

An Analysis of South Korea's Global Competitiveness in Memory and System Semiconductors

Hyung-gon Jeong Senior Research Fellow, Center for East Asian and Advanced Economy Studies (hgjeong@kiep.go.kr)

I. Introduction

South Korea has long been a global leader in memory semiconductors, driven by companies like Samsung Electronics and SK Hynix. However, growing concerns have emerged in recent years about the overall competitiveness of Korea's semiconductor industry, extending beyond memory into the system semiconductor sector. These concerns stem from several factors: the erosion of Korea's technological edge, the rise of Chinese firms, U.S. export controls on China, and proactive industrial strategies by major economies—including the United States, European Union, and Japan—aimed at strengthening their domestic industries.

These shifts have created a more complex and uncertain competitive landscape. China's rapid technological advancement, backed by substantial state investment, is reshaping the global industry. For instance, ChangXin Memory

Technologies (CXMT) has begun mass production of 16nm-class DDR5 DRAM, reportedly surpassing Korean products introduced in 2020. Similarly, Yangtze Memory Technologies Corporation (YMTC) began mass-producing 294-layer NAND flash in early 2025—the first company worldwide to do so—placing it in direct competition with Samsung (286 layers) and SK Hynix (321 layers).

Korea also faces growing challenges in the high-bandwidth memory (HBM) segment. Although Samsung and SK Hynix still lead, U.S. firms—supported by strong patent portfolios and industrial policy—are emerging as formidable competitors. At the same time, Chinese companies are accelerating HBM R&D, suggesting new entrants will soon intensify competition. The convergence of U.S. and Chinese advancements in both capacity

and innovation poses strategic risks to Korea's leadership.

The pressure is even more pronounced in system semiconductors. Chinese firms are advancing in mid-tier design and manufacturing, while U.S. companies dominate advanced segments like AI and high-performance computing (HPC), supported by superior technology and coordinated policy. As a result, Korean firms are caught between two poles of rising competition.

In this context, a reassessment of Korea's role in the global semiconductor value chain is essential. This study examines Korea's recent trade structure and industrial competitiveness in memory and system semiconductors, with the goal of identifying structural challenges and proposing strategic responses to secure long-term competitiveness.

To this end, the study analyzes trade data from the Korea Customs Service and UN Comtrade (2018–2024) using various quantitative indices, including the Trade Specialization Index (TSI), Revealed Symmetric Comparative Advantage (RSCA), Grubel–Lloyd (GL) Index, Trade Intensity (IT) Index, and the Technology Strength Index. These tools help assess Korea's global competitiveness by product segment, evolving trade relationships, and the depth of supply chain integration with key partners.

Ultimately, this research offers a comprehensive diagnosis of the technological, trade, and supply chain challenges facing Korea's semiconductor industry. It aims to provide insights that not only inform Korea's strategic policy choices but also contribute to broader international discussions on industrial resilience, regional cooperation, and competitive adaptation in a rapidly changing global semiconductor landscape.

II. Semiconductor Trade Trends in 2024

1. Export and Import Performance of Korea's Semiconductor Industry

This study adopts a comprehensive scope of the semiconductor industry, encompassing three core semiconductor categories—(i) memory semiconductors, (ii) system semiconductors, and (iii) optoelectronic devices—alongside associated upstream and downstream sectors, including semiconductor manufacturing equipment, silicon wafers, and related materials and components.

In 2024, South Korea's total semiconductor exports reached USD 180.33 billion, while imports stood at USD 120.62 billion, yielding a trade surplus of USD 59.71 billion. This represents the highest level of both exports and trade surplus since 2019, underscoring the sector's robust performance despite intensifying global competition.

Table 1. South Korea's Semiconductor Trade Performance, 2024

Unit: USD million

Category		Exports	Imports	Total Trade	Trade Balance
Semiconductor	Optoelectronic Devices	3,658	4,763	8,421	-1,105
	Memory Semiconductors	88,289	24,192	112,481	64,096
	System Semiconductors	48,264	40,648	88,913	7,616
Semiconductor Manufacturing Equipment		11,993	20,844	32,836	-8,851
Silicon Wafers		1,709	2,613	4,321	-904
Materials and Parts		26,417	27,564	53,981	-1,147
Total		180,329	120,624	300,953	59,706

Note: The semiconductor industry scope in this study is broader than the conventional MTI classification, incorporating upstream and downstream sectors integral to semiconductor production.

Source: Compiled from Korea Customs Service Trade Statistics (2024).

Semiconductor exports grew by 23.3% year-on-year, significantly outpacing the nation's overall export growth of 3.2%. As a result, semiconductors accounted for 26.4% of Korea's total exports—the highest share since 2019—reaffirming the sector's central role in the national economy.

The trade surplus was largely driven by memory semiconductors (USD 64.10 billion) and system semiconductors (USD 7.62 billion). However, persistent trade deficits were recorded in upstream and downstream segments, including semiconductor manufacturing equipment (USD -8.85 billion), materials and components (USD -1.15 billion), optoelectronic devices (USD -1.11 billion), and silicon wafers (USD -0.90 billion).

This structural imbalance reflects Korea's specialization in chip manufacturing, which remains highly dependent on imported preci-

sion equipment and upstream inputs—especially from technologically advanced economies such as the United States and Japan. This dependency highlights a critical vulnerability in Korea's semiconductor supply chain, particularly in light of escalating geopolitical and technological fragmentation.

2. Trends in Korea's Memory Semiconductor Trade

South Korea's memory semiconductor trade in 2024 remained highly concentrated among a limited number of countries. Eight major partners—including China and Hong Kong—accounted for 94.1% of Korea's memory semiconductor exports and 98.0% of its imports, indicating a strong dependence on a narrow set of markets.

Korea's memory semiconductor exports totaled USD 88.29 billion, while imports reached USD 24.19 billion. China was the largest export

destination with a 31.7% share (USD 27.96 billion), followed by Hong Kong (23.8%, USD 20.97 billion), Taiwan (17.5%, USD 15.40 billion), the United States (9.6%, USD 8.50 billion), and Vietnam (9.0%, USD 7.94 billion). On the import side, China alone accounted for 71.5% (USD 17.30 billion), followed by Vietnam (10.7%, USD 2.58 billion) and Taiwan (9.3%, USD 2.26 billion). This pattern highlights Korea's continued reliance on regional suppliers for intermediate memory components.

Multi-Chip Packages (MCP)¹ were the largest export item in Korea's memory semiconductor portfolio, accounting for 48.4% (USD 42.75 billion) of total memory exports in 2024. MCPs also represented 44.0% (USD 10.64 billion) of imports, underscoring Korea's heavy dependence on MCPs in both trade directions. Hong Kong was the top destination for MCP exports, receiving 39.4% (USD 16.82 billion), followed by Taiwan with 31.0% (USD 13.26 billion). Exports to Taiwan rose sharply from USD 1.8 billion in the previous year, driven by surging demand for High Bandwidth Memory (HBM), which is classified as MCP in trade statistics due to its 3D-stacked architecture. China ranked third with USD 5.23 billion—down significantly from USD 9.54 billion in

2022, likely reflecting the effects of U.S. export controls. Vietnam followed with USD 3.44 billion. On the import side, MCPs were overwhelmingly sourced from China, which supplied 67.1% (USD 7.14 billion) of Korea's MCP imports, followed by Taiwan (18.7%, USD 1.99 billion) and Hong Kong (7.1%, USD 0.75 billion).

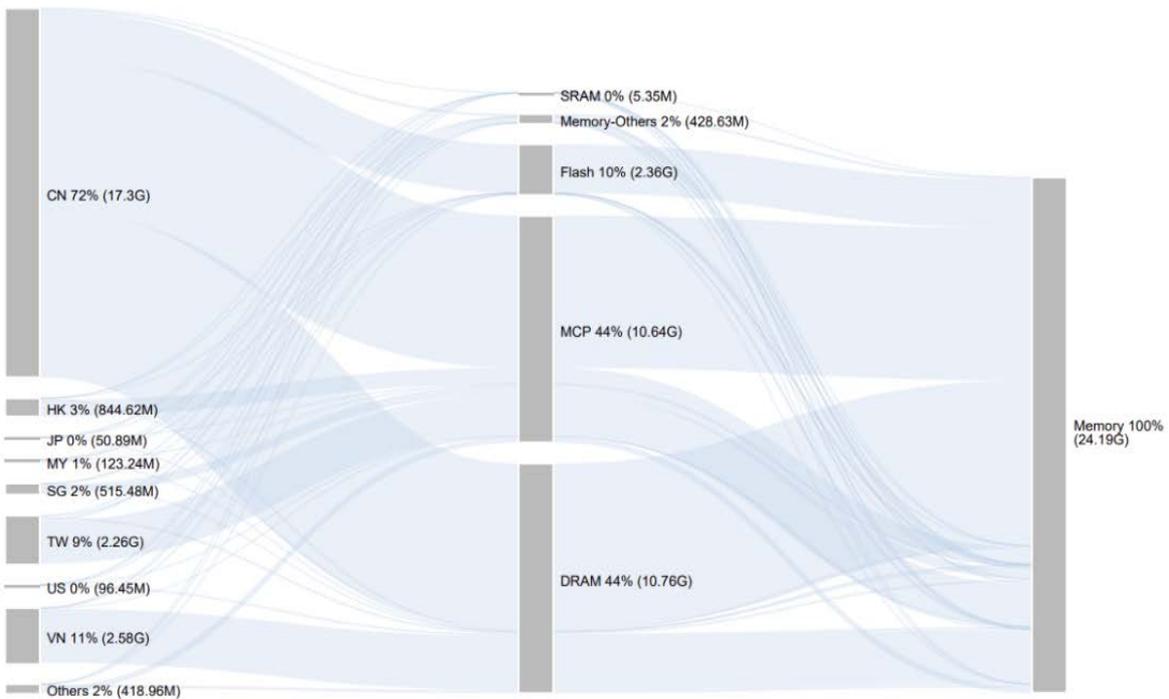
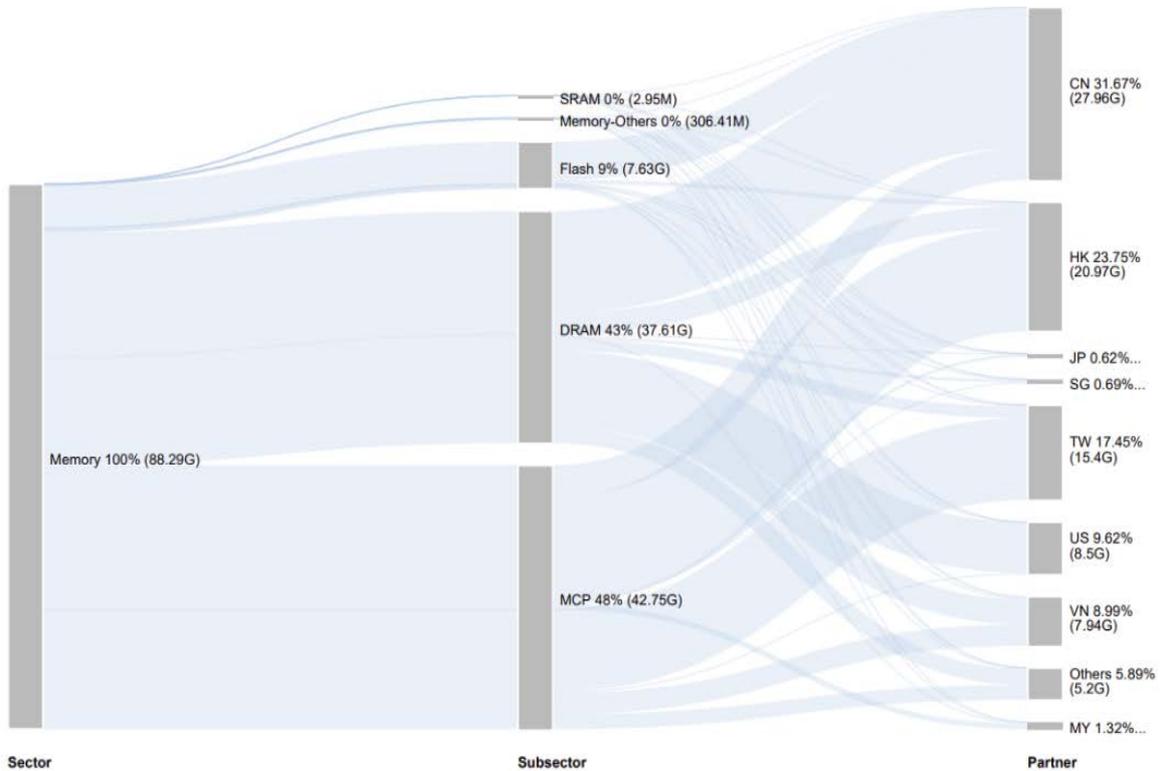
Traditionally the core of Korea's memory semiconductor exports, DRAM² was overtaken by MCPs in 2024, now ranking second. This shift is largely attributable to the rapid growth in HBM exports, which are counted under MCP. In 2024, DRAM exports totaled USD 16.52 billion to China (43.9% of total DRAM exports), USD 8.23 billion to the United States (21.9%), and USD 4.05 billion to Vietnam (10.8%). Notably, China's share has declined steadily from 62.9% in 2018 (USD 28.84 billion), reflecting the Chinese government's push for domestic chip production. On the import side, DRAM sourcing was also highly concentrated, with 72.2% (USD 7.78 billion) imported from China and 23.6% (USD 2.54 billion) from Vietnam. Combined, these two countries accounted for 95.8% of Korea's DRAM imports, while imports from Taiwan and the U.S. were negligible at just 0.8% combined.

