies - Industrial-academic industrialization needs to be increased to promote technological innovation and the development of human resources
Delayed responses to new technologies and new industries	<ul style="list-style-type: none"> - ICT convergence and digitalization continue to raise new issues, but little support is made for MMEIs to deal with these issues effectively - It is necessary to ensure the ICT convergence and digitalization of MMEIs under Manufacturing Innovation 3.0 and creative economy strategies
Lack of reliability and reputation	<ul style="list-style-type: none"> - Lack of reliability in Korean-made equipment limits localization of core equipment production and exports. Most policy support focuses on enhancing reliability of parts
Vulnerable industrial ecosystem	<ul style="list-style-type: none"> - Diverse support measures are needed at the level of the industrial ecosystem that is made up of SMEs, including support for increasing their marketing and distribution capabilities
Summary	Notwithstanding some progresses made, the dearth of R&D investment, original technologies, reliability, testing systems, and ecosystem support holds Korean MMEIs from joining the league of world-class manufacturers

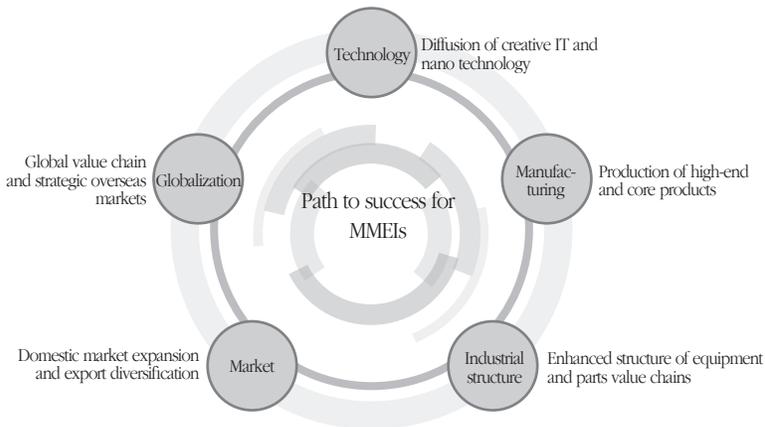
mature and new growth stages of industrial development, however, it is more important to find clients/consumers. As Korea boasts one of the world's most advanced IT industry ecosystems, Korean MMEIs enjoy an advantage in this regard. The Korean government now needs to update its industrial policy paradigm to ensure the sustainable growth of these industries, by switching its focus from finished products (1990s) and parts and materials (2000s) to manufacturing equipment (2010s).

The most important change to be made to the MMEI ecosystem is to ensure a more balanced and mutually productive partnership between producers and clients. As the Korean electronic manufacturing equipment industry is relatively recent in origin, lags technological and price competitiveness, and struggles to establish an economy of scale, the industry's efforts to develop new technologies and improve the reliability of its products need to be supported.

As far as production is concerned, Korean MMEIs need to develop and secure original technologies as well as experienced engineers. There is growing and urgent need for programs for educating and training creative workforces capable of adapting to convergence.

We recommend the following policy and strategic measures that are needed to ensure the balanced and sustainable growth of the MMEI ecosystem in Korea.

Figure 2. Basic Policy Aims in Fostering the Korean MMEIs



- Recognize the centrality of equipment manufacturing to the future of the manufacturing sector, and establish a consistent and continuous long-term plan.

Machine tools, semiconductor equipment, and display equipment are technology-leading products that form the basis of the manufacturing sector at large. The future of the Korean manufacturing sector depends on whether or not Korea gains the ability to produce these high-end machines.

The Korean government began establishing national strategies for promoting the advancement of equipment industries in the 1990s, but these strategies, often focused on single products only, and were quickly replaced by other strategies lacking continuity every time a new President was elected.

