Data Brief

Assessing South Korea's AI Ecosystem

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Executive Summary

South Korea plays an important role in the development of critical and emerging technologies and is fast becoming a major player in artificial intelligence. That said, rising regional tensions and demographic trends may hinder South Korea's ability to maintain and expand its competitive advantages in AI. This data brief examines South Korea's progress in AI across five important indicators of development: hardware, patents, investment, research, and talent. Our main findings regarding South Korea's AI ecosystem are as follows:

Hardware

- South Korea is among the handful of countries globally that produce the high-end semiconductor devices needed for AI development. It accounts for a large proportion of the global market share for certain categories of chips that are in high demand, specifically logic and memory chips.

- Semiconductors are the most important export item for the South Korean economy, representing nearly 19 percent of its exports in 2022—the highest of any industry in the country. Almost 60 percent of South Korea's overall chip exports went to China in 2022, worth $66 billion.

AI Patents

- South Korea ranks third globally in the number of AI patents (applications and granted patents) filed between 2010 and 2021. Samsung and LG account for 9 percent of all AI patents granted in South Korea during that time period.

- Similar to global trends, machine learning is the most patented AI-related technique in South Korea; it featured in 77 percent of all Korean AI patents over the past decade. The country also stands out in AI patents related to fields such as energy management, education, and military, all for which South Korea ranks second globally.

AI Investment

- South Korea's AI market is still nascent but rapidly growing. Investments into South Korean AI companies have increased consistently almost every year since 2014. In 2021, $2.76 billion was invested in privately held Korean AI companies.

- South Korean funders are the primary investors in South Korea's AI market, having taken part in nearly 84 percent of the investment transactions targeting Korean AI companies between 2010 and 2021. But foreign investors, particularly from the United States, have been involved in some of the highest value investments in South Korea's AI start-ups and companies over the past decade.

AI Research

- Between 2010 and 2021, South Korean authors published 68,404 AI-related research papers, ranking 11th globally and trailing behind countries with similar levels of development such as Japan and Italy but ahead of other technologically advanced nations such as the Netherlands.

- The United States is South Korea's most important AI research partner, followed by China. Thirty-one percent of AI-relevant papers authored by Korean researchers over the past decade were written with an international coauthor.

Talent

- Relative to population, South Korea produces more engineering graduates than the United States, China, and India. Although the number of graduates in AI-related fields has increased over the past decade, demand for such talent could soon outpace supply.

- Severe gender disparities in AI-related education could undermine South Korea's ability to cultivate and grow its future AI workforce. In 2021, for example, just 12 percent of doctoral graduates in AI-related fields were women.

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Introduction

AlphaGo's defeat of Korean Go champion Lee Sedol in March 2016 is globally regarded as a major milestone in the development of artificial intelligence.[1] In South Korea, then president Park Geun-hye credited this "AlphaGo shock" with persuading the country of "the importance of AI before it is too late."[2] Two days after the historic match, the South Korean government announced plans to invest $863 million (1 trillion won) in artificial intelligence by 2020.[3] The announcement included funding for a high-profile public-private research center with participation from major industry players, including Samsung, LG Electronics, Naver, and Hyundai Motor Company.[4] Subsequent economic plans and tech initiatives included AI development as a key priority, reflecting the government's continued interest in establishing South Korea as a leading power in AI.[5]

Seoul's policy initiatives in AI follow a well-worn playbook for government-led technology adoption. Since the 1962 Five-Year Economic Development Plan, South Korea's state-led development model has emphasized directing resources into the development of industry, technology, and human capital to drive economic growth.[6] As South Korea advanced from a country where labor was mostly concentrated in basic manufacturing to a highly developed industrial hub, government-directed investment in education and research and development in science and technology created a connected, highly skilled workforce with high rates of digital literacy.[7] In the process, the government strengthened its support of the chaebol—family led industrial conglomerates such as Samsung and SK Group—shielding them from competition while pushing them to invest heavily in R&D.[8]

Today, South Korea spends nearly 5 percent of its gross domestic product on R&D, second only to Israel and ahead of the United States, which spends 3.5 percent.[9] While not without its own shortcomings, South Korea's model of close collaboration and coordination between the government, industry, and academia has helped it leapfrog other larger and more technologically advanced countries to become a global leader in information and communications technologies (ICT), industrial robotics, and chipmaking, among other technologies.[10]

South Korean policymakers see AI at the center of the Fourth Industrial Revolution that could transform the country's economy and society.[11] In 2019, then President Moon Jae-in underlined that if South Korea can "link AI primarily with the sectors in which we've accumulated extensive experience and competitiveness, such as manufacturing and semiconductors, we will be able to give birth to the smartest yet most humanlike artificial intelligence."[12] South Korea's 2019 National AI Strategy aims to make it the world's third most digitally competitive country by 2030 as per the International Institute for Management Development World Digital Competitiveness Ranking, where it ranked tenth at the time.[13] President Yoon Suk-yeol has reaffirmed that AI development is integral to South Korea's long-term economic and strategic aspirations, and he reiterated the promise to raise South Korea's AI competitiveness to third place globally.[14]

To achieve these goals, the Korean government has taken a leading role in supporting both research and industry in key emerging technology sectors. Korean policymakers have facilitated the creation of a favorable regulatory environment for firms, introducing regulatory sandboxes with an "approve first, regulate later" position in selected high-tech industries.[15] In 2020, the government launched the Digital New Deal, redirecting state funds to support AI research and development.[16] South Korea's most recent R&D budgets earmarked $1.8 billion (2.4 trillion won) for development of strategic technologies like AI, biopharmaceuticals, aerospace, robotics, and cybersecurity. Major corporations like Samsung and LG are also investing heavily in AI R&D, both domestically and internationally.[17] With funding from the government, 10 leading South Korean universities now offer AI graduate programs, with further plans to increase state support for AI education at both the undergraduate and graduate levels.[18]

The South Korean government has also demonstrated its commitment to developing the country's AI infrastructure, especially in data. In the aforementioned Digital New Deal, for example, South Korea pledged to create a "data dam" of quality data acquired and held by the government with which companies can train AI systems.[19] Various government agencies are tasked with the collection of data to provide services to benefit the general public as well as meet the needs of the private sector.[20] By making it easier for companies and research institutions to acquire data, policymakers hope to create an innovation environment more conducive for AI development. Seoul has also recently committed to supporting the country's cloud computing sector.[21] While these nascent initiatives hold promise, the ultimate impact they will have on AI development remains uncertain.

South Korea faces several obstacles to meeting its goals in AI. Intensifying strategic competition between the United States and China may adversely impact South Korea's economic interests. Deep trade and technology linkages with a few important partners have propelled South Korea's economic growth but may also make the country more vulnerable to geopolitical upheaval and economic coercion. Finally, South Korea's aging population and declining birth rate will shrink the available labor force while forcing the government to commit more resources toward welfare and social spending to support the elderly.[22]

Against this backdrop, this report assesses South Korea's AI ecosystem by evaluating five indicators pertinent to AI development: hardware, patents, investment, research, and talent. As the following sections elaborate, South Korea excels in semiconductor manufacturing and AI patent production. The AI investment market is growing but remains nascent. South Korea's AI research output is largely on par with peer nations, and the United States is its top AI research partner. Although the number of graduates in AI-relevant fields has grown over the past decade, rising demand from the tech sector could soon outpace supply. What's more, the country has struggled to attract tech talent from abroad and mitigate gender imbalances in AI-relevant academic fields. The last section of the report reflects on challenges and opportunities ahead for South Korea's AI ecosystem, highlighting prospects for U.S.-South Korea collaboration.

Hardware

Today, much of the progress in AI relies on enormous amounts of computational power, which is enabled by computer chips that in turn rely on advanced semiconductors.[23] In short, semiconductors facilitate AI innovation and represent a critical strength in AI for any country. Semiconductor production relies on a complex and globalized supply chain, which, at a high level, includes design and manufacturing, as well as assembly, testing, and packaging.[24]

South Korea is a key player in the semiconductor supply chain. In 2021, Korean companies accounted for 16 percent of the total value added in the global semiconductor supply chain, second only to the United States.[25] Furthermore, South Korea excels in certain critical domains, such as in the production of leading-edge logic and memory chips. Semiconductor exports are a crucial driver of the country's economic growth. China is by far the largest destination for South Korean chip exports, reflecting in part the enormous investments that Korean chipmakers have made into production facilities located in China.

