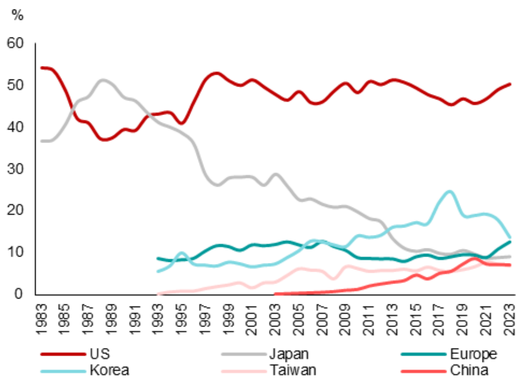
5. Japan's Strategic Comeback in the Global Chip Race [126]

Japan aims to revitalize its semiconductor industry through large government support, international partnerships, and a focus on advanced technologies. However, Japan's chip renaissance faces several obstacles, including rising global competition, technological and financing risks, a lack of trained engineers, high utility costs, and reliance on imported critical raw materials, among others. The government plays a pivotal role in addressing these challenges. Several policy measures are already in place, but effective implementation is crucial for Japan to stage a strategic comeback in the global chip race.

Background

1. **Japan was a global leader in semiconductor production in the 1980s, but is now about a decade behind technology leaders in Korea, Taiwan Province of China, and the U.S.** By the late 1980s, Japanese semiconductor manufacturers had captured more than half of the global semiconductor market, overtaking the U.S. (Figure A5.1). In 1989, six of the top ten semiconductor companies globally were Japanese (Figure A5.2). Japan's state-sponsored Very Large Scale Integration (VLSI) program, launched in 1976, was instrumental in pooling R&D across major semiconductor firms and produced technological breakthroughs, including advances in dynamic random access memory (DRAM) technology. Threatened by Japan's success, the U.S. imposed anti-dumping guarantees, forced Japan to open its market to foreign producers, and applied 100 percent tariffs on Japan's DRAM.[127] Other factors contributing to Japan's semiconductor downfall include the rapid appreciation of the yen after the 1985 Plaza Accord, a failure to invest in logic chips during the personal computer era, the inability of Japanese firms to adapt to a new fabless-foundry model, and increasing competition from then new entrants Korea and Taiwan Province of China. By 2023, Japan's share of global semiconductor sales had declined to less than 10 percent; and at the same time, there were no Japanese companies among the top 10 globally.

Figure A5.1. Share of Global Semiconductor Sales



Source: Semiconductor Industry Association; World Semiconductor Trade Statistics; AMRO staff calculations

Figure A5.2. Top 10 Semiconductor Companies by Revenue

Rank	1989	2023
1	NEC (Japan)	Intel (US)
2	Toshiba (Japan)	Samsung (Korea)
3	Hitachi (Japan)	Qualcomm (US)
4	Motorola (US)	Broadcom (US)
5	Fujitsu (Japan)	NVIDIA (US)
6	Texas Instrument (US)	SK Hynix (Korea)
7	Mitsubishi (Japan)	AMD (US)
8	Intel (US)	STMicro (Switzerland)
9	Matsushita (Japan)	Apple (US)
10	Philips (Netherlands)	Texas Instruments (US)