¹ A Multi-Chip Package (MCP) integrates multiple memory chips—typically NAND flash and mobile DRAM—into a single module, enabling space efficiency, low power consumption, and high performance, especially in mobile devices like smartphones.

² DRAM (Dynamic Random-Access Memory): A volatile memory used as the main memory in computers and electronic devices, offering high speed and large storage capacity but losing data when power is off.

Figure 1. Korea's Memory Semiconductor Export and Import Trends (2024)

(Unit: USD billion, %)



Source: Korea Customs Service, compiled by the author.

Flash memory³ accounted for 9.0% of Korea's memory exports and 10.0% of imports in 2024. Trade in this segment was heavily dependent on China: 81.2% (USD 6.19 billion) of flash memory exports went to China, followed by Hong Kong (8.5%, USD 0.64 billion) and Taiwan (3.8%, USD 0.29 billion). Imports showed a similar pattern, with 80.3% (USD 1.16 billion) sourced from China and 7.9% (USD 0.19 billion) from Taiwan. This indicates Korea's continued reliance on China as both a major market and supply source for flash memory.

Specialized memory types such as Static Random-Access Memory (SRAM)⁴ and Electrically Erasable Programmable Read-Only Memory (EEPROM) represent a small portion of Korea's overall memory semiconductor trade. In 2024, SRAM exports amounted to USD 2.95 million and imports to USD 5.35 million. For other specialized memory—including EEPROM—exports totaled USD 310 million, while imports reached USD 430 million. Although larger than SRAM, these segments remain minor in Korea's overall memory semiconductor trade structure.

³ Flash memory is a non-volatile memory that retains data without power. It includes NAND flash for high-capacity storage and NOR flash for fast read speeds, and is widely used in USB drives, SSDs, and smartphones.

⁴ SRAM is a volatile memory that does not require refresh cycles and is used in high-speed applications such as CPU cache. It is faster but more expensive and

3. Trends in Korea's System Semiconductor Trade

In 2024, Korea's system semiconductor trade remained highly concentrated, with eight export destinations accounting for 91.6% of total exports and eight import sources making up 94.6% of total imports (Figure 2). Exports reached USD 48.26 billion, while imports totaled USD 40.65 billion.

China was Korea's largest export destination, receiving 34.1% (USD 16.45 billion), followed by Vietnam (19.0%, USD 9.15 billion), Taiwan (12.6%, USD 6.08 billion), Hong Kong (10.3%, USD 4.99 billion), and Singapore (7.2%, USD 3.47 billion). On the import side, Taiwan led overwhelmingly with 50.5% (USD 20.53 billion), followed by Japan (14.6%, USD 5.95 billion) and China (8.5%, USD 3.47 billion). This structure highlights Korea's growing reliance on Taiwan for high-value system semiconductor imports, while its export markets are centered around China and Southeast Asia.

Processors and controllers⁵ were the most significant product category in Korea's system

has lower capacity than DRAM.

⁵ Processors and controllers include CPU (Central Processing Unit), MCU (Microcontroller Unit), DSP (Digital Signal Processor), as well as hybrid integrated circuits and multi-chip integrated circuits used for processing and control functions.

semiconductor trade. In 2024, exports of this segment to the top eight destinations totaled USD 23.73 billion, accounting for 49.2% of total system semiconductor exports. Imports were even more concentrated, reaching USD 27.66 billion—68.1% of Korea’s total system semiconductor imports. China was the leading export market, receiving 42.4% (USD 11.16 billion) of Korea’s processor and controller exports. Vietnam followed with 14.0% (USD 3.75 billion), Singapore with 12.1% (USD 3.19 billion), and Taiwan with 8.6% (USD 2.15 billion). On the import side, Korea’s dependency on Taiwan was particularly high, with 57.7% (USD 16.89 billion) of imports sourced from there. Japan (15.7%, USD 4.59 billion) and the United States (7.5%, USD 2.18 billion) followed.

Application-specific system-on-chips (SoCs) constituted the second-largest segment in Korea’s system semiconductor trade. In 2024, exports to the top eight countries amounted to USD 10.82 billion, representing 22.4% of Korea’s total system semiconductor exports. Imports totaled USD 6.78 billion, accounting for 16.7%. Taiwan was the largest export destination for this category, receiving 28.2% (USD 3.33 billion), followed by China (23.0%, USD 2.72 billion) and Vietnam (18.8%, USD 2.22 billion). On the import side, Taiwan again led with 41.3% (USD 3.32 billion), while China (17.9%, USD 1.43 billion), Malaysia (9.5%,

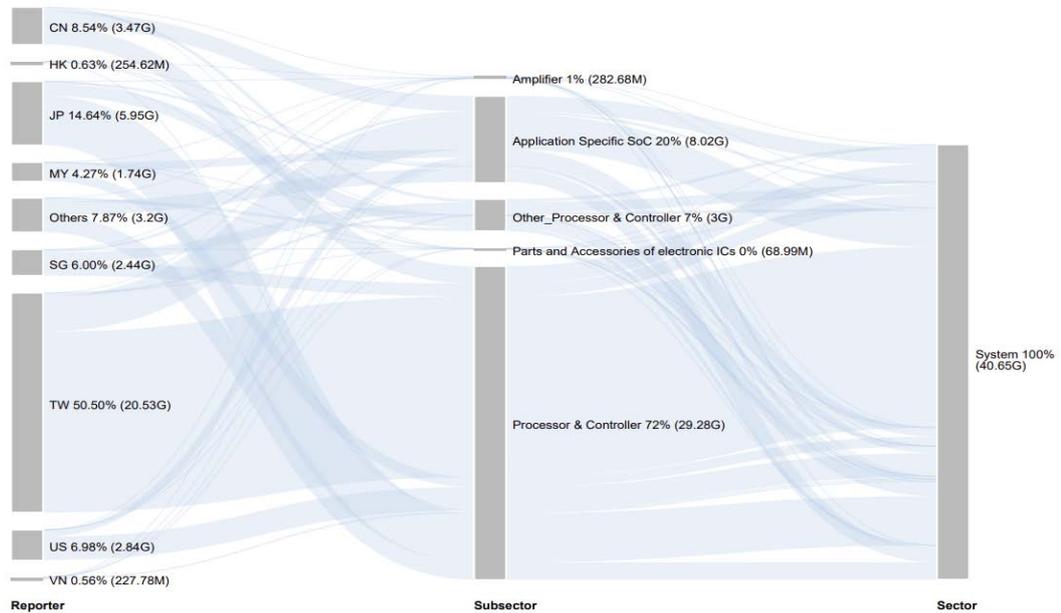
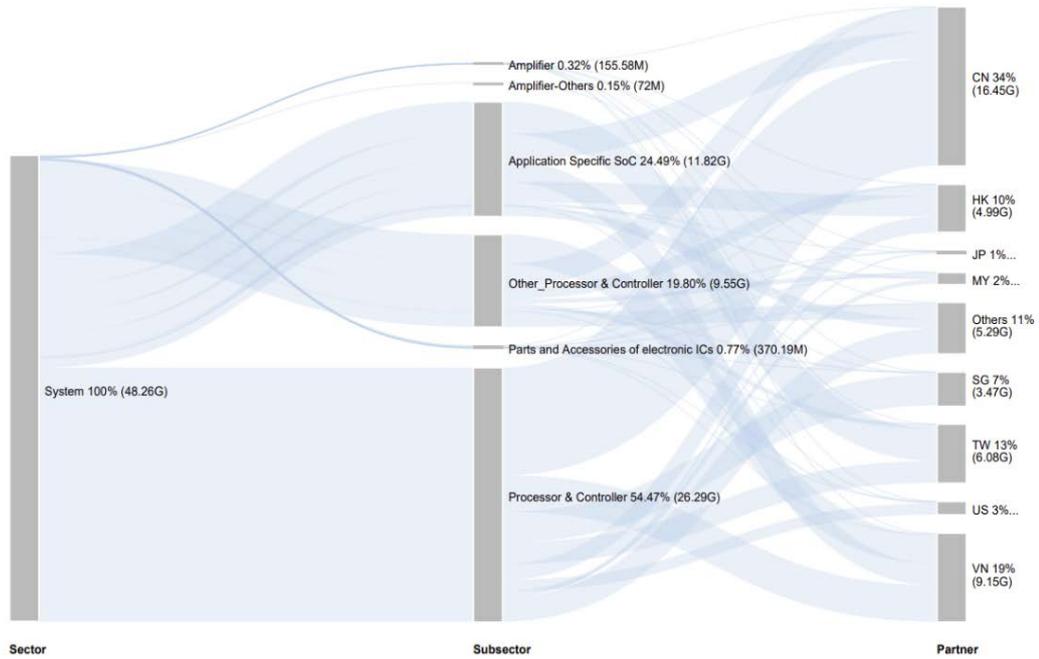
USD 0.76 billion), and the United States (7.9%, USD 0.63 billion) also played notable roles.

Amplifiers and other IC components—including those used for packaging and interconnection—played a relatively minor role in Korea’s system semiconductor trade. In 2024, both exports and imports of analog ICs and related components accounted for less than 1% of total system semiconductor trade, underscoring their limited significance within Korea’s current trade structure.

To better understand Korea’s evolving competitiveness and structural position in the global memory and system semiconductor value chains, the following section presents a detailed analysis using key trade and technology indices. By applying the Trade Specialization Index (TSI), Revealed Symmetric Comparative Advantage (RSCA), Grubel–Lloyd Index (GL), Trade Intensity Index (IT), and Technology Strength Index, the study assesses Korea’s relative advantages, intra-industry trade integration, and trade asymmetries across major product categories and trading partners. This empirical analysis provides a foundation for diagnosing structural challenges and identifying strategic directions for future industrial policy and international cooperation.

Figure 2. Export and Import Trends of Korea's System Semiconductor Industry in 2024

(Unit: USD billion, share %)



Source: Korea Customs Service, compiled by the author.

III. Comparative Analysis of Competitiveness in Memory Semiconductors

1. Comparison of the TSI⁶ and the RSCA⁷ Indices

South Korea has long held a leading position in the global memory semiconductor industry, consistently ranking in the first quadrant (TSI > 0, RSCA > 0), which reflects both a trade surplus and a comparative advantage. However, recent trends show signs of erosion in this competitiveness. As illustrated in Figure 3, Korea's TSI and RSCA values have plateaued or declined, indicating a weakening position. In contrast, China's competitiveness has steadily improved. Its RSCA and TSI indices show a clear upward trajectory, signaling a growing comparative advantage and increasing presence in global memory semiconductor markets. South Korea still shows strong performance across major memory semiconductor segments—DRAM, MCP (Multi-Chip

Package), and Flash memory—with all three categories positioned in the first quadrant.

However, recent data reveal a softening trend. As illustrated in Appendix Figure 1 (MCP) and Figure 2 (DRAM), both RSCA and TSI values for these segments have declined in recent years, suggesting that Korea's dominance is gradually weakening even in its traditionally strongest product lines.