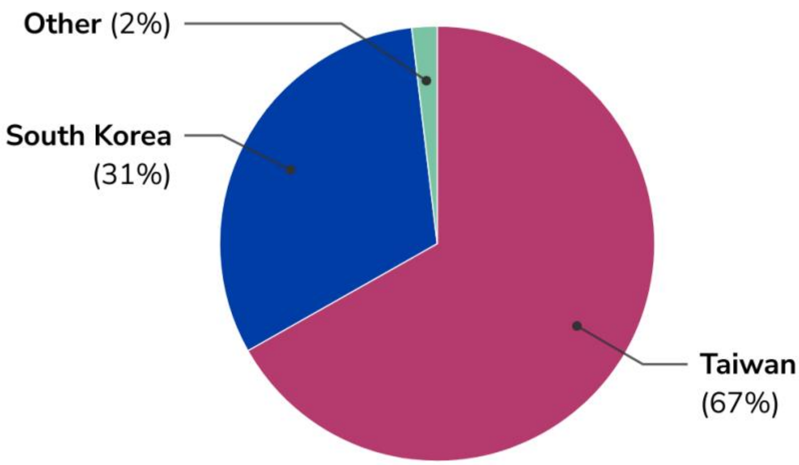
Production

South Korean companies are vital to the production segment of the semiconductor supply chain. They are among a handful of companies—the rest of which are almost all located in China, Germany, Japan, the Netherlands, Taiwan, the United Kingdom, or the United States—responsible for most of the world's semiconductor design, fabrication, assembly, testing, and packaging. South Korean companies are the leading manufacturers of the types of chips required for the development and deployment of AI: leading-edge logic and memory chips. In 2019, logic and memory chips accounted for 57 percent of the total revenue of semiconductor devices worldwide.[26] Together, these devices are forecasted by the Semiconductor Industry Association to account for 90 percent of the growth in the semiconductor industry over the next decade.[27]

Logic chips

Logic chips—which include central processing units (CPUs) and other microprocessors, microcontrollers, digital signal processors, graphics processing units (GPUs), and field-programmable gate arrays (FPGAs)—are used for performing calculations on digital information.[28] Their capabilities hinge upon the design and size of their transistors—that is, the basic elements that allow computers to perform calculations. High density and smaller transistor sizes are essential for computer systems that require costeffective and fast computational operations, making these chips paramount for powering cutting-edge AI algorithms.[29] Today, the leading-edge logic chips have transistors that measure only 3 nanometers.[30]

Figure 1. Leading-Edge (4–5 nm) Logic Capacity by Location, 2021



Source: World Fab Forecast.[31]

Only two firms worldwide can fabricate commercially viable leading-edge (5 nm and below) logic chips: Taiwan's TSMC, which accounts for 67 percent of the leading-edge logic chip capacity and South Korea's Samsung, which contributes 31 percent (Figure 1).[32] Intel is the only other company with plans to produce 5 nm node chips commercially over the next several years.[33]

Memory chips

Memory chips store the digital data on which logic devices perform calculations. There are two predominant types of memory chips, which together comprise 98 percent of the memory chip market: dynamic random access memory (DRAM), which temporarily stores data while a computer operates, and NAND flash memory, which stores data permanently.[34] As Table 1 illustrates, global memory chip manufacturing capacity is highly concentrated in northeast Asia.

Table 1. Total DRAM and NAND Flash Capacity by Country/Region, 2021

Capacity in 200 mm equivalent Wafers per Month

Country/region	DRAM capacity (wafers/month)	Share of global DRAM capacity	NAND flash capacity (wafers/month)	Share of global NAND flash capacity
South Korea	1,984,500	50.3%	1,469,250	27.1%
Taiwan	951,750	24.1%	205,500	3.8%
China	708,750	18.0%	1,044,000	19.3%
Japan	243,000	6.2%	1,884,375	34.8%
United States	58,500	1.5%	231,750	4.3%

Source: World Fab Forecast.[35]

South Korea is the world's largest producer of memory chips. As Table 1 shows, half of global DRAM capacity is based in South Korea, led by Samsung and SK Hynix. The only other major player in this sector is the U.S. firm Micron Technology, whose advanced DRAM capacity is mostly located in Japan and Taiwan.[36] Through September 2022, Samsung, SK Hynix, and Micron made up close to 96 percent of all DRAM revenues. See Figure A1 in the Appendix for each company's yearly share of global DRAM revenues between 2014 to 2022.

In NAND flash memory, as Table 1 shows, fabrication facilities located in Japan account for almost 35 percent of the global capacity. This is closely followed by facilities in South Korea, which account for 27 percent of global capacity. Overall, five firms—Samsung, SK Hynix, Western Digital, Kioxia, and Micron—make up over 90 percent of global NAND revenue. Figure A2 in the Appendix shows each firm's annual share of global NAND revenues.

Nearly 20 percent of global DRAM and NAND manufacturing capacity is located in China. This is in part a reflection of the tens of billions of dollars that SK Hynix and Samsung have invested into their respective memory-chip production facilities located in China.[37] SK Hynix's factory in Wuxi, for example, reportedly accounts for 48 percent of the company's DRAM chip production.[38] Samsung's plant in Xi'an is responsible for around 40 percent of its NAND chip production.[39]

Although South Korea currently leads in the production of memory chips, competitors could challenge Korean firms' preeminence in the market. Memory chips are easier to produce than logic chips and have been relatively commoditized; correspondingly, manufacturers mostly compete on price.[40] Samsung's market share, for instance, has declined from its 2016 peak, when it held almost half of the world's market share in DRAM. In 2022, Samsung accounted for 43 percent of global DRAM revenues. Meanwhile, Micron has grown its market share from 11 percent in 2011 to almost a quarter of the global DRAM market in 2022.[41] China is also allocating enormous state resources to buttress its semiconductor manufacturing sector.[42] China's memory-chip industry is expected to grow rapidly over the next decade as Chinese chipmakers expand their domestic capacity to manufacture mature-node memory chips.[43] That said, U.S.-led efforts to limit China's access to advanced semiconductor technologies could impede Chinese chipmakers' ability to challenge industry leaders like South Korea in the manufacture of advanced node chips, at least in the near future.[44]

Export

Semiconductors are an essential export item for South Korea that both bolsters the Korean economy and supplies the global chip market.[45] In 2022, semiconductors accounted for nearly 19 percent of South Korea's exports—more than any other industry in the country.[46] Semiconductors are also South Korea's fastest growing export industry.[47]

As Table 2 indicates, in 2022, almost 59 percent of South Korea's overall chip exports, worth $65 billion, went to China. Between 2003 and 2010, China's share of South Korea's chip exports grew from 22 percent to 55 percent (see Figure A3 in the Appendix). Importantly, fabricated chips manufactured by South Korean chipmakers that are then exported to China for final assembly, testing, and packaging account for a sizable portion of these exports, which are then re-exported to end users in other countries.[48] While the export data presented here can shed light on semiconductor supply-chain linkages, it should not be interpreted as a measure of supply-chain reliance or market dependence.

Table 2. Percent of Overall Chip Exports from South Korea by Top Destinations, 2022

Destination	Trade value (millions USD)	Share of total export value
China	65,982	58.5%
Vietnam	15,471	13.7%
Taiwan	11,793	10.5%
Singapore	5,541	4.9%
Philippines	3,611	3.2%
India	2,223	2.0%
United States	1,286	1.1%
Brazil	982	0.9%
Japan	948	0.8%

Source: Korea Customs and Trade Development Institute via International Trade Centre.

Table 3 below disaggregates the overall chip exports between logic chips and memory chips. In 2022, China accounted for nearly 46 percent of South Korea's $38 billion in logic chip exports and 72 percent of its $62 billion in memory chip exports. Still, as China is South Korea's largest trade partner and the world's largest consumer of semiconductors, its share of Korean chip exports is not necessarily surprising.

Table 3. Percent Of Logic and Memory Chip Exports from South Korea by Top Destination, 2022

LOGIC			MEMORY		
Destination	Trade value (millions USD)	Share of total export value	Destination	Trade value (millions USD)	Share of total export value
China	17,550	45.7%	China	44,180	71.5%
Vietnam	5,973	15.6%	Vietnam	6,952	11.3%
Singapore	5,216	13.6%	Taiwan	4,053	6.6%
Taiwan	3,911	10.2%	Philippines	2,676	4.3%
Malaysia	1,174	3.1%	India	1,059	1.7%
India	954	2.5%	United States	569	0.9%
Philippines	822	2.1%	Brazil	504	0.8%
United States	631	1.6%	Japan	394	0.6%
Japan	457	1.2%	Indonesia	261	0.4%
Brazil	390	1.0%	Thailand	211	0.3%

Source: Korea Customs and Trade Development Institute via International Trade Centre.

Note: This table only shows exports of logic and memory chips, and excludes other categories of chip exports.