It is crucial for policymakers to realize the importance of the MMEIs as holding the key to the future of industries and economic development, and objectively assess the achievements and shortcomings of the policy support that has been provided so far, with a view of establishing a long-term and consistent policy strategy. There are limits to the current model of supporting certain products capable of catching up with their advanced counterparts in the United States, Germany, and elsewhere. Rather, the focus should shift from products to industries, with support provided for fostering new industries capable of pioneering and leading new markets.

Proactive investment is needed, under stage-by-stage and mid- to long-run strategies, for developing new equipment industries and an industrial ecosystem. Systemic and visionary policies are needed to foster convergence-based and value-chain-expanding

R&D works on equipment and systems, with participation from all involved industries, including materials, equipment, systems, and finished products. The implementation of such policies will require government-wide and interdepartmental collaboration.

- Foster industrial-academic collaboration based on client companies' innovation roadmaps.

Effective innovation of electronic manufacturing equipment, including those used to produce semiconductors and display devices, will require systemic development roadmaps for industrial-academic collaboration that are themselves based on the innovation roadmaps of client companies. Client companies need to discuss the specifications they need with equipment manufacturers before the latter begin to research and development the new equipment they will produce. This is crucial to prevent unplanned modifications to product design during production and also to achieve early successes. Realistic levels of support need to be provided to steer equipment manufacturers to develop original technologies in the long run. Industrial-academic collaboration teams may produce innovative results, but support is crucial to ensure long-term research on testing the business feasibility and completeness of such innovative results.

Policy support is particularly needed to strengthen the ties of cooperation between electronic manufacturing equipment producers and their clients. Korean policymakers may need to provide tax benefits and other incentives to induce greater demand for Korean-made equipment.

- Localize the production of core parts and improve the industrial ecosystem.

The MMEIs are strongly tied to both the front industries that produce finished products for end consumers worldwide and rear industries consisting of SMEs that produce sensors, transportation systems, and operating software for manufacturing equipment. In order to succeed, the MMEIs thus require an industrial ecosystem that supports the connection and mutual effects among industries producing parts and materials, manufacturing equipment, and consumer products. It is critical to localize the production of core parts of manufacturing equipment and thereby respond more promptly to the changing demand of diverse consumers.

As China is rapidly catching up with Korea, the Korean MMEIs need to ensure both the price and technological competitiveness of their products with strong policy support.

- Improve product reliability and support globalization with a reference website.

The main obstacle that prevents the successful globalization of Korean MMEIs is the absence of proven and trusted ways to test and prove the reliability and productivity of their products, despite the massive amounts of efforts individual businesses invest in developing innovative products with global ambitions.

Advanced manufacturing equipment companies already have strong reputations for quality, and can pass their new products with little difficulty on the world market insofar as they provide

proof data. Korean companies, lacking reputations, face burdensome requirements from potential buyers for additional proof and even on-site inspections.

The Korean government should encourage Korean companies to purchase more products from the Korean MMEIs with tax benefits, subsidies, and other incentives. In doing so, the government should also develop and maintain a reference website that provides details on Korean-made equipment actually being put to use by world-renowned Korean companies.

□ Foster specialized equipment production through the CCEIs.

The Korean government has opened up a number of Centers for Creative Economy and Innovation (CCEIs) across the country to support local industrial specialization and the partnership between Korean multinational conglomerates and local SMEs.

In supporting MMEIs through these Centers, it is important not only to support those involved in local specialization industries, but also to provide nationwide support for matters of common interest to manufacturers in all industries and regions, such as technological cooperation and marketing.

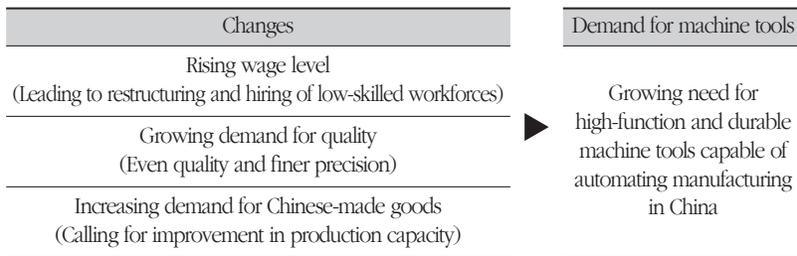
Effective support for MMEIs will not only further promote the specific industries in which various regions specialize, but also help establish a healthy industrial ecosystem nationwide that is more capable of realizing the ideal of creative economy.