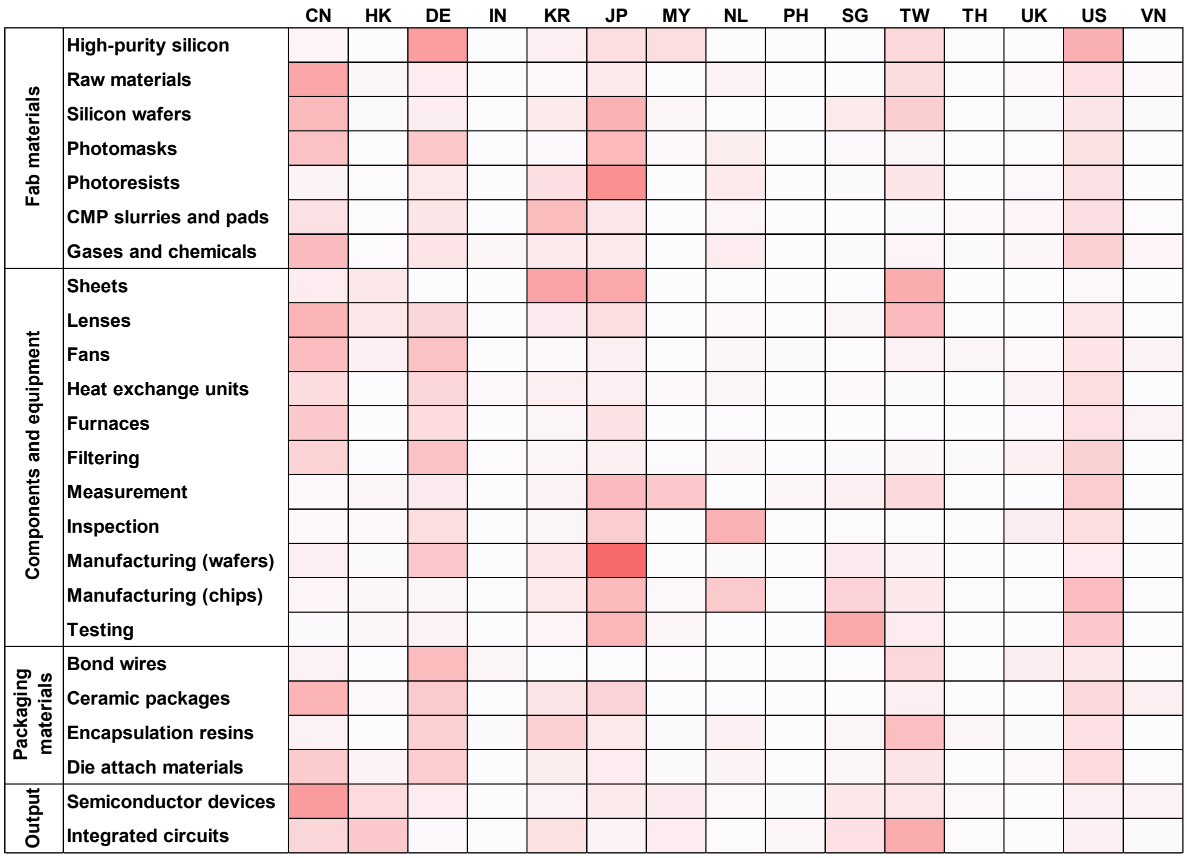
Source: Gartner; IC Insights

2. **However, Japan is still a global leader in other segments of the semiconductor supply chain, particularly manufacturing equipment and materials.** Semiconductor manufacturing involves three main processes, beginning with chip design, fabrication, and finally assembly, test, and packaging (ATP). Each of these processes is a critical component

[126] Prepared by Wee Chian Koh, Economist.
[127] The U.S. accused Japanese semiconductor firms of dumping in the U.S. and other markets, and complained that the U.S. chip industry lacked access to the Japanese market. The 1986 U.S.-Japan Semiconductor Agreement aimed to address these concerns, but a lack of progress led to the U.S. imposing 100 percent tariffs on USD300 million worth of imports from Japan, including semiconductors.

of the semiconductor global value chain.[128] Figure A5.3 shows Japan's key strengths in semiconductor manufacturing equipment and materials. Japanese companies hold a significant 30 percent global market share in manufacturing equipment[129] and about half of the market for semiconductor materials[130]. Japan has managed to retain its global competitiveness in these areas due to several factors. First, firms in the peripheral semiconductor supply chain were not affected by the 1986 U.S.-Japan Semiconductor Agreement and associated trade friction. Second, these firms are committed to technological innovation.[131] Third, Japan's strong industrial base in precision manufacturing, materials science, and high-tech industries offers a foundation for these firms to specialize in niche areas. Fourth, Japan has a strong domestic ecosystem of small- and medium-size suppliers and contractors, and hence a reliable base to source components and parts from. Finally, establishing long-term relationships with major semiconductor foundries, such as TSMC and Samsung, helped foster a secure and stable market that allowed continuous investment in R&D.

Figure A5.3. Export Mapping of the Global Semiconductor Value Chain



Source: S&P Global Trade Atlas; United Nations Comtrade; AMRO staff calculations
Note: CN = China; HK = Hong Kong, China; DE = Germany; IN = India; JP = Japan; KR = Korea; MY = Malaysia; NL = Netherlands; PH = the Philippines; SG = Singapore; TW = Taiwan Province of China; TH = Thailand; UK = United Kingdom; US = United States of America; VN = Vietnam. Data for 2019-2022, normalized by product category. A darker shade represents a larger share of global exports.