In recent years, some of South Korea's largest industry groups, such as the Korea International Trade Association and the Korean Chamber of Commerce and Industry, have raised concerns that Korean chipmakers' supply-chain linkages with China represent a potential vulnerability for the country amid growing geopolitical tensions.[49] Indeed, South Korea is no stranger to Chinese economic coercion.[50] In 2016 and 2017, in response to Seoul's deployment of the Terminal High Altitude Area Defense (THAAD), an American-made antiballistic missile defense system, China boycotted the purchase of South Korean products across several important sectors.[51]

At the same time, China using semiconductors as a tool of economic coercion would be a costly exercise. Despite efforts to develop its domestic semiconductor industry, China continues to be reliant on chips manufactured abroad, especially high-end chips.[52] In March, the Cyberspace Administration of China launched a national security review of Micron, an action that was largely seen as a response to the export controls previously announced by the United States.[53] If Beijing were to implement controls on Micron and

South Korea's chipmakers, it would almost certainly impact China's own ability to procure memory devices, at least in the near term.[54]

Moreover, South Korean chipmakers have demonstrated resilience amid disruptions to the semiconductor supply chain. For example, following Japan's 2019 restrictions on South Korea's access to three chemical inputs essential to the semiconductor production process, South Korean chipmaking companies diversified their sourcing for the restricted chemicals and have been able to maintain their global competitiveness.[55] Ukraine and Russia produce a large portion of the world's rare gasses, such as neon, krypton, and xenon, which are essential for chipmaking. Despite worries of "severe disruptions" to the semiconductor supply chain after Russia's full-scale invasion of Ukraine, South Korean chipmakers have been able to source these rare gasses from domestic suppliers.[56] In recent years, the South Korean government has prioritized identifying potential risks to its supply chains and has announced various measures to promote domestic production of key products.[57] In sum, South Korea remains a global leader in the semiconductor industry, and continued growth and innovation in the sector will be vital to ensure the country's competitiveness in AI.

AI Patents

Patents are designed to protect invention and intellectual property and are a useful indicator of innovation and technological progress in a given field or sector. Patents serve as a link between science, technology, and commercial activity, while comparisons of patent activity across different countries can provide insights into areas of competitive advantage in the global competition for tech innovation and leadership. In this section, we analyze data on AI patents filed in South Korea between 2010 and 2021, drawing on the CSET AI patents dataset developed by CSET and 1790 Analytics. Additional information on our methodology is available in previous CSET publications.[58]

South Korea ranks third in the world in the number of both applications for patents and granted patents related to AI over the past decade, with chaebol such as Samsung and LG among the country's top patent producers. Consistent with global trends in AI patents, machine learning is the most commonly patented AI subfield in the country, while South Korea's AI patent production stands out in fields such as emergency management, education, and military.

AI Patent Output

When comparing patent output across different countries, it is important to acknowledge that there is significant variation in patenting laws, the efficiency of patent-granting institutions, and overall patenting cultures. These differences impact how many patent applications are submitted each year, how long it takes to process an application, and what percentage of applications are granted. South Korea has long regarded its patent system as a vital tool in fostering technology development and promoting economic growth.[59] Most recently, the Korean Intellectual Property Office adopted reforms designed to keep pace with innovation in certain sectors, establishing separate criteria for issuing patents in key emerging technologies, including artificial intelligence and biotechnology.[60]

As Table 4 below shows, South Korea ranks third globally in the number of AI patent applications as well as the number of granted AI patents between 2010 and 2021. During this period of time, inventors in South Korea filed 24,178 AI patent applications, while the Korean patent office granted 13,720. Although South Korea's AI patent output lags behind China and the United States, the country's AI patenting activity nonetheless outpaces that of peer and near-peer countries with major investments in research and development, such as Germany, Japan, and the United Kingdom.

Table 4. Top 10 Locations by AI Patent Applications and Granted AI Patents, 2010–2021

Patent Applications		Granted Patents	
Country/region	**Number of patents**	**Country/region**	**Number of patents**
China	242,449	China	63,755
United States	71,841	United States	35,804
South Korea	**24,178**	**South Korea**	**13,720**
Japan	15,136	Japan	7,122
Germany	3,673	Australia	2,152
Australia	3,114	Canada	1,245
Canada	2,835	Germany	1,100
United Kingdom	1,966	United Kingdom	664
France	1,024	France	562
Taiwan	1,000	India	561

Source: CSET AI patents dataset developed by CSET and 1790 Analytics.

A closer look at South Korea's top patent assignees offers interesting insights about the type of entities that filed and were granted patents for their AI-related inventions (see Figure B1 and Figure B2 in the Appendix for details). Samsung is the top AI patent assignee in South Korea, having been granted 700 AI patents, or about 5 percent of all such patents granted in South Korea between 2010 and 2021. LG ranks second overall, having been granted 593 AI patents. Apart from Samsung and LG, the list of top AI patent assignees in South Korea includes other chaebol like Hyundai, SK, POSCO, KT Corporation, and Doosan Group—all of which play a crucial role in South Korea's AI innovation ecosystem.

Aside from these massive tech conglomerates, there are of course other types of institutions and entities that have successfully patented their AI inventions over the past decade. Of the top 100 AI patent assignees in South Korea between 2010 and 2021, 43 were academic institutions, such as the Korea Advanced Institute of Science and Technology and Yonsei University; 38 were companies, which includes chaebol as well as smaller companies; and the rest were research institutes, nonprofits, or government entities, such as the Electronics and Telecommunications Research Institute.

Key Categories of AI Patents

In addition to overall patent output, we examined the distribution of AI patent applications and granted patents across 36 categories that encompass various AI techniques, functional applications, and application fields.[61] Looking at the distribution of patents across these categories can provide insights into R&D priorities and market trends for certain applications of AI. It can also help to identify particular AI subfields where South Korean inventors have a competitive advantage over their counterparts in other countries. Patents may be included in multiple categories. For instance, a particular AI patent can be both a machine learning patent and an education patent.

Table 5. South Korea's Granted AI Patents in Selected Categories, 2010–2021

Category	Number of granted AI patents	Share of South Korea's total granted AI patents	Share of global granted AI patents	Global rank
Machine learning	10,564	77.0%	10.6%	3
Computer vision	3,974	29.0%	9.8%	3
Personal devices and computing	3,682	26.8%	9.5%	3
Telecommunications	2,704	19.7%	12.7%	3
Business	2,294	16.7%	17.4%	3
Energy management	889	6.5%	16.7%	2
Industrial and manufacturing	889	6.5%	16.6%	3
Education	366	2.7%	25.5%	2
Semiconductors	192	1.4%	17.1%	3
Military	31	0.2%	29.0%	2

Note: This table displays the top five AI patent subfields for South Korea by volume of production. The last five rows of the table highlight notable categories where South Korea accounts for a particularly large portion of the global share of patents.

Source: CSET AI patents dataset.

Reflecting global trends, machine learning is the most prevalent category of AI patents in South Korea, featuring in 77 percent of the AI patents granted in the country, as Table 5 shows. Also in line with global trends, computer vision was the second most frequently patented AI category in South Korea, closely followed by the personal devices and computing subfield. Notably, while South Korea is ranked third globally when looking at the overall number of granted AI patents over the past decade, it ranked second in energy management—which is closely linked to the country's semiconductor industry—as well as in education, even though these categories account for a relatively small share of South Korea's total granted AI patents. South Korea also came in second globally in the number of AI patents granted in the military category. Although the number of military patents is merely a fraction of South Korea's total AI patent output, this finding resonates with previous CSET research that showed South Korea ranked fourth globally in military robotics patents granted between 2005 and 2019.[62] South Korea's AI patent applications in selected categories can be seen in Figure B3 in the Appendix.

To sum up, South Korea has a vibrant AI innovation ecosystem that is producing a high volume of AI patent applications and granted AI patents. In recent years, South Korean regulators have focused on modernizing the country's patenting system, lowering patent fees, and supporting small businesses in overseas patent disputes.[63] While large conglomerates are a key source of AI patents, a notable share is also granted to academic and research institutions, with both being vital to the country's AI innovation ecosystem.

AI Investment

South Korea has a thriving commercial market, which has traditionally been dominated by big business groups, most notably the chaebol. Since 2013, however, the government has increasingly provided financial support for the start-up ecosystem, aiming to stimulate job creation and promote innovativeness among small- and medium-size enterprises while continuing to support chaebol innovation.[64]

Our assessment of Crunchbase data indicates that investment in privately held AI companies headquartered in South Korea has grown in recent years, especially since 2018. Domestic investors have powered the expansion of South Korea's AI market, but foreign investors, especially from the United States, have also made high-value investments in Korean AI companies.

Overview of AI Investment in South Korea

As of August 2022, Crunchbase listed about 564 privately held AI companies headquartered in South Korea. For comparison, at that same point in time, the United States had 15,410 AI companies (the most in the world), followed by the United Kingdom with 2,824, India with 2,440, China with 2,026, Japan with 852, and Australia with 610.[65]

Between 2010 and 2021, Korean AI companies raised about $3 billion across 215 investment transactions. Many of the investments tracked by Crunchbase lack publicly disclosed transaction amounts. When including imputed values for non-public transactions, our estimates suggest that South Korea's AI companies raised about $7 billion over the same period of time. The largest investment transaction featured in our dataset was the $1.725 billion acquisition of Hyperconnect, a leading social discovery and video technology company, by the U.S.-based Match Group in 2021.[66]

Nearly 75 percent of the 215 investment transactions targeting South Korea's AI companies entailed early-stage funding—such as pre-seed, seed, angel, and series A funds—when investors tend to put down less capital than in later funding stages. Although there has been a notable increase in both the number of investment transactions and the overall value of deals supplying capital to South Korea's AI start-ups and companies, this sector of Korea's AI ecosystem is still in its early stages.