South Korea has consistently maintained a high level of competitiveness in key memory semiconductor segments, including DRAM, MCP (Multi-Chip Package), and Flash memory. While the country continues to occupy a position in the first quadrant (TSI > 0, RSCA > 0) across all three categories, indicating strong comparative advantage and trade surplus, recent data reveal a gradual decline in its competitive edge. As illustrated in Appendix Figure 1 (MCP) and Figure 2 (DRAM), the RSCA and TSI values for these segments have

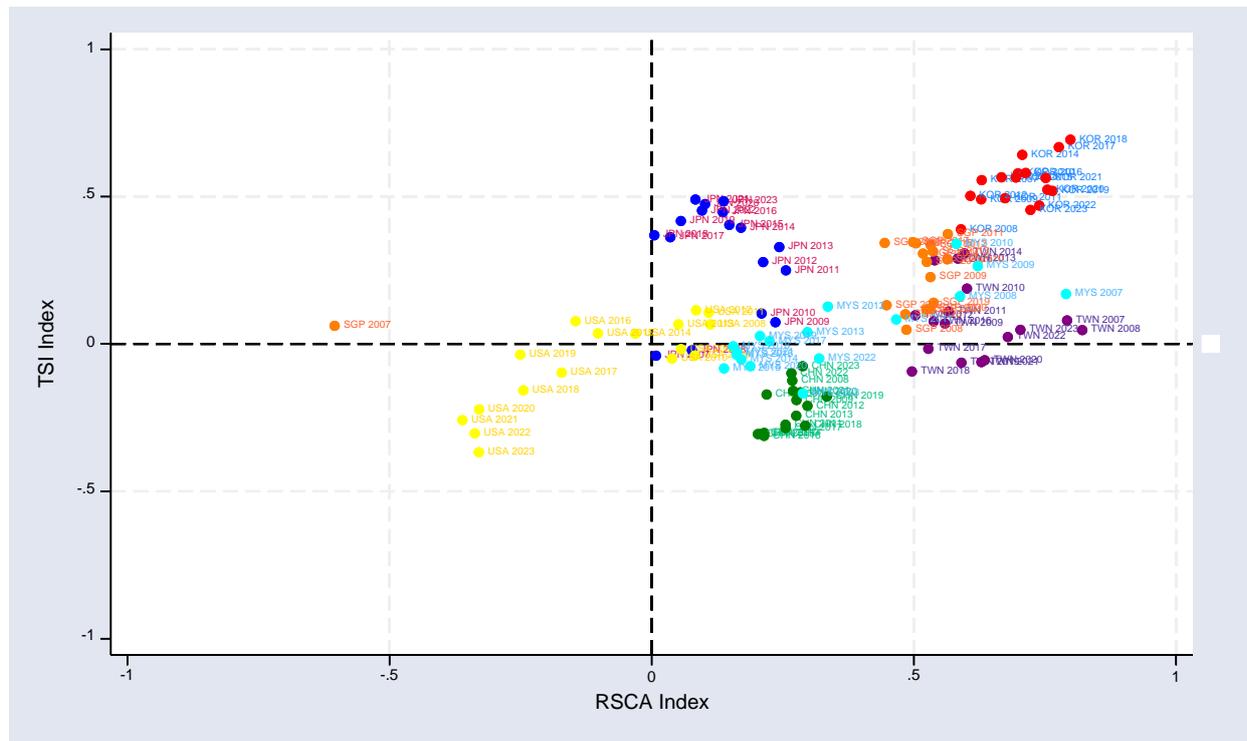
⁶ The Trade Specialization Index (TSI) is used to analyze trade patterns by focusing on trade balances, indicating whether a country is a net exporter or importer of a particular product. It helps policymakers and businesses understand a country's degree of specialization and its dependency on specific products in international trade. The TSI serves as an indicator of a country's relative comparative advantage in exports, based on the assumption that a higher level of exports relative to imports for a given product reflects greater competitiveness. The TSI can be interpreted using five classification groups: Very Strong Competitiveness ($0.5 \leq \text{TSI} \leq 1.0$), Strong Competitiveness ($0.0 \leq \text{TSI} < 0.5$), Neutral Competitiveness ($\text{TSI} = 0.0$), Weak Competitiveness ($-0.5 \leq \text{TSI} < 0.0$), Very Weak Competitiveness ($-1.0 \leq \text{TSI} < -0.5$).

⁷ The Revealed Comparative Advantage (RCA) index is commonly used to assess trade competitiveness, but it has certain limitations. An RCA value greater than 1 is interpreted as indicating a comparative advantage, whereas a value below 1 suggests a comparative disadvantage. However, the RCA index is inherently asymmetric: values for products with a comparative advantage can be unbounded and large, whereas values for products with a disadvantage are constrained between 0 and 1. This asymmetry can distort interpretation. To address this issue, the present study adopts the Revealed Symmetric Comparative Advantage (RSCA) index, which transforms RCA values into a symmetric scale ranging from -1 to 1. This allows for a more balanced and interpretable analysis of comparative advantage and disadvantage.

shown a downward trend in recent years, suggesting that South Korea’s dominance in these markets may be weakening.

United States, Japan, and Taiwan has remained largely one-directional. As shown in Figure 2, from 2018 to 2023, Korea recorded

Figure 3. Comparative Changes in Memory Semiconductor Competitiveness (2007–2023)



Note: The figure plots the RSCA index (x-axis) and TSI (y-axis) for selected countries. The first quadrant (RSCA > 0, TSI > 0) indicates high competitiveness, with both comparative advantage and trade surplus. The second quadrant shows a trade surplus without comparative advantage, the third indicates low competitiveness (trade deficit and disadvantage), and the fourth reflects comparative advantage with a trade deficit.

Source: Compiled using data from UN Comtrade.

2. Comparison of the Grubel-Lloyd (GL) Index⁸

South Korea’s intra-industry trade in DRAM has deepened with China, while trade with the

meaningful levels of intra-industry DRAM trade only with China, as reflected by relatively high GL index values. In contrast, GL indices for the United States and Japan stayed

⁸ The Grubel–Lloyd (GL) index measures the level of intra-industry trade (IIT) for a specific product and reflects the extent to which exports and imports of that product are balanced. The index ranges from 0 to 1. A value of 0 indicates that there is no two-way trade for the product—that is, trade occurs exclusively in one direction, either export or import. In contrast, a value of 1 implies perfect balance between exports and imports, meaning all trade in the product is intra-industry.

A higher GL index suggests a greater degree of intra-industry trade, indicating that the country is both exporting and importing significant volumes of the same product category. Conversely, a lower GL index points to a more unidirectional trade pattern, implying strong dependence on either imports or exports.

near zero, indicating a predominantly export-driven trade structure with little reciprocal import activity.

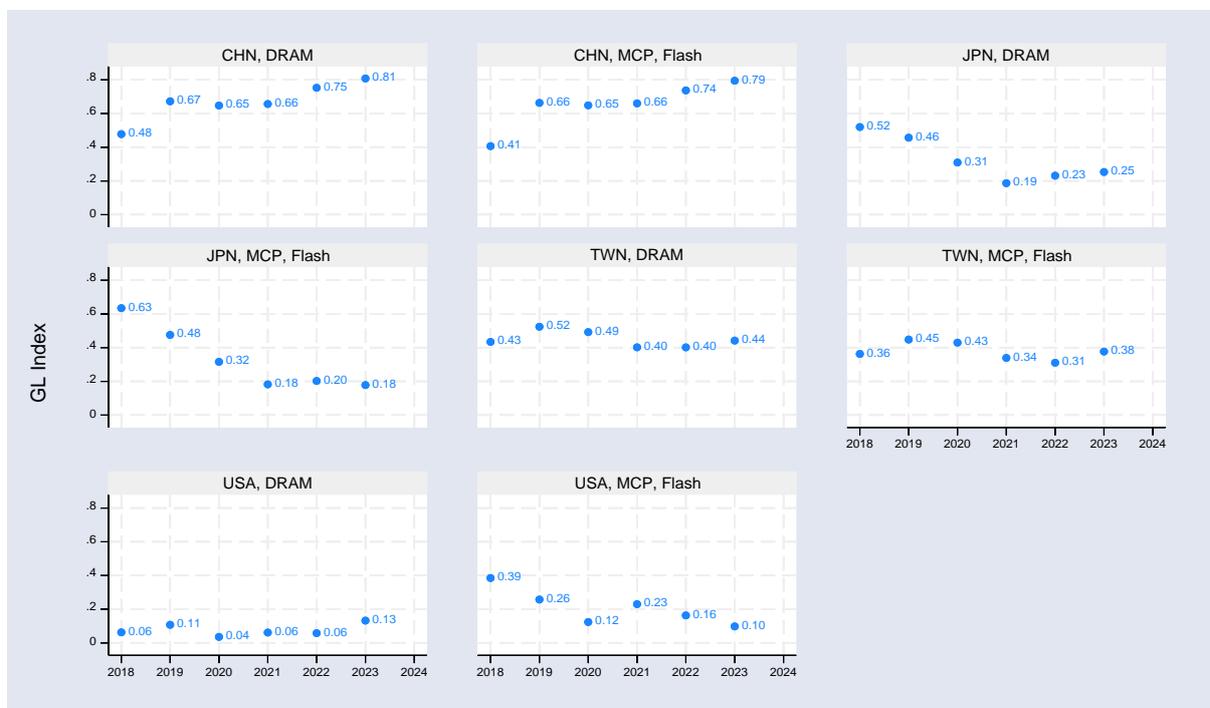
China’s GL index for DRAM rose markedly from 0.48 in 2018 to 0.81 in 2023, suggesting increased bidirectional trade. This trend may be attributed to re-imports of DRAM products manufactured by Korean firms at Chinese facilities—such as SK Hynix’s Wuxi fab—as well as growing domestic memory production within China.

Japan’s position in Korea’s memory semiconductor trade has continued to weaken. The declining GL index and shrinking share of Korean memory exports to Japan point to loosening supply chain integration. This is likely reinforced by the expansion of Micron’s DRAM production in Japan, which has contributed to the development of a more independent, Japan-centered memory supply chain, increasingly detached from Korean firms.

In the MCP (Multi-Chip Package) and Flash memory segments, Korea’s GL indices with the United States and Japan have remained consistently low, reflecting a one-way trade structure centered on Korean exports. However, Korea’s GL index with China in these segments has steadily increased—from 0.41 in 2018 to 0.79 in 2023 when MCP and Flash are combined—indicating greater two-way trade

ing supply chain integration. This is likely reinforced by the expansion of Micron’s DRAM production in Japan, which has contributed to the development of a more independent, Japan-centered memory supply chain, increasingly detached from Korean firms.

Figure 4. Comparative Changes in GL Indices for DRAM and MCP/Flash Memory Trade (2018–2023)



Source: UN Comtrade, compiled by the author.

activity. This structural shift reflects the growing role of China in final-stage packaging and assembly, where MCPs such as eMCPs are assembled in China and re-imported to Korea as finished goods.

Although Japan is home to Kioxia, a major NAND Flash producer, Korea–Japan intra-industry trade in this segment remains limited. The continuing decline in their GL index since 2018 suggests weakening bilateral interdependence. Similarly, Micron—headquartered in the United States—produces NAND Flash primarily in offshore facilities like Singapore, resulting in minimal direct trade with Korea. Accordingly, the GL index for Korea–U.S. trade in NAND Flash remains close to zero.

3. Comparison of the Trade Intensity (IT) Index⁹

South Korea exhibits a high level of trade intensity with China in the memory semiconductor sector, indicating strong bilateral interdependence (Figure 5). Both export and import IT indices exceed 1, suggesting trade volumes between the two countries are significantly higher than their respective global trade averages. In the DRAM segment, Korea’s export IT index with China has remained stable at

around 1.56, while the import IT index rose from 1.62 in 2018 to 1.82 in 2023. This upward trend reflects a gradual shift from a one-sided export structure toward more balanced two-way trade, driven by China’s expanding domestic production and assembly capabilities.

In Multi-Chip Packages (MCPs), Korea’s export IT index with China increased from 1.20 to 1.41 between 2018 and 2023, fueled by demand in China’s growing smartphone and server markets. Although the import IT index for MCPs declined slightly from 3.22 to 2.92, it remains high, underscoring Korea’s continued reliance on Chinese-assembled MCPs.