[128] Electronic design automation (EDA) software is used to design chips, while core intellectual property (IP) consists of reusable modular designs to allow design firms to license to others. The fabrication process is a complex and intricate series of steps that turns designs into chips, encompassing photolithography, deposition, doping, and etching, among others. Various semiconductor manufacturing equipment and materials are used. ATP involves cutting a finished wafer into separate chips, mounting on a frame with wires to connect the chip to external devices, enclosing in a protective casing, and testing to ensure its operation.
[129] Tokyo Electron and SCREEN have a combined 88 percent market share for coaters/developers and 57 percent share for wafer cleaning equipment. Advantest has a 58 percent market share for testing equipment. The lithography equipment market is dominated by Netherlands' ASML (62 percent), followed by Japan's Canon (31 percent) and Nikon (7 percent).
[130] Shin-Etsu and SUMCO have a combined 53 percent market share for silicon wafers. Shin-Etsu, JSR, Tokyo Ohka Kogyo, and Fujifilm Electronics Materials together command 87 percent of the market for photoresists.
[131] For instance, Tokyo Electron invests significantly in R&D and has more than 22,000 patents.

3. **Supply chain disruptions during the COVID-19 pandemic and intensified U.S.-China tensions have led to a major rethink of the role of semiconductors.** Chip shortages during the pandemic severely affected Japan's sizable automobile industry, which had huge knock-on effects across the entire supply chain, from automotive parts and coating suppliers to car dealerships. Taiwan Province of China is Japan's top chip supplier, accounting for almost 60 percent of Japan's semiconductor imports. Cross-strait relations between China and Taiwan Province of China pose a risk to chip supplies and the electronics industry. At the same time, the U.S., for national security reasons, has been trying to contain China's rapid development of dual-use semiconductors. The U.S. is turning to its allies to keep China's fledging chip industry at bay.[132] Japan is an integral part of this endeavor given its dominance in critical manufacturing equipment and materials. A confluence of economic and geopolitical factors makes this an opportune moment for Japan's semiconductor industry to make a comeback. These include the importance of strengthening supply chain resilience; vulnerabilities associated with relying on semiconductors imports, especially from Taiwan Province of China; Japan's position as an indispensable node in the U.S.-led alliance; and its ambitions of developing emerging technologies such as artificial intelligence, quantum computing, and 5G communications.

New Industrial Policy for Semiconductors

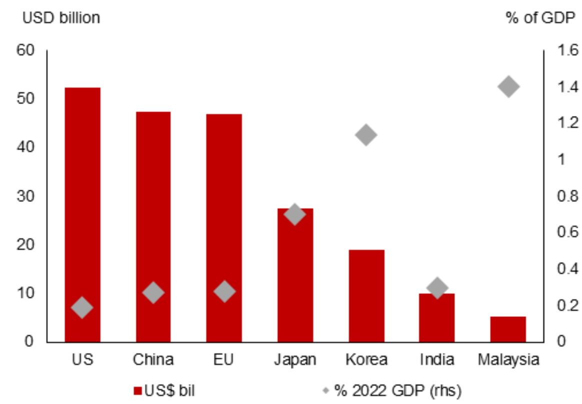
4. **Japan's semiconductor revitalization strategy consists of three steps: (i) strengthening domestic production capacity; (ii) forming alliances with the U.S. on next-generation technology; and (iii) developing game-changing future technology.** The Ministry of Economy, Trade, and Industry (METI) announced a new strategy in June 2021 to revive the semiconductor industry. As part of the first step, Japan Advanced Semiconductor Manufacturing (JASM)—a joint venture between TSMC, Sony, and Denso—has opened a new plant in Kumamoto to produce 12–28 nanometer (nm) logic chips. Construction for a second plant will commence at the end of 2024 with the same partners, plus Toyota, focusing on 6–40nm chips. The second step involves Rapidus, a government-backed startup with a consortium of eight major Japanese companies—Toyota, Sony, Denso, Kioxia, NEC, NTT, Softbank, and Mitsubishi UFJ. Rapidus is collaborating with IBM and IMEC, Europe's leading microelectronics R&D center, to mass-produce 2nm chips by 2027.[133] Also crucial to this step is the establishment of the Leading-Edge Semiconductor Technology Center (LSTC), which spearheads R&D while Rapidus handles production. In the third step, Japan aims to produce game-changing technology based on the convergence of photonics and electronics, which would benefit artificial intelligence data centers and 6G technologies that demand ultra-high speed data transmission, low latency, and energy efficiency.