Assessing AI Investment Activity

Investment into South Korea's AI companies has increased dramatically since 2014, mirroring global trends. Table 6 below presents the yearly number of investment transactions targeting South Korea's AI companies and their respective overall disclosed and estimated values, based on Crunchbase data. Investors are not obligated to share information about the amount of money they put down for a given deal. As a result, Crunchbase data on disclosed investment value can be incomplete and likely underestimates the scale of investments made in a given country's AI companies. As such, we fill in missing transaction values using a multistage estimation process where we impute an estimated value using the median amount for funding rounds of the same investment stage, target country, and year.[67]

Looking at Table 6 below, two points are worth explaining further before continuing to the discussion of AI-related investment trends. First, there is a large discrepancy between disclosed and estimated investment values for the years 2015 and 2019. This stems in large part from the fact that several major investment transactions in these years did not disclose the actual value of investments made. Specifically, disclosed transaction value data is missing for the 2015 acquisition of a speech-recognition tech start-up, Hodoo English, and the 2019 acquisitions of a position-tracking start-up, Polariant, and the machine vision software developer Sualab. The estimated value reported in Table 6 therefore accounts for the fact that acquisitions tend to be high-value deals.

Second, both the disclosed and estimated investment values for 2021 are much higher than any of the figures listed in previous years. This jump is largely the result of the aforementioned $1.725 billion acquisition of the Korean company Hyperconnect by Match Group. Several other investment transactions topped the $100 million mark, making 2021 a hugely successful year for Korea's limited but growing private AI market.

Table 6. Investments into South Korea's AI Companies, 2010–2021

Year	Number of investment transactions	Disclosed investment value (millions USD)	Estimated investment value (millions USD)
2010	0	$0	$0
2011	1	$40*	$40*
2012	4	$32	$32
2013	1	$1	$1
2014	8	$10	$10
2015	10	$13	$892
2016	19	$62	$66
2017	25	$27	$49
2018	35	$137	$146
2019	38	$155	$1,964
2020	37	$176	$207
2021	41	$2,762	$2,787

*We manually confirmed the disclosed value for the investment transaction in 2011, as the transaction value was publicly available but not included in Crunchbase.[68]

Source: CSET analysis of Crunchbase.

In terms of trends over time, as Table 6 indicates, there was a slight dip in investment value (disclosed and estimated) in 2017 compared to the previous year, even as the number of transactions continued to rise. In 2018, there was a fivefold increase in the value of disclosed investments compared to the previous year, and the overall amount of money raised by Korean AI companies has continued to grow since then. In 2020, Korean AI start-ups raised $175 million in investments, with some high-caliber deals such as the $41.8 million pre–series D financing round backed by the state-run Korea Development Bank and others into Riiid, a start-up building AI-based personalized learning for students.[69] Another example from 2020 is the $26 million series C round into a medical AI company called Lunit, led by Asian investors such as Korea's Shinhan Investment and China's Legend Holdings of Lenovo Group.[70]

A closer look at the type of investors active in South Korea's AI market reveals that domestic investors were involved in nearly 84 percent of the transactions targeting South Korean AI companies. Investors often prefer domestic markets over foreign investment opportunities for a number of reasons, such as low cost of doing business, familiarity with regulations, and local networks for information and deal sourcing.[71] A similar pattern—where domestic investors play the most prominent role in their country's AI market—can be seen in China, Japan, the United States, among other countries.[72] Table 7 shows the number of investment transactions, as well as their disclosed and estimated value, that investors from China, Japan, South Korea, the United Kingdom, and the United States made into South Korea's AI companies over the past decade.

Table 7. Investments into South Korean AI companies by Investors' Country, 2010-21

Investor Country → Recipient Country	Number of investment transactions	Disclosed investment value (millions USD)	Estimated investment value (millions USD)
🇺🇸 → 🇰🇷	48	$2,089	$3,862
🇰🇷 → 🇰🇷	180	$1,287	$3,147
🇯🇵 → 🇰🇷	10	$323	$340
🇨🇳 → 🇰🇷	12	$294	$295
🇬🇧 → 🇰🇷	4	$231	$232

Source: CSET analysis of Crunchbase.

While Korean investors took part in the most investment rounds funding Korean AI companies, deals that involved U.S.-based investors brought the most capital into Korea's AI market. That said, more than half of the value in deals that included U.S.-based investors came from the Match Group acquisition of Hyperconnect in 2021. Investors from China, Japan, and the United Kingdom are also among the top foreign investors in South Korea's emerging AI start-ups and companies.

While South Korean investors are active in funding AI start-ups and companies domestically, over the past decade, they have also often gone abroad in pursuit of opportunities in other countries and AI markets. According to Crunchbase data, as Table 8 shows, the United States is the top destination for Korean investors; they have participated in 122 transactions totaling more than $3 billion in funds for American AI companies between 2010 and 2021.

Table 8. Investments into Global AI Companies from Investors Based in South Korea, 2010–2021

Investor Country → Recipient Country	Number of investment transactions	Disclosed investment value (millions USD)	Estimated investment value (millions USD)
🇰🇷 → 🇺🇸	122	$3,457	$3,920
🇰🇷 → 🇨🇳	18	$2,202	$2,202
🇰🇷 → 🇮🇱	21	$342	$358
🇰🇷 → 🇨🇦	4	$262	$262

Source: CSET analysis of Crunchbase.

South Korean investors have also pursued high-value opportunities in China, where they participated in only 18 investment transactions but were part of deals that amounted to more than $2 billion invested in Chinese AI companies. Headlining these deals are SK Hynix's 2019 $600 million investment into the autonomous driving software company Horizon Robotics and, in 2017, a $400 million investment into Megvii, a Chinese image-recognition and deep-learning software company that included among other investors South Korea's second largest chaebol, SK Group.

Over the past decade, it appears that South Korean investors have been part of deals that channeled similar amounts of capital into AI companies based in the United States and China as that invested into domestic AI companies. This is perhaps not surprising given the size of the American and Chinese AI ecosystems. Moreover, as previously mentioned, much of the investment in Korean AI companies takes place during the early stages of pre-seed, seed, angel, and series A funding, where investors tend to put down less capital. Crunchbase data also shows that South Korean investors most frequently invest alongside funders from the United States and, to a lesser extent, from China (see Figure C1 in the Appendix for more details). In these transactions, South Korean investors can leverage the local expertise and networks of their American and Chinese investment partners to better take advantage of business opportunities in those countries.[73]

Overall, South Korea's private equity and venture capital AI investment ecosystem is still nascent but growing rapidly, with 2021 being a particularly successful year. The Korean government has announced plans to increase support for small- and medium-size enterprises in the tech sector, Korean investors are funding promising AI companies in their country, and foreign investors, especially from the United States, appear keen to invest as well. At the same time, Korean investors view the strong U.S. AI market as a priority destination for investment. Going forward, there is much to gain from deepening technological collaboration and strengthening AI-related investment ties between South Korea and the United States, a topic we elaborate on in the conclusion of this report.

AI Research

Academic research drives innovations in AI and contributes to advancements made in a variety of industries and sectors, including biotechnology, manufacturing, ICT, and national security.[74] In this section we analyze South Korea's AI research output between 2010 and 2021, examine the impact and influence of the country's AI publications as proxied by paper citations and participation in top AI conferences, review the top AI subfields South Korean researchers are focusing on, and assess patterns of international research collaboration.[75] Overall, South Korea's AI research output over the past decade has placed it right outside of the top 10 locations with the most AI publications globally, trailing behind countries with comparable levels of development like Japan and Italy but ahead of other technologically advanced counterparts such as Taiwan and the Netherlands.

AI Research Output

Our analysis of South Korea's AI research output draws on the CSET merged corpus of scholarly literature, which includes Digital Science Dimensions, Clarivate's Web of Science, Microsoft Academic Graph, China National Knowledge Infrastructure, arXiv, and Papers With Code. Between 2010 and 2021, we identified 68,404 AI papers that listed one or more South Korean authors. Table 9 presents the top 15 countries/regions by production of AI-relevant scholarly papers over the past decade, where South Korea ranks 11th, ahead of the Netherlands, Spain, and Taiwan but behind Australia, Canada, and Italy.

Table 9. Top 15 Producers of AI Publications, 2010–2021

Country/region	Number of AI publications
China	745,604
United States	466,758
India	159,357
United Kingdom	131,823
Germany	120,544
Japan	116,714
France	87,743
Australia	77,108
Canada	75,736
Italy	74,442
South Korea	**68,404**
Spain	64,388
Taiwan	39,680
Netherlands	38,776
Brazil	37,926

Source: CSET merged corpus.

Because overall research output is not necessarily an indicator of influential work or meaningful contribution to progress in AI research, we also consider citations of AI papers and the number of AI papers accepted to top computer science conferences (for additional details, see Figure D1 and Figure D2 in the Appendix). Between 2010 and 2021, AI publications written by researchers and scholars from South Korea were cited 771,947 times. South Korea ranked 14th globally in the number of citations of AI-relevant papers, behind the Netherlands, Spain, and Switzerland—countries that otherwise trail South Korea in number of publications.