In contrast, Japan’s IT indices with Korea—both for exports and imports—remain below 1, indicating relatively weak bilateral trade dependence in memory semiconductors. Korea exports little to Japan in this segment, while imports remain limited due to Japan’s reliance on domestic production (e.g., Micron Japan) and alternative sourcing channels.

Trade intensity between Korea and Taiwan in memory semiconductors also remains low, reflecting Taiwan’s industrial specialization in system semiconductors—particularly foundry services—rather than memory production.

⁹ The Trade Intensity Index (IT Index) is an indicator that measures the strength of trade linkages—or mutual trade dependency—between two countries. For example, China’s export intensity with South Korea is calculated by dividing the share of South Korea in China’s total exports by South Korea’s share in total global imports. An index value greater than 1 indicates that

trade between the two countries is more intensive than the global average, implying a relatively strong bilateral trade relationship. Conversely, a value less than 1 suggests weaker trade linkages and lower trade complementarity between the countries.

However, a modest increase has been observed since the early 2020s, largely due to rising Korean exports of High Bandwidth Memory (HBM) chips to Taiwan. Major Korean firms like Samsung and SK Hynix supplied large volumes of HBM to Taiwanese packaging companies in 2022–2023, responding to AI-related demand. This shift led to a slight uptick in Korea’s export IT index with Taiwan.

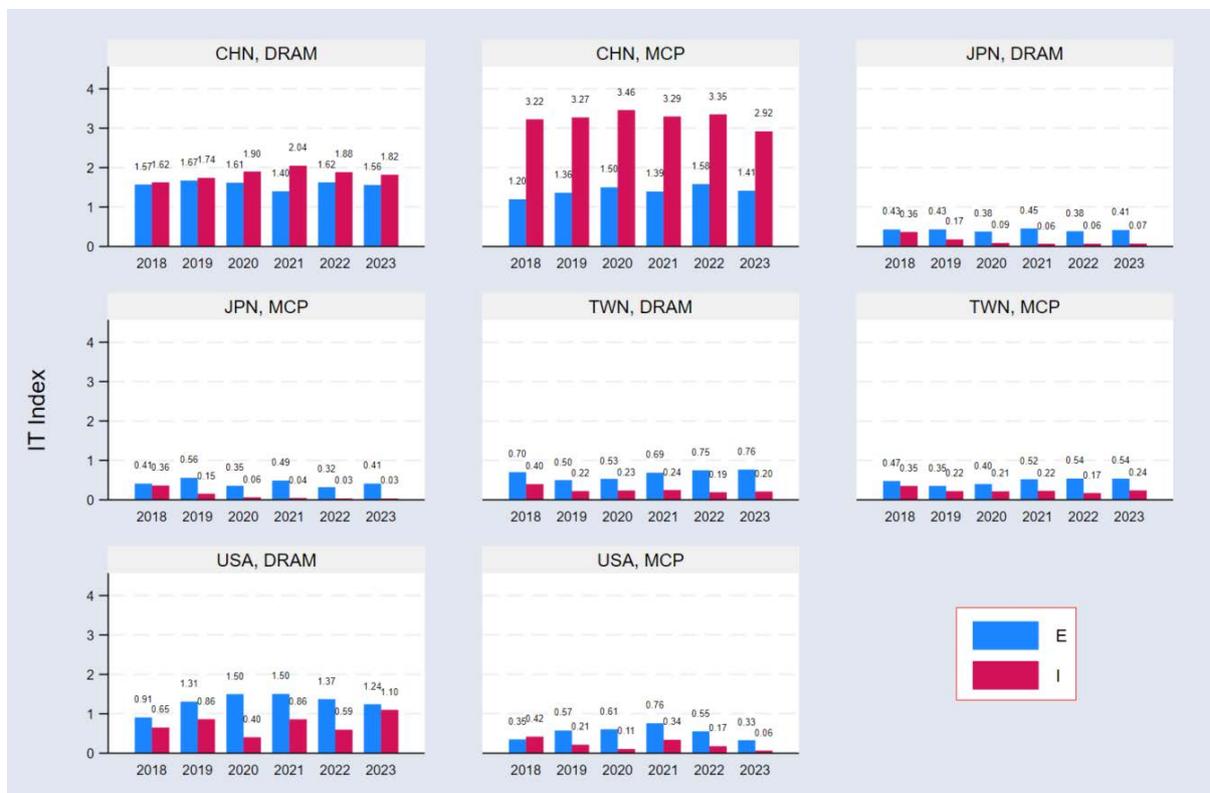
Korea’s trade intensity with the United States in memory semiconductors remains lower than with China but higher than with Japan or Taiwan. Despite being a major global semiconductor market, the U.S. often sources

memory through domestic firms such as Micron or imports indirectly through third countries. As a result, Korea–U.S. trade in memory semiconductors is less intense compared to Korea–China exchanges.

4. Analysis of the Technology Strength Index

Figure 6 presents memory semiconductor patent registrations by the world’s top 10 companies over the past two decades. Korean and U.S. firms—particularly Samsung Electronics (5,680 patents), SK Hynix (2,881), and Micron Technology (4,934)—have led in patent activity, underscoring their central role in global memory semiconductor innovation. All

Figure 5. Comparative Changes in IT Indices for DRAM, MCP, Flash, and SRAM (2018–2023)



Source: Compiled using data from UN Comtrade.

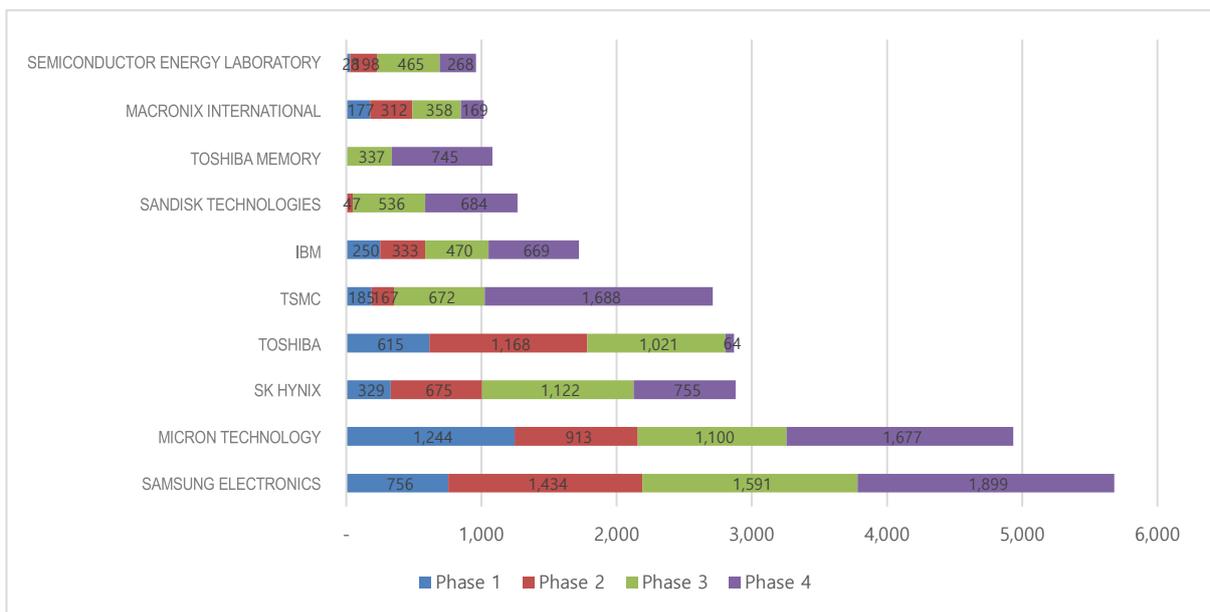
three companies showed a consistent upward trend from the first period (2004–2008) through the fourth (2019–2023), with a notable acceleration in filings during the most recent decade, reflecting the growing strategic importance of intellectual property.

SK Hynix exhibited particularly rapid growth in the latest period, indicating a shift from manufacturing-centered operations to more innovation-driven competitiveness. TSMC, although primarily a foundry firm, also showed a steady rise in memory-related patents, suggesting a potential expansion into memory technologies. Meanwhile, Japanese and U.S.

firms such as IBM, SanDisk, and Toshiba Memory maintained relatively stable levels of patent activity, though companies like Toshiba and IBM have recently slowed their filing pace—possibly reflecting shifts in business focus or declining competitiveness.

The Technology Strength Index (TSI),¹⁰ which combines patent quantity and influence, further highlights the technological leadership of Samsung Electronics, Micron Technology, and SK Hynix. Samsung has consistently maintained one of the highest TSI scores across all four periods, reaffirming its global

Figure 6. Memory Semiconductor Patent Registrations by Top 10 Global Companies



Note: Phase 1: 2004–2008; Phase 2: 2009–2013; Phase 3: 2014–2018; Phase 4: 2019–2023.
 Source: Author’s calculation using the KIWEE database, Korea Intellectual Property Promotion Agency.

¹⁰ The Technology Strength Index (TSI) combines the number of patents with their qualitative impact, calculated by multiplying patent counts by the Patent Impact Index (PII). The PII measures how often patents

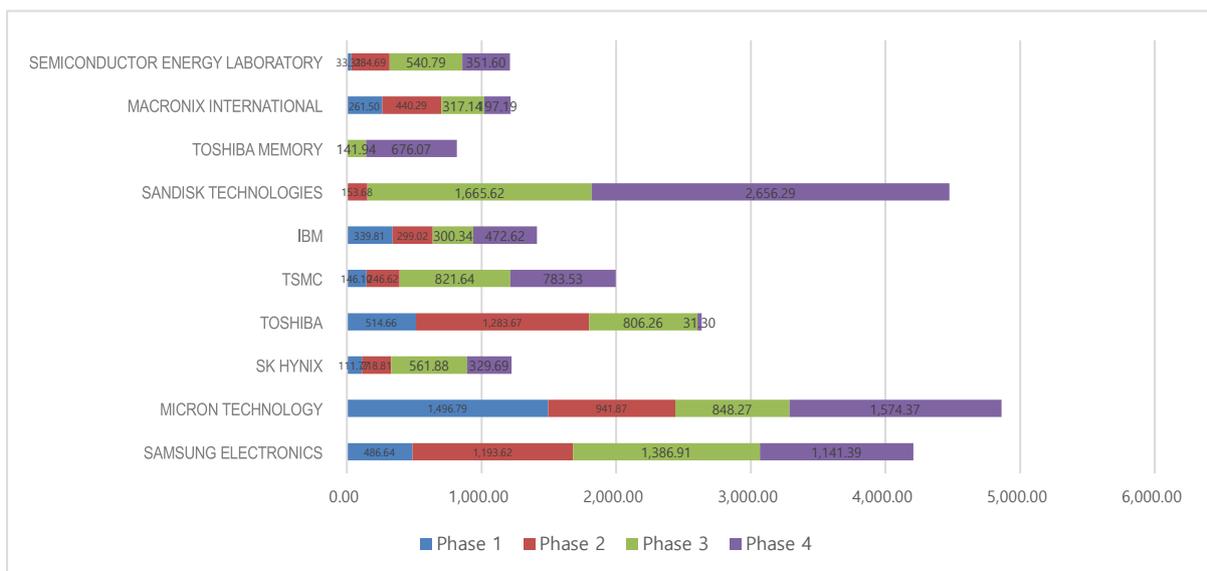
are cited in subsequent inventions, indicating their technological influence.

leadership. However, Micron’s TSI has recently approached—or in some periods, surpassed—that of Samsung, signaling intensifying technological competition between the two firms. A notable development is SanDisk’s sharp increase in TSI during the fourth period (2019–2023), making it the top-ranked firm by technological influence. This suggests SanDisk may emerge as a key competitor in next-generation NAND flash technologies, including QLC and 3D NAND, posing a direct challenge to Samsung’s leadership in this segment.

Samsung Electronics has steadily increased its Technology Strength Index (TSI) from the first period (2004–2008) to the fourth (2019–2023), maintaining its position as a global technology leader in memory semiconductors.