5. **Fiscal support for the semiconductor industry in Japan has outpaced that in other major economies, as a share of GDP.** The Japanese government earmarked JPY3.9 trillion (USD27 billion) from fiscal year 2021 to 2023 to support the semiconductor industry, equivalent to 0.7 percent of GDP (Figure A5.4). As a share of GDP, this amount is larger than the money set aside by the US CHIPS Act and the European Chips Act. Most of the subsidies have gone to JASM and Rapidus (Figure A5.5). About two-fifths of the capital cost of JASM's Kumamoto semiconductor fabrication plant was subsidized, based on the condition that it will have a minimum 10 years of domestic production and will prioritize domestic shipments at

[132] The U.S. has proposed a Chip 4 alliance, including Japan, Korea and Taiwan Province of China, to coordinate policies on semiconductor supply chain security.
[133] About 100 engineers from Rapidus are in Albany, New York, working with IBM engineers on technology development. Meanwhile, extreme ultraviolet lithography equipment from ASML used for manufacturing advanced semiconductors is scheduled to be delivered at the end of 2024. Pilot production is expected to start as early as in April 2025 in Hokkaido.

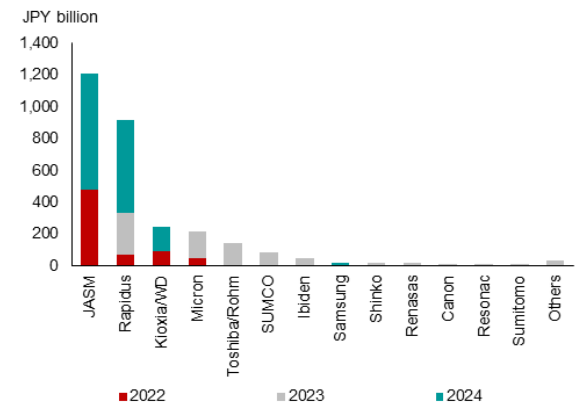
times of global shortage. In the case of Rapidus, one-fifth of the cost to begin mass production will be borne by the government. In November 2024, the Japanese government announced a plan to provide an additional JPY10 trillion (USD65 billion) through fiscal year 2030 to support the semiconductor industry in the form of subsidies, investments through government-affiliated institutions, and debt guarantees for loans originating from private sector financial groups.

Figure A5.4. Fiscal Support for the Semiconductor Industry



Source: National authorities; various media articles; AMRO staff calculations

Figure A5.5. Japanese Government Subsidies to Semiconductor Firms



Source: Ministry of Economy, Trade, and Industry; AMRO staff calculations

6. **Japan's policies to revitalize its semiconductor industry mark a clear departure from the past.** Japan's industrial policies in the postwar era can largely be characterized as inward-looking and risk averse. Independent technology development was emphasized, with alliances among major Japanese companies a norm—such as the VLSI project—primarily to gain global market share through mass production. However, policymakers were reluctant to allow major foreign-owned semiconductor manufacturers to operate in Japan. During the decades of economic stagnation beginning in the 1990s, government support for the industry has become more subdued.[134] This time around, however, Japan's new industrial policy for semiconductors reflects policymakers' sense of urgency, heavily emphasizing national security and supply chain resilience. The new approach leverages strong international technology alliances and provides very substantial subsidies to foreign firms. Unlike in the 1980s when Japan dominated mass production of DRAM chips, the latest focus of technology development—through Rapidus and LSTC—is on cutting-edge chips aimed at AI companies that prioritize bespoke chips that can outperform more generic chips, with shorter turnaround production times. This strategy recognizes that Japan cannot directly compete with leading producers like Taiwan Province of China and Korea.