In terms of AI papers accepted at top computer science conferences between 2016 and 2021, South Korea ranked 12th globally, ahead of India, which is a top producer of AI-related papers, as well as Italy and the Netherlands, but behind Israel, Singapore, and Switzerland. Notably, last year South Korea was recognized as the third most impactful contributor to the IEEE/CVF Conference on Computer Vision and Pattern

Recognition, the top engineering and computer science conference as ranked by Google Scholar.[76] South Korea also ranked third and fourth in the IEEE/CVF International Conference on Computer Vision and the European Conference on Computer Vision, both highly prestigious conferences.[77]

AI Research Collaboration

International collaborations in AI research can enhance the quality and impact of academic research, allowing researchers to pool resources, share relevant skills and knowledge, and work together to address cross-national challenges.[78]

Thirty-one percent of AI-related papers authored by Korean researchers between 2010 and 2021 featured coauthors from another country. For comparison, 45 percent of the AI-related papers published by U.S.-based researchers during that period were co-authored with counterparts from other countries, while nearly 65 percent of papers published by researchers from the United Kingdom were the result of international collaborations. South Korea's rates of research collaboration in AI were more reminiscent of Taiwan or Japan, where international collaborations accounted for 35 percent and 27 percent of total AI-related papers, respectively. Table 10 shows South Korea's top 10 AI research collaboration partners.

Table 10. South Korea's Top AI Research Collaboration Partners, 2010–2021

Collaborator country	Number of coauthored AI publications	Share of South Korea's total AI publications
United States	8,558	12.5%
China	5,166	7.6%
India	1,564	2.3%
United Kingdom	1,434	2.1%
Pakistan	1,250	1.8%
Australia	1,138	1.7%
Canada	1,077	1.6%
Germany	1,045	1.5%
Japan	947	1.4%
Vietnam	707	1.0%

Source: CSET merged corpus.

Over the past decade, the United States has been South Korea's most frequent partner in AI research. Collaborations with U.S. researchers account for 40 percent of South Korea's internationally coauthored AI papers and over 12 percent of total South Korean AI publications. These results correspond with previous CSET research on collaboration between the Quad countries, which showed that AI researchers from Australia, India, and Japan most often collaborate with counterparts from the United States as well.[79]

China is also an important research partner for South Korea, as nearly 25 percent of South Korea's internationally coauthored AI papers and almost 8 percent of all South Korean AI publications were written with Chinese coauthors. China, notably, is also a key AI research partner for the Quad countries. Between 2010 and 2020, nearly 17 percent of America's internationally coauthored AI papers were written with Chinese counterparts, while collaboration with Chinese researchers accounted for 16 percent of Japan's, 12 percent of Australia's, and 5 percent of India's internationally coauthored AI papers.[80]

AI Research Subfields

Alongside overall research output, research quality indicators, and international collaboration patterns, it is worth paying attention to the specific areas of focus AI researchers in South Korea are exploring in their publications. As Table 11 shows, machine learning, computer vision, and data science are among the top AI fields in which Korean researchers tend to publish, which is consistent with global publication trends. While South Korea ranks 11th globally in overall AI research output between 2010 and 2021, it ranked fifth in the world in AI-related research on computer networks and sixth in automotive engineering.

Table 11. South Korea’s AI Research Publications: Key Fields of Study, 2010–2021

Field	Number of papers	Global rank
Machine learning	7,419	10
Optics	3,762	8
Computer vision	3,621	7
Data science	2,748	9
Automotive engineering	2,254	6
Speech recognition	2,184	8
Algorithm	1,671	7
Pattern recognition	1,640	8
Radiology	1,560	9
Microeconomics	1,509	9
Data mining	1,341	11
Artificial intelligence	1,245	10
Computer network	1,235	5
Theoretical computer science	1,196	12
Database	1,183	12

Source: CSET merged corpus.

Although we are reluctant to draw a direct link between government policy and scholarly research output, it is worth noting that some of South Korea’s AI-related research overlaps with priority areas identified by the South Korean government. Industrial policy programs like the Digital New Deal, for example, have highlighted priority areas such as autonomous driving technology and biotechnology, both sectors that may overlap with South Korea’s AI research output in automotive engineering and radiology, respectively.[81]

As a whole, South Korea is a prolific producer of AI-relevant research, ranking in the top 15 worldwide in terms of overall production of AI-relevant papers, citations, and participation in prestigious computer science conferences over the past decade. South Korea's performance in AI research is generally on par with others in a similar economic bracket, such as Italy, Spain, and Taiwan, albeit lagging behind regional powers such as Japan and global AI research leaders such as the United States and China. South Korea's international collaboration rate is similar to that of others in the region, such as Japan and Taiwan, but notably lower than that of Australia, Canada, the United Kingdom, and the United States. The United States is South Korea's most prolific AI research partner, although researchers from South Korea also often collaborate with counterparts from China.

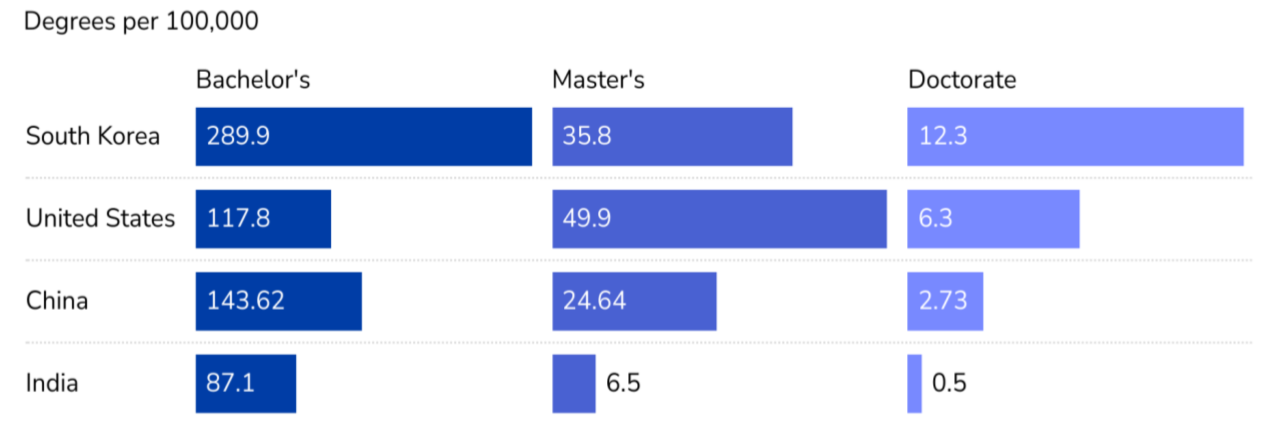
Talent

South Korea's investment in human capital and digital literacy have helped cultivate a skilled workforce.[82] Since 2010, the country has experienced a notable increase in the number of bachelor's and doctoral degree recipients in AI-related fields. Moreover, from a comparative standpoint, South Korea has a higher proportion of students graduating with AI-relevant degrees than countries like China, India, and the United States. That said, demand for high-skilled technical talent could soon outpace supply, and industry leaders are increasingly concerned about the stiff competition for qualified candidates and being able to fill existing and anticipated positions.[83] Despite some policy shifts, South Korea has struggled to attract talent from abroad, while persistent gender imbalances in AI-related fields of study undermine efforts to develop and cultivate the AI-ready workforce of the future. Addressing these workforce challenges over the next decade will be critical if South Korea aims to remain competitive in emerging technologies on the global stage.

Highly Developed AI-Relevant Talent Pool

The South Korean government has consistently invested in science, technology, engineering, and mathematics (STEM) education, which has resulted in a comparatively high share of graduates in these fields and contributed to the development of a highly skilled technical workforce.[84] Consider the field of engineering, for example: as Figure 2 shows, when adjusted for working-age population size (ages 15 to 64), in 2021 South Korea awarded more bachelor's and doctoral degrees in engineering than did China, India, and the United States, as well as more master's degrees than China and India. Figure E1 in the Appendix shows the number of 2021 engineering graduates in each of these four countries.