However, Micron Technology’s TSI has recently reached levels comparable to—or even exceeding—Samsung’s, indicating intensifying competition between the two firms. This shift reflects the rising technological influence of both Korean and U.S. companies, while Japanese firms have gradually lost ground over time. SanDisk, in particular, recorded a sharp increase in TSI during the fourth period, surpassing all other competitors. This suggests its potential emergence as a market leader in next-generation NAND flash technologies, including QLC and 3D NAND. Although Samsung continues to rank among the top in TSI, its technological dominance is increasingly challenged. To sustain its global competitiveness, Samsung must secure leadership in emerging segments such as High Bandwidth

Figure 7. Technology Strength Index (TSI) of the Top 10 Global Memory Semiconductor Companies



Note: Phase 1: 2004–2008; Phase 2: 2009–2013; Phase 3: 2014–2018; Phase 4: 2019–2023.
 Source: Author’s calculation using KIWEE DB, Korea Intellectual Property Promotion Agency

Memory (HBM), AI semiconductors, and high-performance DRAM—areas that are expected to drive the next wave of innovation in the memory semiconductor industry.

IV. Comparative Analysis of Competitiveness in System Semiconductors

1 Comparison of the TSI and the RSCA Index

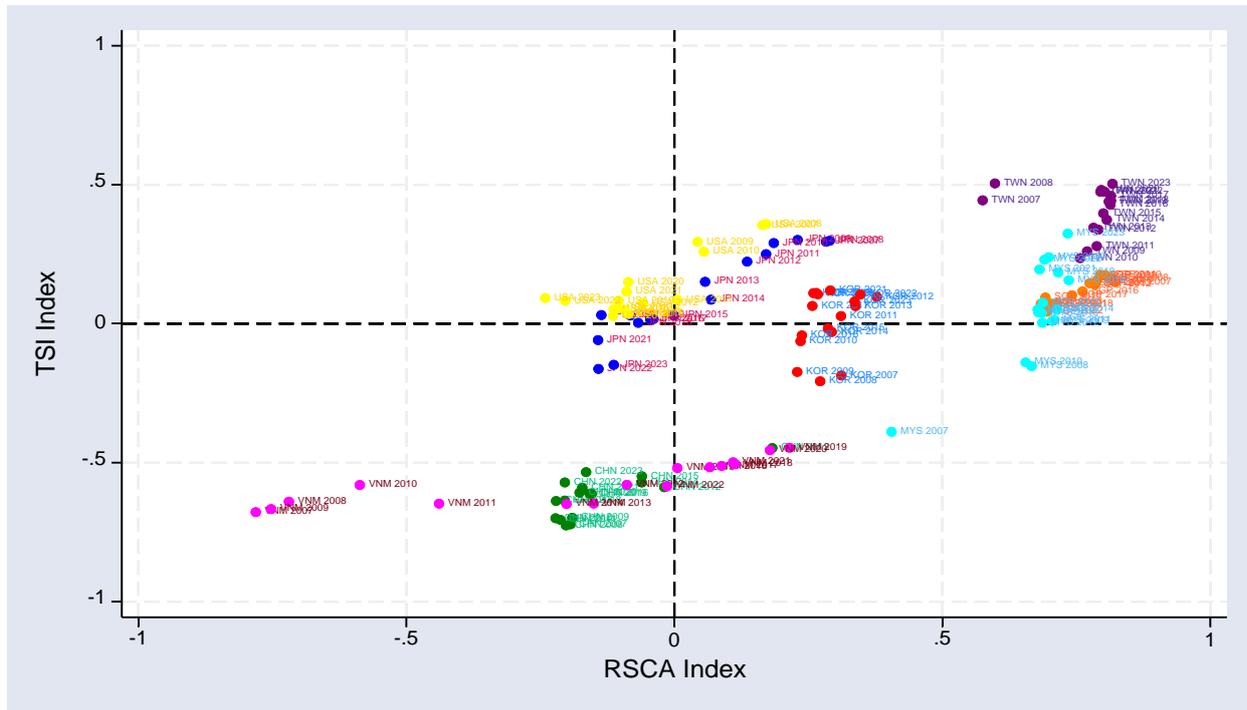
As shown in Figure 8, South Korea's system semiconductor industry remains in the zone of competitive advantage ($TSI > 0$, $RSCA > 0$), indicating a generally strong global position. However, the competitiveness gap with leading countries—particularly Taiwan—has widened over time. While Korea maintains a comparative advantage based on the RSCA index, the rate of improvement has slowed compared to Taiwan and the United States. The TSI has also plateaued, suggesting growing difficulty in sustaining Korea's position in global export markets.

In contrast, China remains in the third quadrant ($TSI < 0$, $RSCA < 0$), indicating limited competitiveness. Yet, both indices have shown consistent upward trends, reflecting expanding domestic capacity in design and manufacturing. The rise in China's RSCA signals strengthening capabilities—particularly in legacy chips—supported by state-led efforts to grow domestic foundries such as SMIC and

Hua Hong Semiconductor. Despite U.S. export controls, China continues to increase the share of domestically produced system semiconductors, potentially eroding Korea's market share in mid- and low-end segments. Korea's competitiveness in system semiconductors varies significantly by subsegment, reflecting structural asymmetries in technological strength and industrial specialization.

In processors and controllers, Korea shows a level of competitiveness comparable to, or slightly above, that of Taiwan. Especially in the sub-category of other processors and controllers, Korea has improved its position over time, with recent indicators falling within the first quadrant, signaling solid export and comparative advantage (Appendix Figure 3). In contrast, Korea's competitiveness in application-specific SoC has historically remained weak, with indicators in the third quadrant. While recent data suggest movement toward the second quadrant ($TSI > 0$, $RSCA < 0$), overall competitiveness remains limited (Appendix Figure 4). Taiwan, meanwhile, has consistently improved in this segment, with both TSI and RSCA trending upward—highlighting its growing dominance and the widening gap with Korea. For parts and accessories of electronic ICs used in system semiconductor production, Korea has consistently remained in the second quadrant ($TSI > 0$, $RSCA < 0$), indicating export specialization without clear comparative advantage. This suggests a need to enhance technological and industrial capacity in this area (Appendix

Figure 8. Comparative Changes in System Semiconductor Competitiveness (2007–2023)



Note: The figure plots the RSCA index (x-axis) and TSI (y-axis) for selected countries. The first quadrant (RSCA > 0, TSI > 0) indicates high competitiveness, with both comparative advantage and trade surplus. The second quadrant shows a trade surplus without comparative advantage, the third indicates low competitiveness (trade deficit and disadvantage), and the fourth reflects comparative advantage with a trade deficit.

Source: Compiled using data from UN Comtrade.

Figure 5). The amplifier segment shows the weakest performance, with Korea consistently positioned in the third quadrant (TSI < 0, RSCA < 0). Although there are early signs of improvement, the industry remains in a low-competitiveness zone (Appendix Figure 6).

2. Comparison of the Grubel–Lloyd (GL) Index

The Grubel–Lloyd (GL) Index reveals that Korea’s intra-industry trade (IIT) in system semiconductors has generally increased between 2018 and 2023, though the trend varies by product segment and trading partner.

In the processor and controller segment, Korea’s intra-industry trade (IIT) remains limited, as reflected in consistently low Grubel–Lloyd (GL) index values across most major partners. With China, the GL index remained within the 0.34–0.38 range, underscoring a predominantly one-way, export-oriented trade structure. In 2024, Korea exported USD 11.16 billion worth of processors and controllers to China, while imports from China amounted to only USD 1.63 billion. A similar asymmetry is evident in Korea’s trade with Japan, where the GL index declined from 0.25 in 2018 to 0.17 in 2022, before recovering slightly to 0.27 in 2023. Japan continues to hold a strong position

in industrial and automotive MCUs, power ICs, and analog control chips, while Korea remains primarily specialized in mobile application processors (APs). This imbalance is further reinforced by Japan's vertically integrated design–manufacturing model and its strengthening partnership with TSMC, which is expanding its foundry operations in Japan.

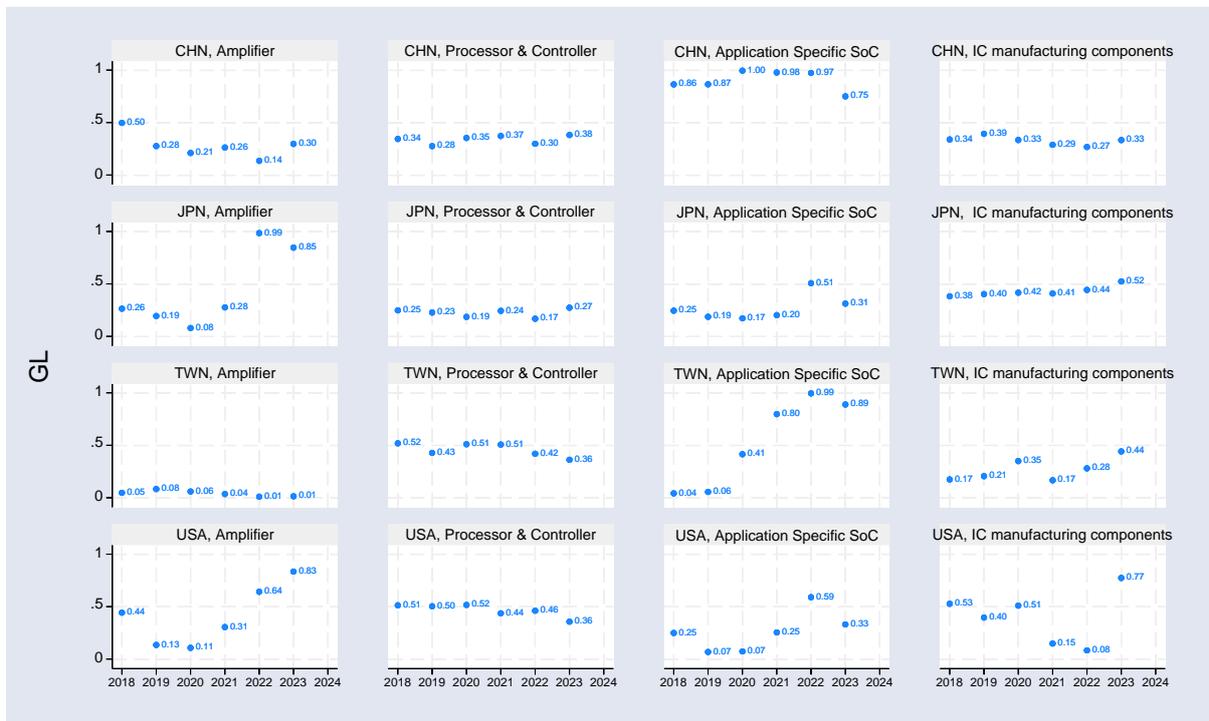
GL indices in the amplifier segment are generally low, indicating limited two-way trade. However, trade with Japan stands out: the Korea–Japan GL index surged from 0.26 (2018) to 0.99 (2022), suggesting near-parity in trade. Despite this, Korea still imports significantly more than it exports. With China and Taiwan, GL values remain very low—0.14 and 0.01, respectively—highlighting continued asymmetry in favor of imports, especially from China.

The application-specific SoCs (ASICs and custom chips) segment exhibits the most dynamic transformation in Korea's system semiconductor trade. Korea's GL index with China increased significantly from 0.86 in 2018 to 0.97 in 2022, before declining slightly to 0.75 in 2023—indicating a still-robust but somewhat rebalanced level of intra-industry trade. A more dramatic shift has occurred in Korea's trade with Taiwan. Between 2018 and 2024, Korea's exports of application-specific SoCs to Taiwan surged from USD 38.45 million to USD 3.33 billion, while imports rose

from USD 1.83 billion to USD 3.32 billion, reflecting a newly established trade equilibrium. This evolution has been driven by soaring demand for AI, high-performance computing (HPC), and automotive semiconductors, accompanied by functional specialization in back-end processes such as packaging and module integration. A new trade pattern has emerged in which Korea imports intermediate chips, conducts domestic post-processing, and re-exports finished or semi-finished products—often back to Taiwan or to other regional partners. Trade with the United States and Japan in this segment has also expanded, with GL indices peaking at 0.59 and 0.51, respectively, in 2022. Although both declined slightly in 2023, the overall trend points to a gradual increase in two-way trade. Nevertheless, Korea continues to import more than it exports in these markets, highlighting ongoing asymmetries in high-value chip segments.