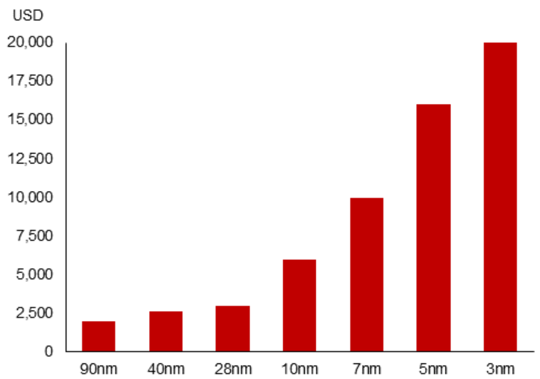
Challenges

7. **Japan's chip renaissance attempts are faced with several obstacles, including rising global competition, technological and financing risks, and manpower issues.** While potential economic gains from the new semiconductor revitalization plan can be substantial, they are not guaranteed. Major competitors and new entrants (such as India and Vietnam) have similar ambitions and want to capture a share of the global semiconductor economic pie. An endless global subsidy race can result in the waste of government resources if they fail to ignite technological breakthroughs. The government's gambit on Rapidus for cutting-edge chips, which relies on IBM's 2nm technology, is a risky investment. At present,

[134] For instance, the lack of strategic prioritization and a passive industrial policy have been cited as factors that led to the failure of Elpida Memory—a merger of the DRAM operations of NEC, Hitachi, and Mitsubishi. Elpida, Japan's sole maker of DRAM chips, was acquired by U.S.-based Micron Technology in 2013.

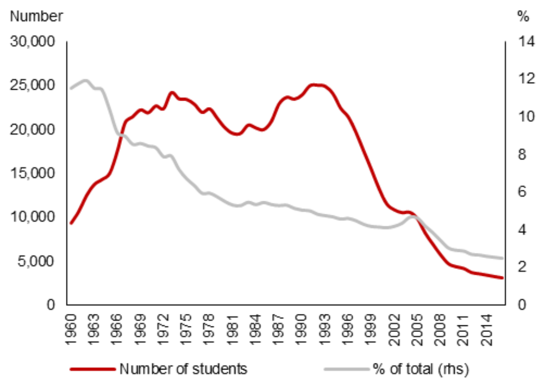
Japan's most advanced chip technology is at the 40nm node. The attempt to progress to 2nm within two years is an "unparalleled technological feat", according to analysts (Shivakumar et al. 2023). Although Rapidus is receiving government subsidies to the tune of nearly JPY1 trillion, its consortium members have only put up a combined JPY7.3 billion. The financing falls short of the expected JPY5 trillion needed to start mass production. Capital expenditure for leading-edge semiconductor manufacturing has increased sharply and will continue to escalate (Figure A5.6). Moreover, chip companies must invest during down cycles to be ready for the rebound, but Rapidus' joint entity structure might delay decision-making. Another concern is the effectiveness of LSTC in bridging R&D and commercialization. As most of its committee members are from academia, linking research from the lab to manufacturing at the fab will be challenging. Compounding these challenges is a severe shortage of engineers. Experienced Japanese semiconductor engineers have left for larger markets, such as China, Korea, and Taiwan Province of China, and are already in their 50s. Japan's declining birthrate and number of graduates suggest that the local talent pool is insufficient to meet industry demand. Interest in science, technology, engineering, and mathematics (STEM) fields has also waned among the college students (Figure A5.7), exacerbating the talent issue. Relatedly, many of Japan's small- and medium-size suppliers are owner-operated and are facing problems with business succession.