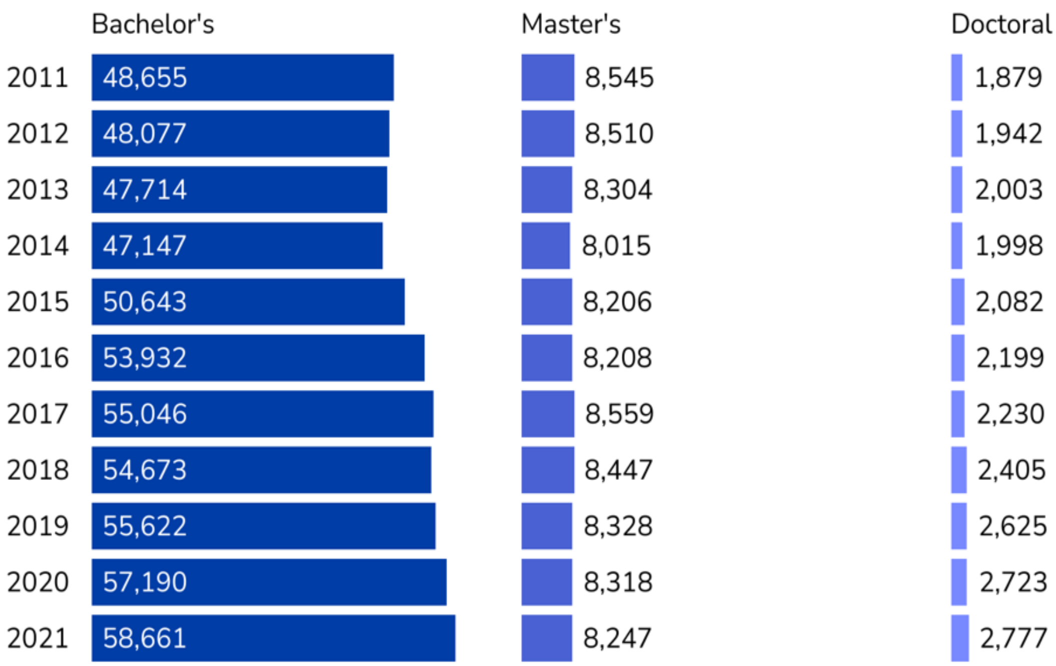
Figure 2. Engineering Graduates per Working-Age Population, 2021



Source: *Statistical Yearbook of Education* (South Korea), All India Survey of Higher Education, Ministry of Education (China), National Center for Education Statistics (United States).[85]

Building on the successful model of government investment in science and technology education and skill development, South Korea has recently announced a number of initiatives that allocate additional resources specifically to cultivating AI talent.[86] Although it is too early to judge the success of these recent government efforts to enhance AI education, we do have data that allows us to assess how the number of graduates in AI-relevant fields of study, such as "computer science and computer engineering" and "information and communication engineering," has evolved over the past decade.[87]

Figure 3. Number of South Korean Graduates in AI-Relevant Fields of Study by Degree, 2011–2021



Source: South Korea *Statistical Yearbook of Education* (2011–2021 editions).

As Figure 3 shows, between 2011 and 2021, the number of bachelor's degree recipients in AI-relevant fields increased by 20 percent, while the number of doctoral degree recipients grew by 47 percent. The number of master's degrees awarded in AI-relevant disciplines, however, has declined over the last decade. By comparison, the United States experienced increases of 61 percent, 66 percent, and 20 percent for bachelor's, master's, and doctoral degrees in STEM, respectively, between 2011 and 2020.[88] Despite the noteworthy upward trajectory in the production of AI-relevant bachelor's and doctoral degrees in South Korea, continued growth is far from guaranteed. Indeed, Korea's Science and Technology Policy Institute projects that the number of graduate students in science and engineering will begin to decline around 2025 due to demographic trends.[89]

Challenges in Attracting and Developing AI Talent

Seoul has begun to recognize the limitations of existing strategies to develop South Korea's workforce amidst the country's demographic challenges. As one South Korean official suggested, the country could address long-term labor force declines by attracting talent from "senior, female, and foreign workers."[90] We evaluate South Korea's ability to attract tech talent from abroad before assessing graduation trends for women in AI-related fields.

When demand for high-skilled labor outpaces the supply of talent, one avenue for expanding the talent pool is to encourage students and workers who previously left to pursue education or employment opportunities elsewhere to return to their home country. Around 50,000 students from South Korea study in China each year, for example.[91] The most recent data from the 2021–2022 academic year shows that 40,755 South Korean students studied in colleges and universities across the United States, with nearly 30 percent of them enrolled in engineering, math, or computer science departments and programs.[92] There is, however, little evidence that students educated abroad return to South Korea at high rates. For instance, 75 percent of South Korean doctoral students who received their degrees from U.S. institutions between 2012 and 2017 indicated they planned to stay in the United States after graduation.[93]

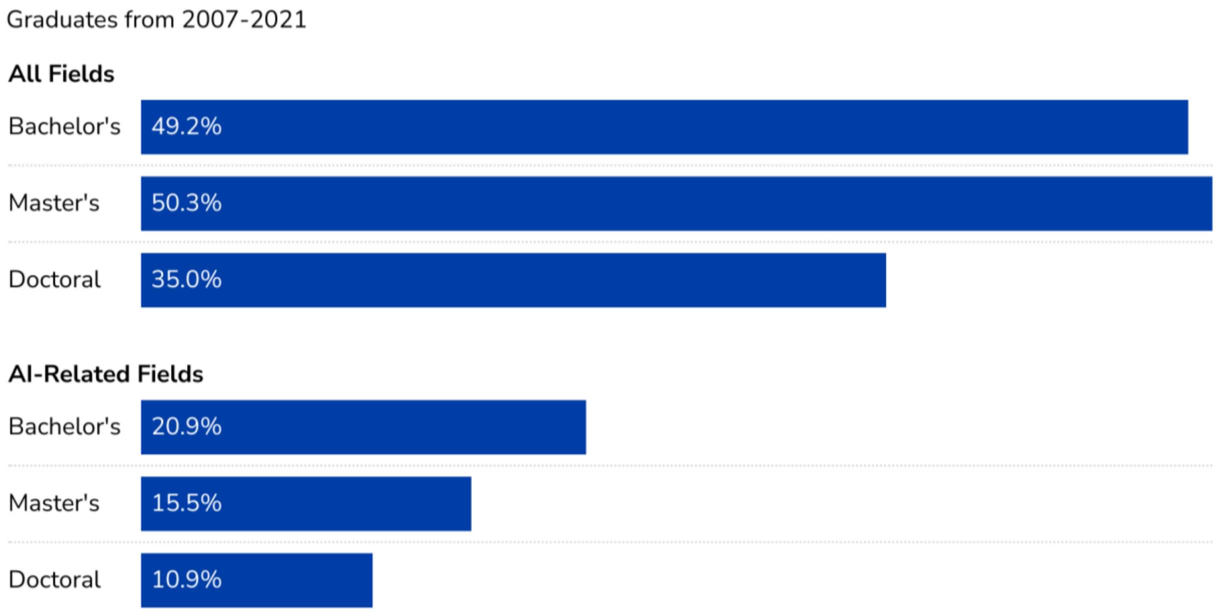
South Korea has also struggled to attract foreign-born talent. In 2015, for example, the government issued just under 20,000 E-7 high-skill work visas. And despite the government's stated interest in attracting more high-skilled talent from abroad, the number of E-7 visas has not surpassed 21,400 in any year since.[94] Indeed, according to the OECD's World Competitiveness Yearbook, South Korea ranked among the less attractive destinations for skilled talent migration among OECD countries.[95] Foreign professionals often face difficult workplace conditions and reportedly have found it challenging to adjust to South Korea's work culture and highly competitive job market. These and other factors may be deterring international tech talent from pursuing career opportunities in South Korea as well as contributing to lower retention rates for these foreign workers.[96]

Disparities in Korea's AI Workforce: Women in AI

Despite the growth in the number of graduates in AI-relevant fields over the past decade, demand for technical talent from South Korea's high-tech industry could soon outpace supply. In addition to the challenges the country has faced in attracting talent from abroad, South Korea's ability to cultivate and grow its future AI workforce is further undermined by severe gender gaps in AI-related fields. For instance, OECD data from 2015 showed that only Japan had worse gender imbalances in science, mathematics, and computing at the doctoral level than South Korea.[97] Similarly, UNESCO reported that very few high-income countries had lower proportions of women in STEM research than South Korea.[98]

Drawing on data from South Korea’s Ministry of Education, Figure 4 shows the proportion of women graduates in AI-related fields compared to the proportion of women graduates in all fields of study. Whereas the number of women who graduated with bachelor’s degrees and master’s degrees across all fields was almost equal to the number of male graduates between 2007 and 2021, there were more than four men graduating with AI-relevant degrees for every woman graduate. During this period of time, nine out of 10 doctoral graduates in AI-relevant fields were men.

Figure 4. Proportion of Women Graduates by Academic Degree in South Korea: All Fields and AI-Related Fields, 2007–2021

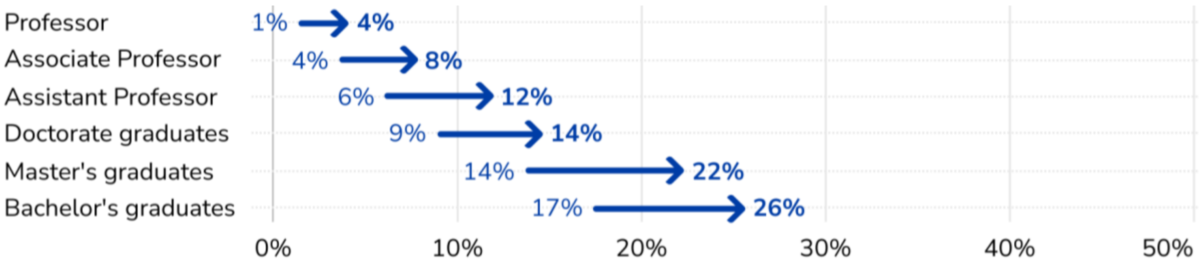


Source: South Korea *Statistical Yearbook of Education* (2007–2021 editions).