In the IC manufacturing components segment—which includes materials and parts for packaging and assembly—Korea continues to exhibit a predominantly export-oriented trade structure, with relatively limited intra-industry trade. The GL index with China declined from 0.34 to 0.27 before recovering slightly to 0.33 in 2023, reflecting Korea's ongoing export dominance in this area. With Japan, the GL index increased moderately from 0.38 to 0.52, yet the bilateral trade structure remains asymmetric, as Korea continues to depend heavily on high-end Japanese materials and equipment.

Figure 9. Comparative Changes in GL Indices for System Semiconductors (2018–2023)



Source: Compiled using data from UN Comtrade.

Korea’s trade with Taiwan in this segment also reflects constrained intra-industry integration. The GL index stood at 0.44 in 2023, indicating limited but gradually improving IIT. Taiwan’s structural reliance on imported IC components contributes to this imbalance. Nonetheless, there are emerging signs of a more balanced trade relationship, driven by rising Taiwanese demand for Korean-made packaging and assembly inputs.

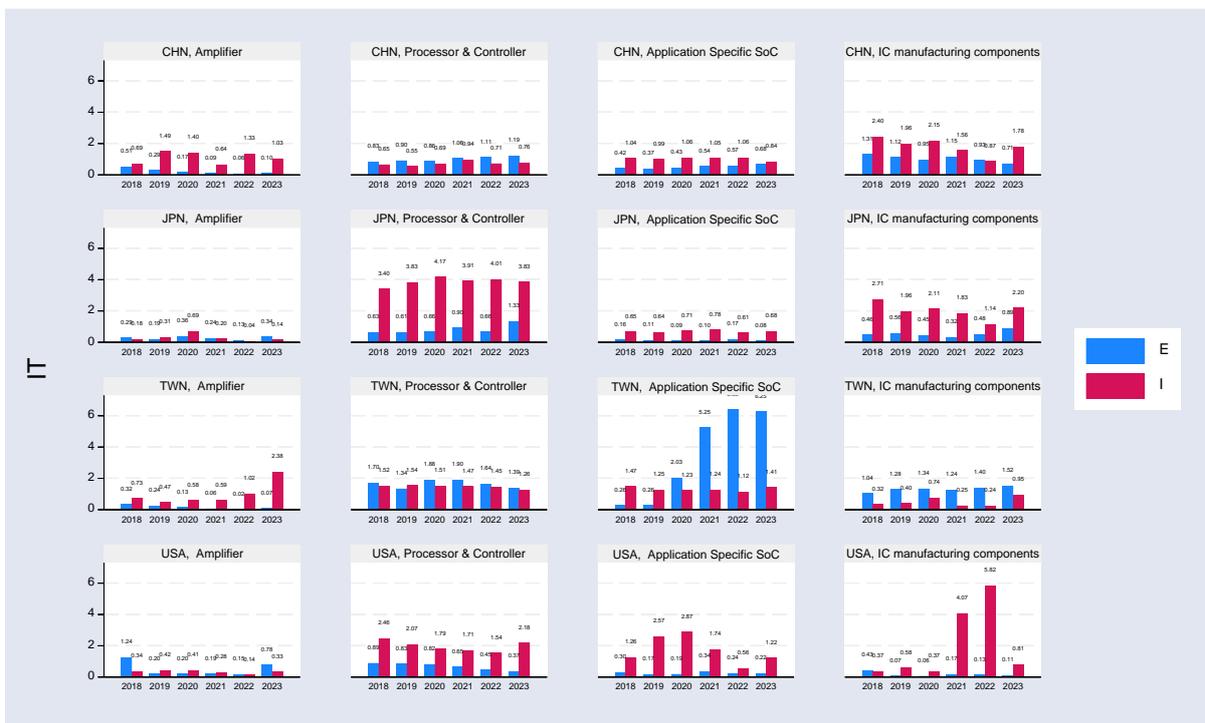
3. Comparison of the Trade Intensity (IT) Index

Figure 10 illustrates the evolution of Korea’s trade intensity with major partner countries in system semiconductors from 2018 to 2023.

The data reveal distinct trends of interdependence and structural asymmetry across key product categories.

Korea’s trade intensity in processors and controllers shows clear signs of strategic interdependence with certain partners. Export intensity toward China increased from 0.8 in 2018 to 1.2 in 2023, reflecting rising demand for Korean chips amid the expansion of China’s electronics and AI industries. A similar trend is seen with Japan, where export intensity rose to 1.3 in 2023, up from below 1.0 in earlier years. With Taiwan, export intensity remained

Figure 10. Comparative Trends in IT Indices for System Semiconductors (2018–2023)



Source: Compiled using data from UN Comtrade.

consistently high, between 1.3 and 1.9, underscoring a stable and complementary trade structure. On the import side, Korea's dependence on Japanese processors and controllers remained pronounced, with import intensity ranging from 3.4 to 4.2 throughout the period. Imports from Taiwan also remained stable at 1.3 to 1.5, driven by fabless-foundry cooperation. Meanwhile, U.S. import intensity stayed elevated between 1.5 and 2.5, while export intensity toward the U.S. declined from 0.9 to 0.4—indicating growing imbalance in the bilateral trade structure.

The Application-Specific SoCs segment experienced the most dynamic change. Korea's export intensity toward Taiwan surged from

0.3 in 2018 to 6.3 in 2023, driven by rising demand for Korean SoCs in back-end processing and AI applications. Export intensity with China also increased steadily from 0.4 to 0.7, while remaining low with Japan (0.1–0.2) and the U.S. throughout the period. On the import side, Korea maintained relatively stable intensity across partners: 1.0–1.1 with China, 1.1–1.5 with Taiwan, and 0.6–0.8 with Japan. Although import intensity from the U.S. temporarily declined, it rebounded in later years, reflecting continued reliance on U.S.-based custom chip technologies. The Korea–Japan and Korea–U.S. relationships in this segment remain structurally asymmetric, with Korea

largely dependent on imports of industrial-grade or specialized SoCs.

Korea's export intensity in the amplifier segment remained low across all major partners. With China, it declined from 0.5 in 2018 to 0.1 in 2023, suggesting increased Chinese self-sufficiency. Export intensity with Japan and Taiwan also remained marginal (0.0–0.4), indicating Korea's limited competitiveness in analog ICs. Conversely, Korea's import intensity from China remained steady (0.7–1.0), signaling ongoing reliance. From Taiwan, import intensity increased sharply, from 0.5–0.7 in earlier years to 2.4 in 2023, driven by rising demand for analog-to-digital converters and power control chips. In contrast, import intensity from Japan rose briefly to 0.7 before falling to 0.1 in 2023, suggesting a declining trade relationship in this segment.

Korea's trade intensity in IC manufacturing components highlights divergent trends. Export intensity with China declined from 1.3 in 2018 to 0.7 in 2023, as China enhanced its domestic production capacity. In contrast, Korea's export intensity toward Taiwan remained strong, exceeding 1.0 throughout and peaking at 1.5 in 2023. With Japan and the U.S., Korea's export intensity remained below 1.0, though with a gradual upward trend. Import intensity tells a different story. With Japan, it stayed consistently high, confirming Korea's dependence on Japanese high-end materials and packaging components. Korea's import intensity from

China decreased sharply from 2.4 to 0.9, then rebounded to 1.8 in 2023—suggesting a partial return to China as a cost-efficient supplier. With Taiwan, import intensity rose modestly, reaching 1.0 in 2023, though overall volumes remained limited due to Korea's robust domestic back-end processing capabilities.

4. Analysis of the Technology Strength Index (TSI)

This section evaluates the technological competitiveness of major global players in the system semiconductor sector based on patent activity and the Technology Strength Index (TSI). Figures 11 and 12 present the number of patents filed by the world's top 10 system semiconductor companies and their corresponding TSI scores over four time periods (2004–2023).

Samsung Electronics leads in total patent filings, with 2,220 patents registered over the analysis period. Its filings surged notably in the fourth period (2019–2023), recording more than a sixfold increase compared to the first period. This rapid growth reflects Samsung's strategic push to diversify beyond memory semiconductors—where it holds a dominant position—toward becoming a key player in the system semiconductor space. This shift aligns with Samsung's broader initiative to expand its foundry services and strengthen its portfolio in logic chips, AI semiconductors, and high-performance SoCs. However, despite the high volume of patents,

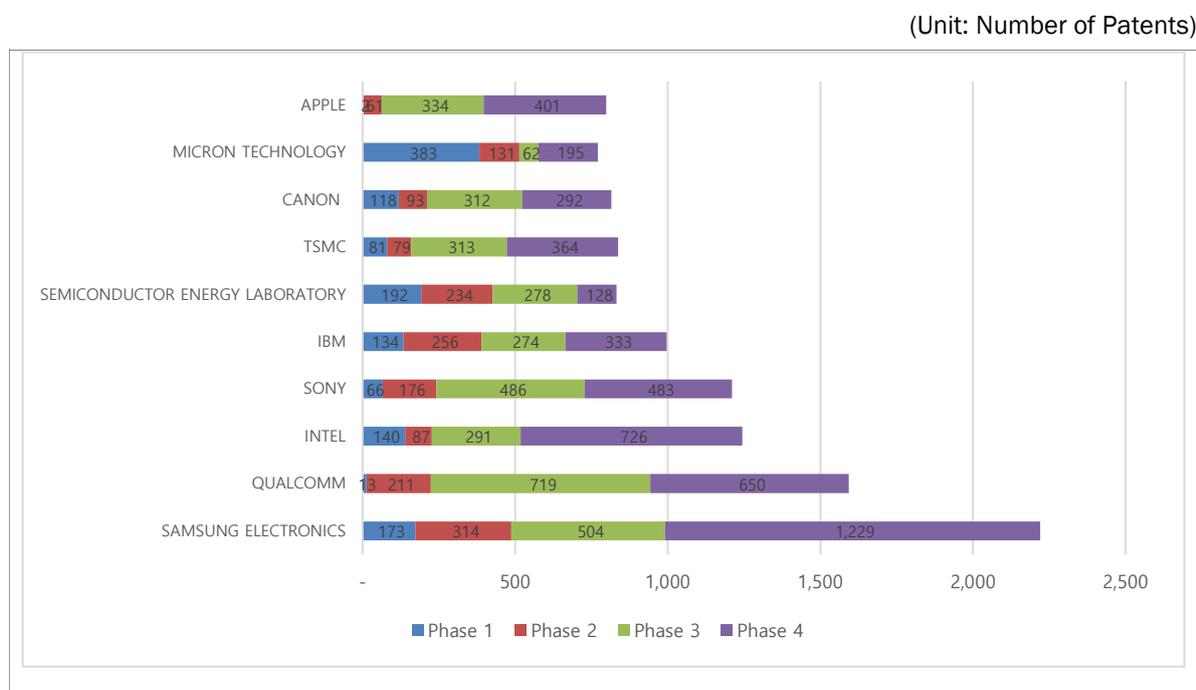
Samsung’s TSI has remained relatively stagnant—recording 0.69, 0.41, 0.43, and 0.64 across the four periods—indicating that the qualitative impact or influence of its patented technologies has not kept pace with the increase in quantity. This suggests a need for Samsung to prioritize high-value core patents and elevate the strategic focus of its R&D investment toward innovation leadership, not just portfolio expansion.

Qualcomm has demonstrated steady growth in both patent volume and technological influence. Its filings increased sharply during the third and fourth periods, reflecting continued leadership in mobile SoCs, 5G communica-

tions, and AI-enabled semiconductor platforms. Qualcomm’s business model, which is deeply rooted in fabless design, emphasizes intellectual property creation and licensing. This model is reflected in its consistent TSI performance, which supports its dominant position in the global mobile and IoT chipset market.