Figure A5.6. TSMC's 12-inch Wafer Cost by Process Node



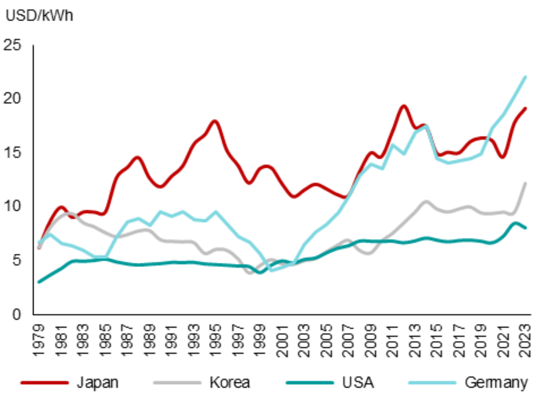
Source: DigiTimes; TSMC

Figure A5.7. Junior College Enrolment in Science and Engineering



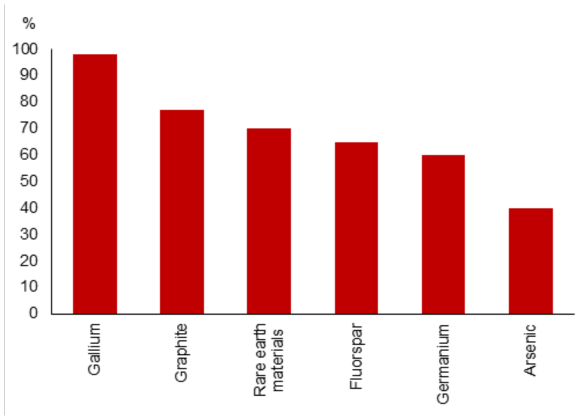
Source: Ministry of Education, Culture, Sports, Science, and Technology; AMRO staff calculations

Figure A5.8. Electricity Costs in Select Economies



Source: International Energy Agency; National authorities; AMRO staff calculations

Figure A5.9. China's Share of Global Production of Key Tech Materials



Source: United States Geological Survey; AMRO staff calculations

8. **Other challenges include back-end supply chain vulnerability, high utility costs, and a reliance on imported critical materials.** Although TSMC's fabrication facilities in

Kumamoto will help strengthen front-end domestic production, the wafers processed in the fabs still need to be sent to Taiwan Province of China for the back-end ATP process by outsourced semiconductor assembly and test (OSAT) firms, and then imported again into Japan. Similarly, when Rapidus goes into production, its promised short turnaround time strategy will be challenging without domestic OSAT firms. Having affordable public infrastructure to keep manufacturing costs low is important for Japan's chip competitiveness. Advanced fabs consume about 5 million gallons of water per day. Authorities in Kumamoto and Hokkaido are confronting challenges to ensure adequate water supplies (Satoh 2024). Semiconductor manufacturing is also extremely energy intensive. Japan's electricity costs are double those in Korea and the U.S. (Figure A5.8). Another challenge is reducing the reliance on imported raw materials. China currently dominates the global supply of key inputs, such as gallium, germanium, graphite, and rare earth metals (Figure A5.9), and Japan relies on China for most of these supplies, vital for compound semiconductors, electric vehicles, renewable energy, and military technology. Substituting critical mineral suppliers will be extremely difficult.

9. The government has a pivotal role to play in effectively responding to these challenges.

- **R&D collaboration.** The government should encourage greater collaboration between academia and industry in developing indigenous technology. In particular, the LSTC's R&D planning committee could be expanded to ensure a diverse representation of Japanese semiconductor companies, which would help shape the R&D roadmap and alignment with future industry needs.
- **Financing.** In terms of Rapidus' funding, private funding by consortium members remains indispensable, given their lack of capital commitment thus far. In addition, demand-side incentives, such as tax breaks or R&D grants, to prospective buyers of cutting-edge chips from Rapidus might secure customer base crucial to Rapidus' commercial viability.
- **Manpower.** To tackle the lack of skills and talent, regional consortia have already been established to design new semiconductor-related curriculum. Other initiatives can include developing a database of semiconductor skill requirements and job vacancies to improve job matching. But the overarching workforce shortage requires broader reforms, particularly immigration policies to increase the number of experienced semiconductor engineers. Currently, the Specified Special Worker (SSW) program requires proficiency in Japanese and allows for a maximum stay of five years in Japan, which limits the pool of international talent. The government could consider placing specific semiconductor job functions in a separate SSW category without the abovementioned requirements.
- **Infrastructure.** To ensure a reliable and affordable supply of water and electricity to advanced fabs, the government can collaborate with utility companies to build dedicated infrastructure designed for fabs, such as water treatment plants and substations, as well as provide tax breaks or subsidies to these utility providers to ensure competitive water and electricity tariffs.
- **Critical materials.** For Japan to reduce its reliance on China for critical semiconductor raw materials, it needs to establish partnerships with alternative suppliers that are resource rich, such as Australia, Canada, and the U.S., invest in domestic processing capabilities and recycling facilities, and build strategic reserves.

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