When assessing trends over time, South Korea has seen some, albeit limited, improvements in the proportion of women AI graduates. Between 2007 and 2021, the proportion of degrees awarded to women in AI-related fields grew from 20 to 25 percent at the bachelor's level, from 13 to 19 percent for master's degrees, and from 10 to 12 percent for doctoral degrees (for annual data from 2007–2021, see Figure E2 in the Appendix). Although not an exact comparison, these trends are not dissimilar to the growth of women in STEM in the United States, where the proportion of degrees awarded to women in those fields grew from 35 percent to 37 percent for bachelor's degrees, from 31 percent to 36 percent for master's degrees, and held constant at 34 percent for doctoral degrees over a similar period of time.[99]

The persistence of gender imbalances over time and the "leaky pipeline" phenomenon—where women are progressively lost or left out of STEM subjects and careers at each stage of the education system—is clearly illustrated in Figure 5 below, which depicts the change in the percentage of women in engineering degree programs and academic positions in South Korea over a period of 14 years.

Figure 5. Change in Percentage of Women in Engineering between 2007 and 2021 by Academic Degree and Rank in South Korea[100]



Source: South Korea *Statistical Yearbook of Education* (2007 and 2021 editions).

Although the proportion of women in engineering has grown since 2007, the gender gap remains extremely wide at higher levels of academia. As Figure 5 above shows, in 2021, women held only 4 percent of engineering professor positions in South Korea and less than 13 percent of assistant professor and associate professor positions. While our work does not track these imbalances in industry, other studies have shown that Korean women drop out of the labor market after having a child at higher rates than in most OECD countries, indicating that the gender gaps in engineering and other AI-related fields are likely pervasive throughout industry, not just academia.[101]

To sum up, South Korea has a highly developed AI-relevant talent pool and has experienced growth in the number of graduates from AI-related degree programs over the past decade. That said, demand is likely to outpace supply, especially considering that the country is struggling to attract talent from abroad and experiencing significant gender imbalances in both academia and industry. While Seoul is pushing to diversify its technology industrial base, small and medium enterprises have trouble competing with the chaebol for talent and are left with fewer viable candidates to fill vacant positions.[102] At the same time, South Korea's largest companies are in fierce competition with global technology giants such as Alphabet, Alibaba, and TSMC. Korean companies need to be able to cultivate and attract talent in order to maintain their position in the international technology market and continue to fuel innovation. If South Korea is not able to develop new sources of potential AI talent, demographic challenges and increased competition from abroad may dull its competitive edge in emerging technologies.

Conclusion

South Korea plays a key role in the global supply chains for AI chips, is a prolific producer of AI-related patents, has a growing AI investment market, is an important contributor to the global production of AI-relevant research, and has fostered a highly developed AI workforce. At the same time, the country faces challenges. South Korea's supply chain linkages to China make it sensitive to external disruptions from geopolitical volatility. South Korea's AI-relevant research output is lower than that of researchers in some peer countries, and the AI-relevant publications emerging from South Korea are cited less frequently than the work published by researchers in peer nations. Large conglomerates continue to play an outsize role in the production of AI patents, and the country's AI start-up ecosystem is still nascent. Finally, although South Korea has experienced some growth in the number of students graduating from AI-relevant bachelor's and doctoral programs over the past decade, the rise in demand for AI talent may outpace the supply of qualified professionals able to fill technical roles.

Rising regional tensions are putting pressure on the export-led model on which South Korea has long relied to achieve its economic and technological development goals.[103] Indeed, South Korea has already borne the consequences of strained relations with its neighbors. China's punitive economic response to South Korea's decision to deploy THAAD in 2016 resulted in billions of dollars of losses for key Korean industries.[104] In 2019, Japan restricted three important chemical inputs to the semiconductor industry, threatening to disrupt Korea's chip production.[105] Other U.S.-led initiatives that are intended to counter China's advances in emerging technologies, such as the Chip 4 Alliance, could result in further adverse economic consequences for South Korea as a result of potential Chinese retaliation.[106]

On the domestic front, demographic trends pose another challenge for South Korea's ability to meet its goals in AI development and continue leading in emerging technologies. With an aging population, the nation likely faces a future where it may be forced to navigate a shrinking labor force while needing to ensure high labor productivity growth and investment in R&D in order to maintain its role as a leading innovator in emerging technologies.[107] Cultivating new potential sources of AI-ready talent and further developing existing pools of technical workers will be vital to achieve continued innovation in South Korea's AI sector.

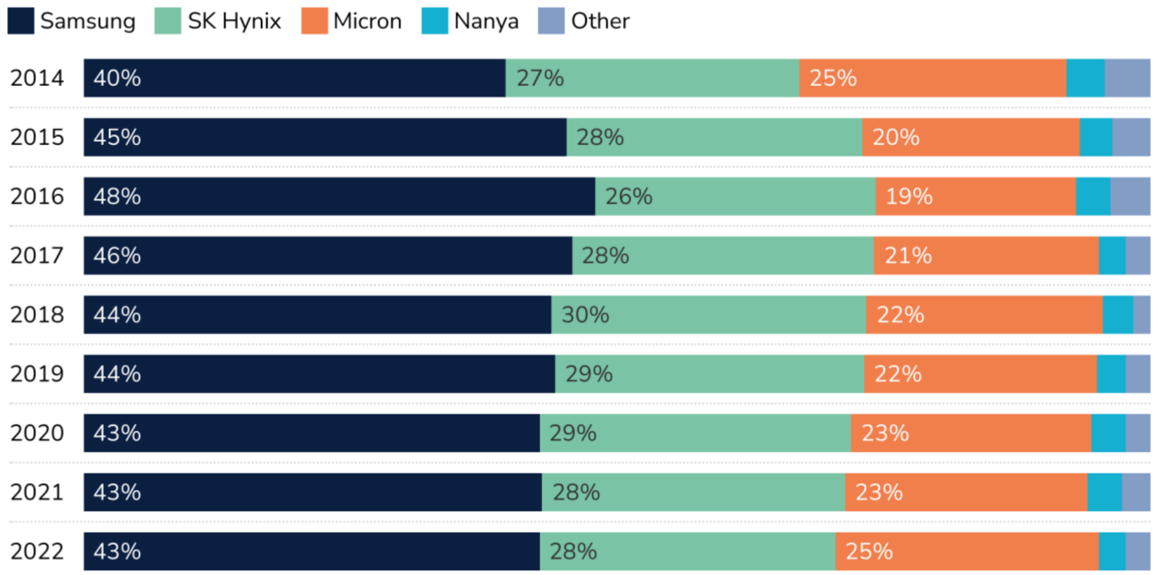
As an important "middle power" with close economic ties to both the United States and China, South Korea will continue to play a crucial role in tech, trade, and security issues in the Asia Pacific region.[108] For the United States, cooperation from Seoul is essential for ensuring the success of the Biden administration's key regional initiatives, including the Indo-Pacific Economic Framework for Prosperity, the Summit for Democracy, and the Chip 4 Alliance.[109] But maintaining the close partnership between the two countries will increasingly require Washington to mitigate how the intensifying competition with China is affecting South Korea's industry, economy, and security.

In the semiconductor space, Washington will need to coordinate closely with South Korean government and industry leaders to minimize the adverse impact that U.S., Dutch, and Japanese export controls may have on Korean firms involved in semiconductor supply chains. Continued policy and financial support for "friendshoring" is one pathway, as seen with Samsung building a new foundry in Texas with the help of nearly $1 billion in state and federal subsidies.[110] Ensuring that South Korea's chipmaking industry has sufficient time to adjust to policy changes is also important for reducing friction, for instance by allowing an extension of the yearlong exemptions granted to several Korean chipmakers operating in China after the export controls were first announced.

The United States and South Korea have a long history of prolific and multifaceted technological cooperation, and there is a strong interest in deepening and broadening collaboration on critical and emerging technologies such as artificial intelligence.[111] While our analysis shows that South Korean AI researchers already collaborate with their U.S.-based counterparts more often than with researchers from any other country, there is still much to be done to promote and expand tech cooperation. Such efforts could include a continuous rotation of high-level experts in critical and emerging technology areas, advancing women's participation in STEM-related sectors, and establishing programs to bolster linkages between American and Korean students, scientists, engineers, and entrepreneurs.[112] Fostering ties between centers of AI innovation in the United States and South Korea will advance both countries' technological, security, and economic interests going forward.