- Support the exports of machine tools to China.

We need also to assess and survey the trends in the current Chinese manufacturing sector, and redefine opportunities and strengths for the exports of Korean-made machine tools. The developed countries that have so far led the demand for machine tools have reached a point of saturation, with new demand found in emerging economies today. As China has growing need to enhance its processing technologies amid the rising wage level, it has rising demand for machine tools that help minimize the required labor and contribute to quality improvements.

The Chinese state announced China’s Manufacturing 2025 in May 2015, listing a series of ambitious policy measures and programs with the goal of fostering and upgrading 10 major manufacturing industries by 2025. The 10 target industries include the high-precision number-controlled machine tool industry, which attests to China’s intention on developing innovative automation technologies so as to improve the quality of its manufactured products.

Figure 3. Changes in the Chinese Manufacturing Sector and Rising Demand for Machine Tools



Source : KIET.

The changes in the Chinese manufacturing sector and policy goals have opened up new opportunities and potential markets for the Korean machine tool industry. Korean businesses and policy-makers alike ought to keep up to date with industrial and policy developments in China and use that knowledge to facilitate Korean machine tool businesses' entry into the country.

Korean businesses seeking entry into China under this situation should cater closely to the characteristics and requirements of Chinese companies, particularly by focusing on the turnkey delivery of middle-grade products. Chinese clients possess little complex engineering skills, and therefore prefer turnkey delivery of machine tools. Korean businesses may face mounting competition from their Japanese and Taiwanese counterparts, but could still thrive thanks to the price competitiveness of their products.

Korean businesses should also expand and strengthen the customer service network. Chinese clients may have been more concerned with the amount of the initial cost at first, but an increasing number of them are concerned with the running cost today.

- Cater to the growing demand for turnkey and packaged system solutions.

Manufacturers so far have purchased the equipment and facilities they needed for each process, and organized their own assembly lines. This way of working, however, affects the quality of end products, is less productive, and can cost companies long periods of time in setting up assembly lines. More and more client companies today prefer equipment manufacturers to provide turn-

key or packaged system solutions, setting up the assembly lines. This way, producers of smartphones and other such end products can focus solely upon manufacturing activities, while equipment manufacturers set up assembly lines complete with hardware and software solutions for production and quality control.

Advanced equipment manufacturers abroad have responded to this trend with their “family company” policies, aggressively advertising their willingness to provide and install all the equipment and operation solutions demanded by their clients. They have thus gained an upper hand over the turnkey business market. The unit manufacturing equipment market worldwide has been growing somewhat slowly, whereas the turnkey market has been expanding explosively.

- Establish systems of collaboration over open innovation.

It is crucial to promote cooperation among the involved businesses, client companies, and research communities in order to enhance the efficiency of R&D investment in the MMEIs and also to enhance the capability of these industries for technological innovation.

The growing complexity and convergence of manufacturing equipment makes open innovation and participation by diverse companies and research centers more efficient than R&D at the level of individual companies. Companies and research organizations do not compete with each other and can guarantee the confidentiality of the projects on which they work together. Resorting to research centers can also help companies find new business

opportunities, diffuse R&D risks, shorten the R&D period, and minimize the R&D cost, while gaining quality results.

The policy programs supporting national R&D projects in Korea today actively encourage industrial-academic collaboration. Yet the majority of companies handle R&D and innovation on their own. The government may need to provide better incentives to promote and strengthen industrial-academic partnership between companies and research organizations. These incentives need to be systematized to reflect businesses' actual needs from the very beginning to the later stages so that technologies that cater to these needs can be invented.