Intel, traditionally a vertically integrated manufacturer with strengths in CPUs and x86-based architectures, showed gradual growth in patent activity across all periods. However, its overall increase in filings has been modest relative to its peers. While Intel has recently made strategic moves to expand into the foundry and AI accelerator markets, the relatively modest rise

Figure 11. System Semiconductor Patent Filings by the Top 10 Global Companies



Note: Phase 1: 2004–2008; Phase 2: 2009–2013; Phase 3: 2014–2018; Phase 4: 2019–2023.
 Source: Author’s calculation using KIWEE DB, Korea Intellectual Property Promotion Agency

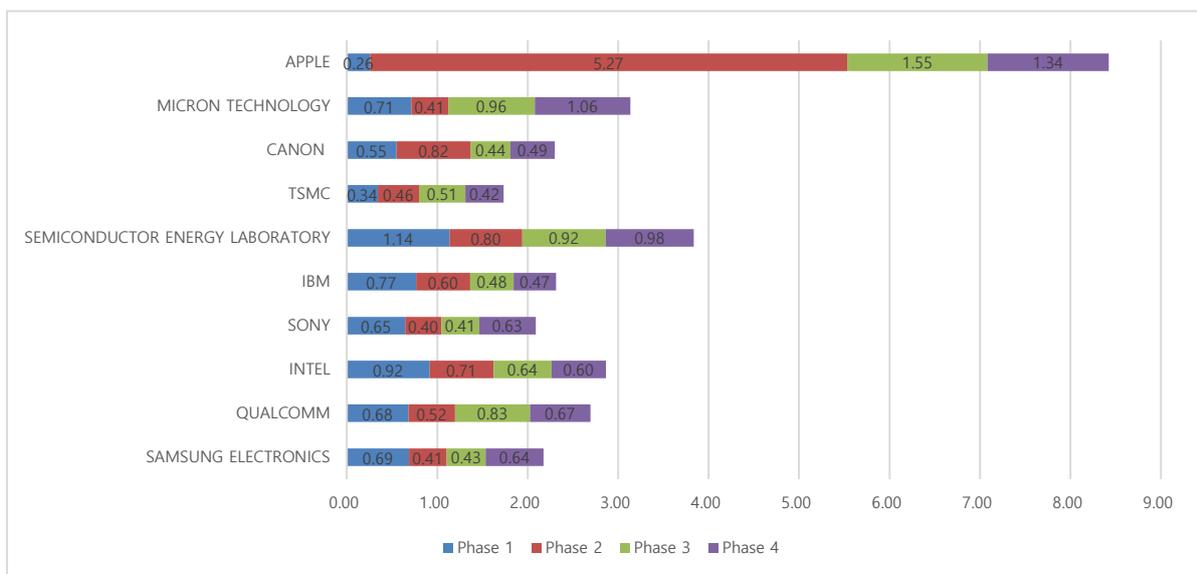
in TSI suggests that its transformation has not yet translated into breakthrough innovation in design-led technologies. Future changes in Intel’s patent impact will likely serve as an indicator of the effectiveness of its ongoing reorientation.

Apple presents a unique profile. Although its total number of filings is comparatively low, its TSI peaked sharply at 5.27 in the second period (2009–2013)—the highest among all firms. This reflects Apple’s focused and impactful approach to proprietary chip design, particularly the introduction of Apple-designed SoCs such as the A-series (iPhone) and later the M-series (Mac). Apple’s business model is vertically integrated at the design level but relies on outsourcing manufacturing to partners like TSMC. Its influence lies not in broad patent quantity but in tightly integrated

hardware-software optimization. Although Apple’s TSI has trended downward in recent periods, it remains relatively high, signifying continued technological leadership in device-specific system semiconductor design.

Micron Technology, while primarily known as a memory chip manufacturer, has gradually expanded its technology base into system semiconductors related to AI and high-performance computing. Its TSI increased steadily from 0.71 to 1.06 over the analysis period, indicating growing influence in areas such as HBM (High Bandwidth Memory) and memory-controller integration. This trajectory reflects Micron’s shift from a commodity DRAM/NAND producer to a value-added solution provider in data-centric semiconductor ecosystems.

Figure 12. Technology Strength Index Assessment of the Top 10 Global System Semiconductor Companies



Note: Phase 1: 2004–2008; Phase 2: 2009–2013; Phase 3: 2014–2018; Phase 4: 2019–2023
 Source: Author’s calculation using KIWEE DB, Korea Intellectual Property Promotion Agency

TSMC, the global leader in semiconductor foundry services, displays a relatively low TSI across all four periods—ranging from 0.36 to 0.42. This is not a reflection of weak technological capacity but rather a structural outcome of its business model. TSMC focuses on process innovation, yield optimization, and advanced manufacturing nodes (e.g., 3nm, 2nm), rather than chip design. As a pure-play foundry, it operates as a manufacturing partner to fabless firms like Apple, NVIDIA, and AMD. Consequently, its patent activity—and thus TSI—is lower, but its market influence remains unmatched in manufacturing capability.

V. Conclusion and Policy Implications

1 Memory Semiconductor Industry: Competitiveness Trends and Implications

The global memory semiconductor industry remains highly concentrated in a few countries. Korea's trade structure is characterized by a vertical division of labor with most trading partners, with intra-industry trade observed primarily with China, reflecting an integrated supply chain structure between the two countries. Since 2018, the GL index between Korea and China has steadily increased, indicating the expansion of two-way trade, driven by China's growing production capacity in the memory semiconductor sector. While this

deepening trade integration may increase mutual dependence in the short term, it could also pose risks to Korea's export market share in the long term. Korea should therefore respond by strengthening its technological competitiveness, particularly in sectors where supply chain interdependence is intensifying. Korea's trade with Japan has weakened, while trade with the U.S. and Taiwan remains stable or shows only slight increases. The decline in Korea's competitiveness indicators (RSCA, TSI) in the memory semiconductor industry suggests weakening technological leadership, necessitating strategic R&D investment to secure next-generation core technologies. While Korea maintains its global leadership in DRAM, MCP, and NAND flash memory markets, China's localization policies and intensified global competition represent growing structural challenges. Although Samsung Electronics and SK Hynix hold high technological influence, the technology gap with Micron is narrowing, and SanDisk is rapidly increasing its technological influence. In this context, Korean firms must actively respond through increased patent filings and securing of next-generation technologies, particularly in HBM, AI semiconductors, and high-performance DRAM. Furthermore, the U.S. government's policy support for its domestic semiconductor firms will present an additional challenge for Korean companies competing in the global market.

2. System Semiconductor Industry: Competitiveness Trends and Implications

The analysis of competitiveness indices (RSCA, TSI) and technological influence shows that Korea's competitiveness in the system semiconductor sector has generally stagnated or declined. While Taiwan and the U.S. have strengthened or maintained their market positions, Korea's market share has not demonstrated clear growth. Despite Samsung Electronics maintaining a dominant position in patent filings, it lags behind Apple, Qualcomm, and Micron in terms of securing high-impact and innovative patents. Korea must focus on securing advanced technologies such as AI semiconductors, sub-3nm processing, next-generation transistor structures, and strengthening its manufacturing process capabilities. Efforts to enhance Korea's competitiveness should leverage its strengths in advanced manufacturing and memory expertise while narrowing the technology gap in system semiconductors. Given the supply chain vulnerabilities revealed in specific areas such as analog ICs, Korea needs to strengthen alliances with key partners that have competitiveness in these sectors to secure supply chain resilience. Expanding domestic R&D support and fostering companies specializing in analog and mixed-signal semiconductors will be critical. Partnerships with the U.S., Japan, and Taiwan will serve as strategic assets, and Korea should promote intra-industry trade based on mutual investments and industrial cooperation.

3. Building Stronger Supply Chains Through Global Cooperation

Data-driven analysis reveals both strengths and weaknesses in Korea's memory and system semiconductor trade structures. Korea has developed a close trade relationship with China in both sectors, while strategic links with the U.S. and Japan remain weak. A dual-track strategy is necessary—in the short term, Korea should stably manage its China-centered supply chains, while in the medium to long term, strengthening technology cooperation with allied countries is essential. To enhance supply chain resilience, Korea must support the strengthening of its domestic production base and promote the localization of key materials and equipment.

As shown by the GL index and trade intensity analysis, Korea's memory semiconductor industry remains highly dependent on China, with insufficient diversification. Korea must maintain cooperative production channels with China while preparing hedging strategies for scenarios involving reduced exports to China. Given rising geopolitical risks and potential policy changes, it is essential for Korea to pursue market and product diversification strategies, expanding its product portfolio to mitigate trade concentration risks. Although intra-industry trade between Korea and the U.S., Japan, and Taiwan remains limited, these countries are key strategic partners from a geopolitical and supply chain stability perspective. Korea

should actively explore new market opportunities through technology cooperation, standardization efforts, and joint investments with these countries. In particular, to respond to growing demand for advanced semiconductors (AI, HPC), Korea should promote ecosystem synchronization centered on technology collaboration with the U.S. Establishing a global co-production system connecting the U.S. fabless model with Korea's foundry and memory expertise is critical. Korea should differentiate its strength in memory technologies (HBM, CXL, DRAM) by integrating them into AI computing, strengthening its technology alliance with the U.S. in areas such as HBM3/HBM4 and high-bandwidth interface technologies. Strategic small-scale investments in the U.S., such as AI/HPC-focused test lines, design support centers, and packaging R&D hubs, will allow Ko-

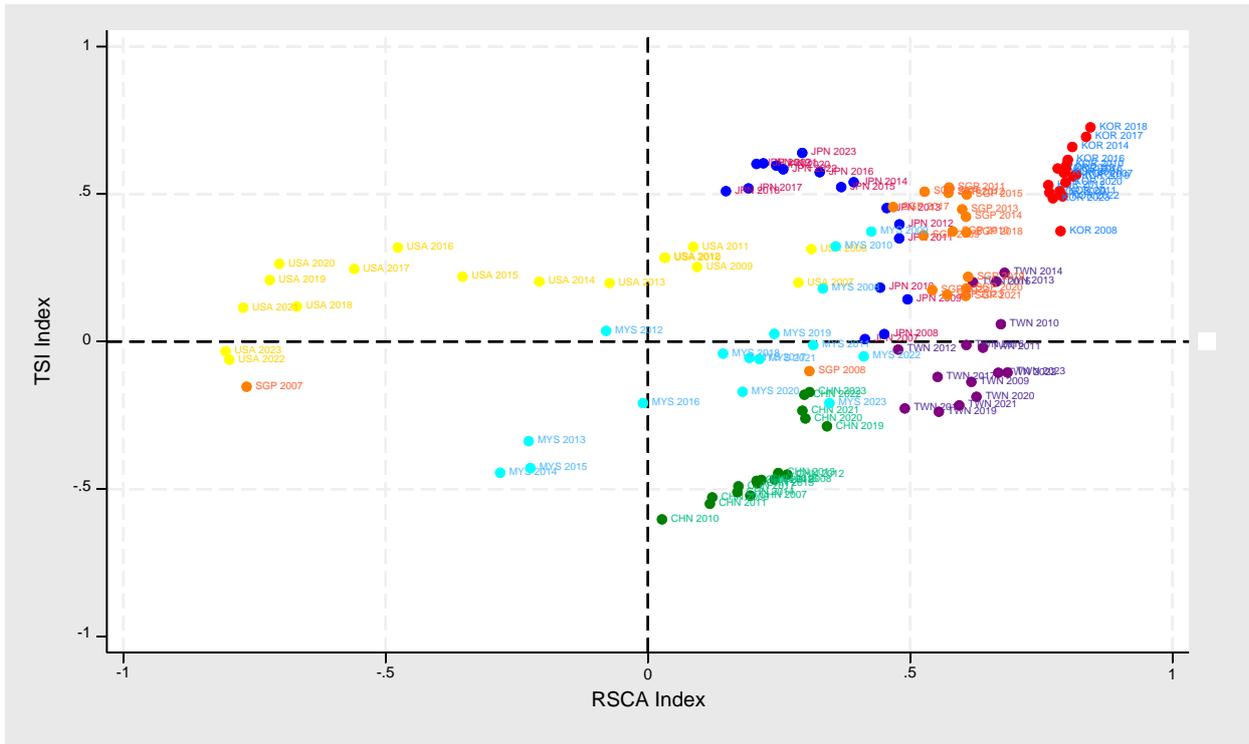
rea to test the market before expanding investments gradually. In the long term, Korea should expand strategic investments to secure global competitiveness in system semiconductors through enhanced patent quality, IP portfolio expansion, and the development of a design house ecosystem. Collaborating with U.S. fabless and IP firms (e.g., NVIDIA, AMD, Intel) through joint development, licensing, and design partnerships will be essential. Through government-level cooperation between Korea and the U.S., supporting joint fabless development programs and building a virtuous cycle of technology collaboration, design integration, test production, customer acquisition, and ecosystem trust will help position Korean firms as indispensable players within the U.S.-led semiconductor supply chain. [KIEP](#)