Appendix A: Additional Hardware Figures

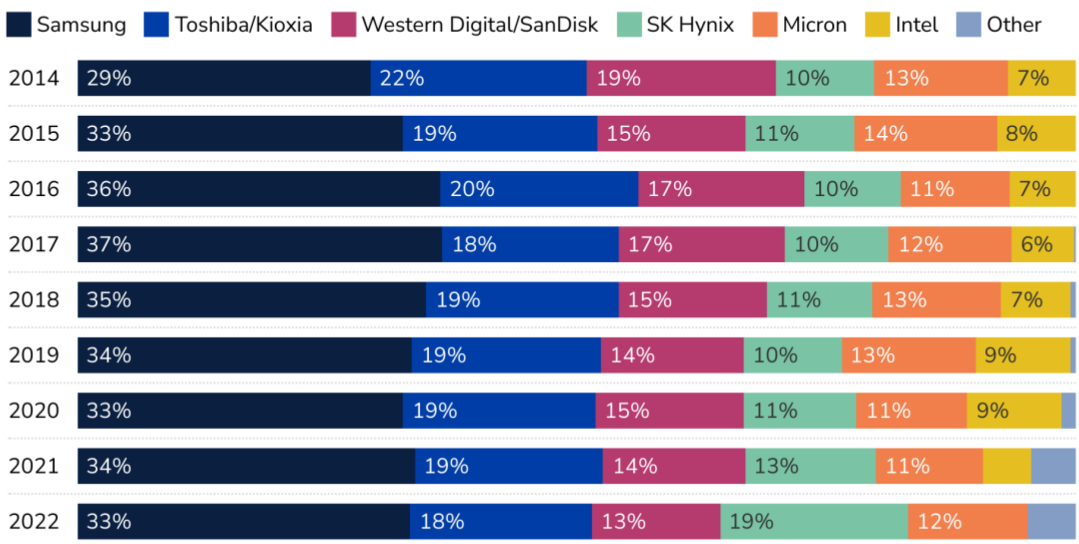
Figure A1. Share of DRAM Revenues by Company, 2014–2021



Note: Data from before 2014 was not sourced from DRAMeXchange and TrendForce, so we have chosen to omit data from 2011–2013. Revenues from Q4 2022 are not included in this data.

Source: DRAMeXchange and TrendForce, via Statista.

Figure A2. Share of NAND Revenues by Company, 2014–2021



Note: Toshiba Memory was rebranded to Kioxia in October 2019. Western Digital acquired SanDisk in May 2016. SanDisk revenues before 2014 were not available, which is why we choose to report figures from 2014–2022. Revenues from Q1 2015 and Q4 2022 are not included in this data.

Source: DRAMeXchange and TrendForce, via Statista.

Figure A3. Share of South Korea Chip Exports by Destination, Selected Destinations, 2003–2022

Year	Total exports (millions USD)	China	Vietnam	Taiwan	Singapore	United States	Japan
2003	$15,469.05	22.4%	0.0%	13.4%	10.5%	15.0%	17.5%
2010	$37,904.49	55.8%	0.2%	11.0%	11.8%	3.4%	7.2%
2011	$39,664.76	54.8%	1.7%	12.4%	11.9%	2.7%	6.4%
2012	$41,346.58	57.9%	5.0%	7.7%	11.7%	2.7%	5.0%
2013	$47,118.83	60.2%	5.4%	7.1%	11.4%	2.5%	2.7%
2014	$51,543.87	64.3%	5.1%	7.2%	8.3%	1.2%	2.1%
2015	$52,174.93	68.9%	5.0%	5.7%	7.2%	0.9%	2.1%
2016	$52,282.68	67.9%	7.8%	5.8%	6.2%	0.9%	1.8%
2017	$86,106.17	70.3%	10.0%	4.7%	3.4%	0.7%	1.0%
2018	$109,782.25	70.9%	9.2%	5.6%	2.3%	1.3%	0.8%
2019	$79,082.28	67.3%	12.4%	5.1%	2.6%	1.6%	0.9%
2020	$82,885.12	66.1%	12.5%	7.1%	2.7%	1.5%	0.8%
2021	$109,297.61	64.6%	11.7%	9.2%	3.1%	1.3%	0.9%
2022	$112,847.16	58.5%	13.7%	10.5%	4.9%	1.1%	0.8%

Source: Korea Customs and Trade Development Institute and UN COMTRADE via International Trade Centre.

Appendix B: Additional Patent Figures

Figure B1. Top Assignees in South Korea by Granted AI Patents, 2010–2021

Assignee	Number of granted AI patents	Assignee type
Samsung	700	Company
LG Corporation	593	Company
Korea Advanced Institute of Science and Technology	447	Education
Yonsei University	299	Education
Hyundai Motors	263	Company
Seoul National University	262	Education
Korea University	224	Education
Electronics and Telecommunications Research Institute	191	Facility
Hanyang University	170	Education
Kia Motors	167	Company
Agency for Defense Development	147	Government
SK Group	120	Company
Naver	119	Company
Inha University	119	Education
Sungkyunkwan University	118	Education

Source: CSET AI patents dataset.

Figure B2. Top 100 AI Patent Assignees by Type, 2010–2021

Assignee type	Number of assignees	Number of granted AI patents
Education	43	3,548
Company	38	3,236
Facility	8	600
Industry-Academy Cooperation	5	192
Government	2	188
Nonprofit	3	149
Healthcare	1	30

Source: CSET AI patents dataset.

Figure B3. South Korea's AI Patent Applications in Selected Categories, 2010–2021

Category	Number of AI patent applications	Share of South Korea's total AI patent applications	Share of global AI patent applications	Global rank
Machine learning	18,295	75.7%	6.0%	3
Computer vision	6,659	27.5%	4.9%	3
Personal devices and computing	6,617	27.4%	6.0%	3
Telecommunications	4,860	20.1%	10.4%	3
Business	4,087	16.9%	9.1%	3
Industrial and manufacturing	1,599	6.6%	11.5%	3
Energy management	1,419	5.9%	8.8%	2
Education	647	2.7%	15.6%	3
Semiconductors	375	1.6%	16.0%	3
Military	37	0.2%	18.6%	3

Source: CSET AI patents dataset.

Appendix C: Additional Investment Figures

Figure C1. Coinvestment with South Korean Investors by Investor Location

Investor location	Number of transactions	Disclosed (millions USD)	Estimated (millions USD)
United States	147	$5,182	$5,209
China	44	$3,329	$3,332
United Kingdom	19	$2,232	$2,232
Canada	9	$1,168	$1,168
Taiwan	9	$1,166	$1,166
Japan	36	$1,034	$1,045
Netherlands	3	$656	$656
Singapore	18	$649	$649
Cayman Islands	5	$477	$477
Russia	1	$460	$460

Source: CSET analysis of Crunchbase.

Appendix D: Additional Research Figures

Figure D1. Top Producers of AI Publications by Number of Citations, 2010–2021

Country	Number of citations
United States	10,945,034
China	7,757,180
United Kingdom	2,868,630
Germany	2,092,698
Canada	1,939,450
Australia	1,715,509
France	1,528,947
Italy	1,279,723
India	1,063,419
Spain	951,486
Japan	905,095
Netherlands	836,258
Switzerland	832,960
Korea	771,947
Israel	711,213

Source: CSET merged corpus.

Figure D2. Top 15 Producers of AI Publications at Top Computer Science Conferences, 2016–2021

Country	Number of AI publications
United States	31,137
China	19,283
United Kingdom	6,717
Australia	4,759
Germany	4,350
Canada	3,430
Israel	2,816
France	2,798
Japan	2,229
Singapore	2,223
Switzerland	2,181
South Korea	2,077
India	2,069
Italy	1,774
Netherlands	1,134

Source: CSET merged corpus.

Note: This table shows AI publications at top computer science conferences. We adopt the top computer science conferences determined by CSRankings.[113] Below is the list of conferences:

- AAAI Conference on Artificial Intelligence
- International Joint Conference on Artificial Intelligence
- IEEE Conference on Computer Vision and Pattern Recognition
- European Conference on Computer Vision
- International Conference on Machine Learning
- International Conference on Knowledge Discovery and Data Mining
- Conference on Neural Information Processing Systems
- Annual Meeting of the Association for Computational Linguistics
- Conference of the North American Chapter of the Association for Computational Linguistics
- Conference on Empirical Methods in Natural Language Processing
- International ACM SIGIR Conference on Research and Development in Information Retrieval
- International World Wide Web Conference

Appendix E: Additional Talent Figures

Figure E1. Engineering Graduates by Degree, 2021

	Bachelor's degrees	Master's degrees	Doctoral degrees
South Korea	107,198	13,226	4,536
China	1,403,297	240,740	26,659
United States	254,472	107,806	13,667
India	828,120	61,538	4,556

Source: South Korea *Statistical Yearbook of Education* (2021 edition), All India Survey of Higher Education, Ministry of Education (China), National Center for Education Statistics (United States).[114]

Figure E2. Proportion of Women Graduates in AI-Related Fields by Degree, South Korea, 2007–2021

Year	Bachelor's	Master's	Doctoral
2007	10.5%	13.0%	20.2%
2008	10.4%	12.7%	18.8%
2009	11.0%	12.9%	18.7%
2010	10.4%	13.1%	18.7%
2011	10.4%	14.0%	19.6%
2012	9.6%	14.1%	19.9%
2013	11.4%	16.3%	19.5%
2014	10.8%	14.9%	19.5%
2015	11.3%	14.8%	20.7%
2016	10.7%	16.4%	21.8%
2017	11.0%	17.0%	21.9%
2018	12.1%	16.9%	21.9%
2019	10.6%	18.1%	22.2%
2020	10.8%	18.3%	23.2%
2021	11.7%	19.4%	24.6%

Source: South Korea *Statistical Yearbook of Education* (2007–2021 editions).

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