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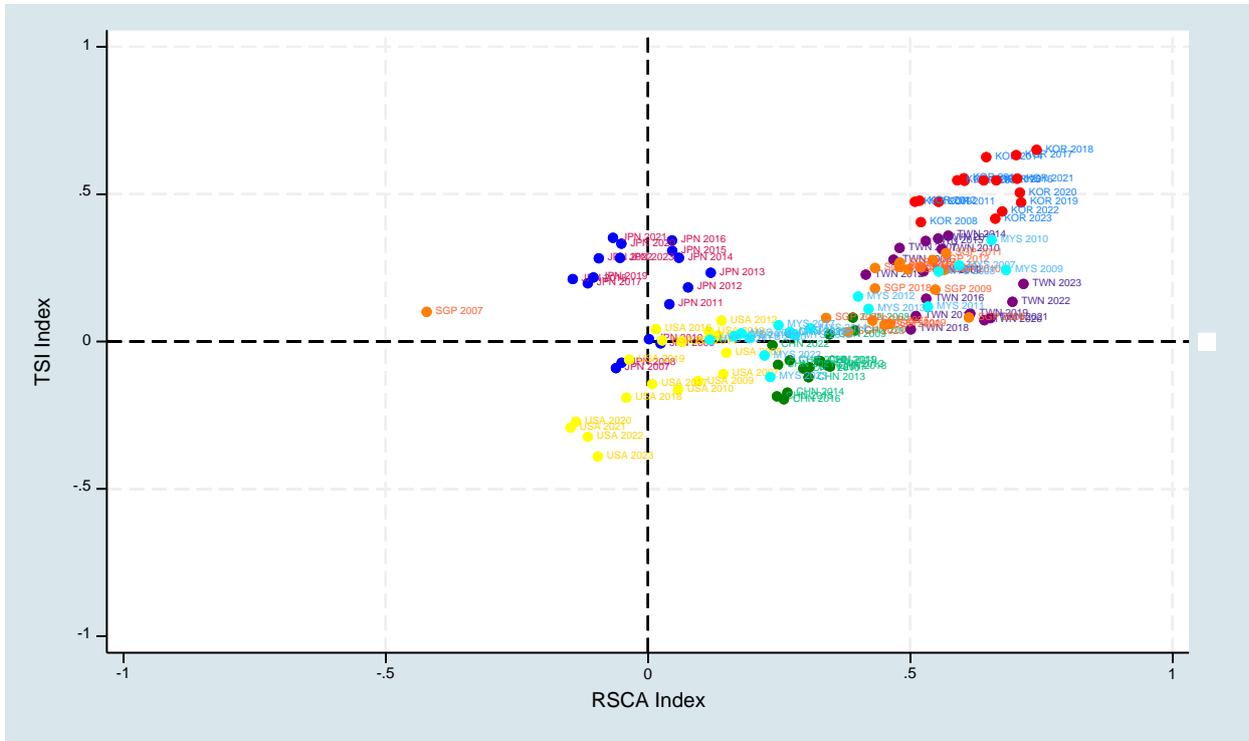
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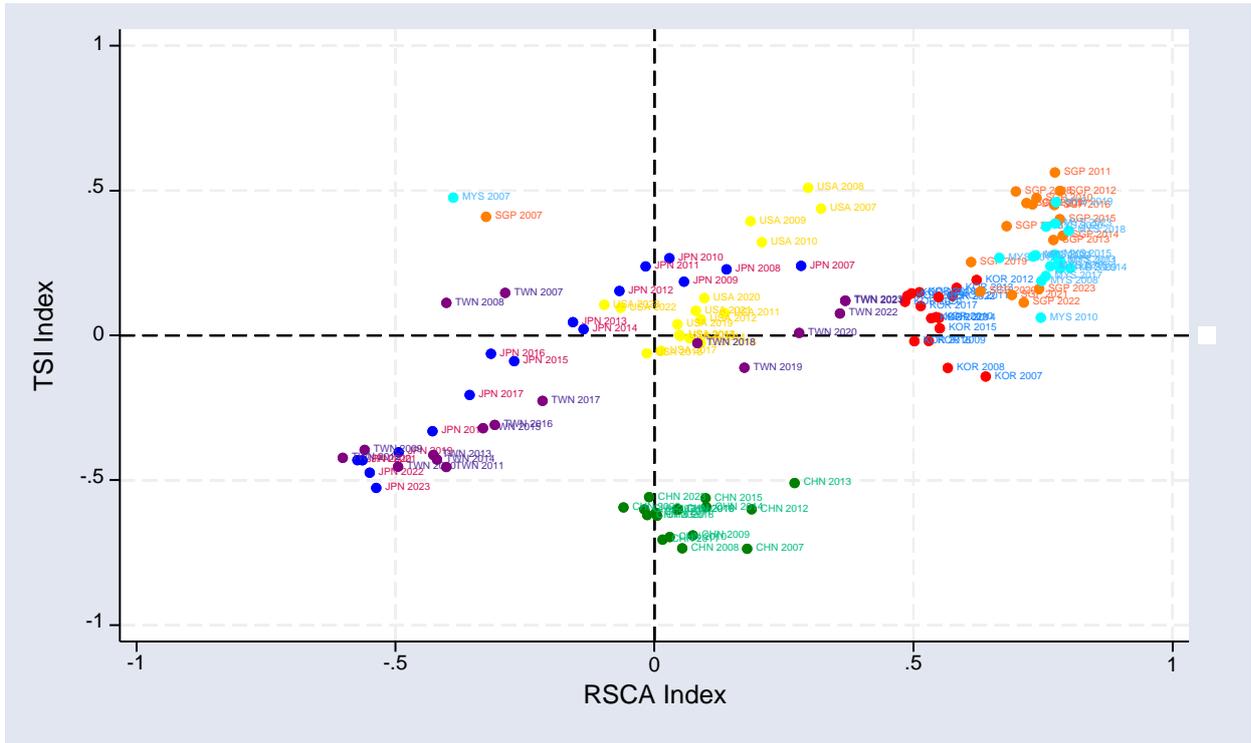
Appendix Figure 1. Trends in Competitiveness of Memory MCP (Multi-Chip Package) and Flash



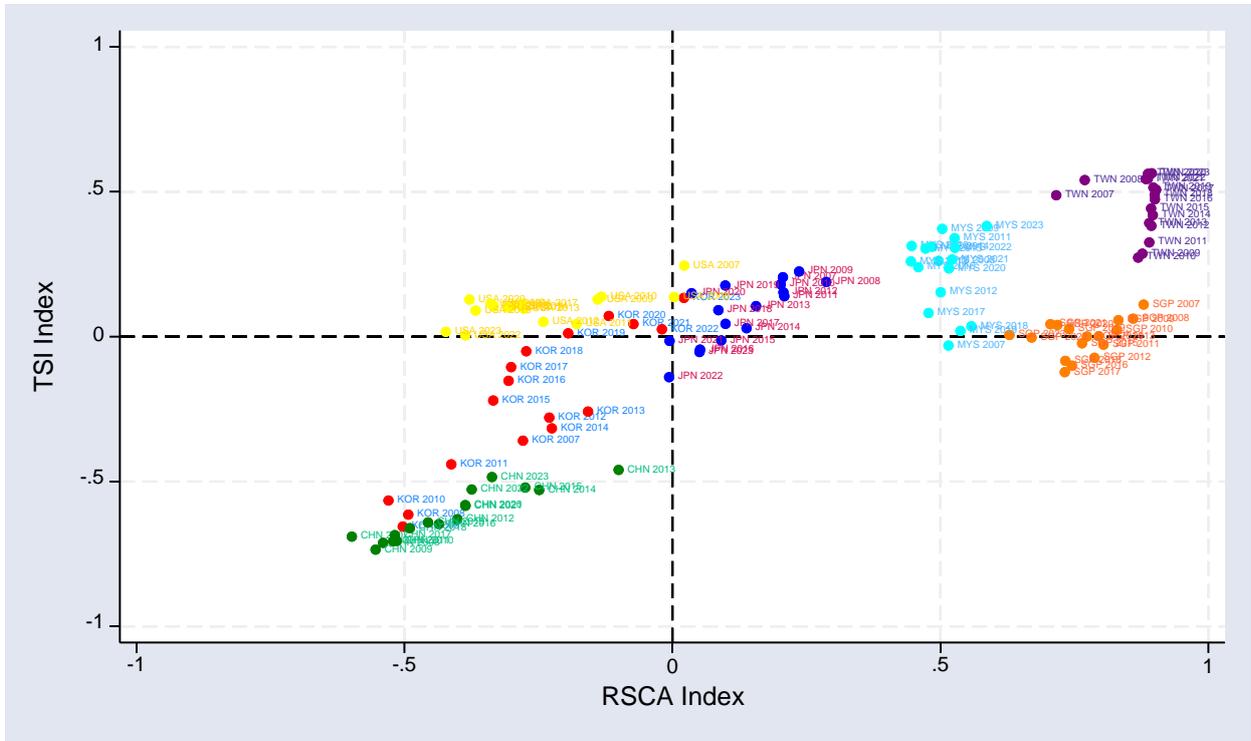
Appendix Figure 2. Trends in DRAM Competitiveness



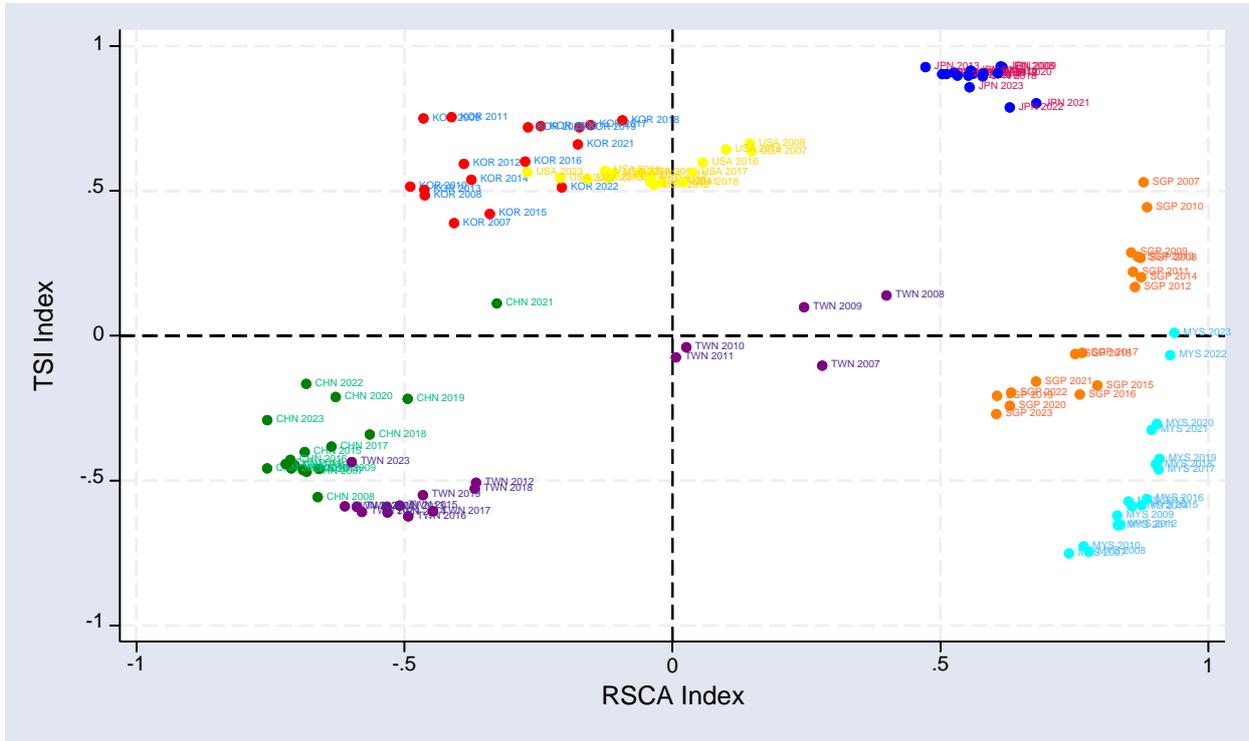
Appendix Figure 3. Competitiveness Trends in Processors & Controllers



Appendix Figure 4. Competitiveness Trends in Application-Specific SoCs



Appendix Figure 5. Competitiveness Trends in Parts and Accessories of Electronic ICs



Appendix Figure 6. Competitiveness Trends in Amplifiers

