Where Is Rapidus Heading? Questions Raised about "Semiconductor Support" through Examination of Taiwan's TSMC

Rapidus Corporation is building a factory in Chitose, Hokkaido, with the aim of domestically producing next-generation semiconductors (photographed in May 2024)
Photo: tokinoun / PIXTA

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Massive support for the semiconductor industry

The semiconductor industry is the target of huge government subsidies in Japan. In 2021, the Ministry of Economy, Trade and Industry (METI) attracted Taiwan Semiconductor Manufacturing Company, Ltd. (TSMC), a Taiwanese semiconductor manufacturer and the world's largest foundry (semiconductor contract manufacturing) company, to Kumamoto Prefecture.

The first and second fabs of Japan Advanced Semiconductor Manufacturing, Inc. (JASM), which TSMC established as a joint venture with Sony Semiconductor Solutions and others, are scheduled to receive subsidies totaling up to 1.208 trillion yen under the framework of the Amended 5G Promotion Act, which came into effect in 2022.

In 2022, Rapidus Corporation (hereinafter Rapidus), a foundry company, was established with strong support from METI and investment from eight private companies. The company introduces cutting-edge technology with a circuit line width of 2 nm (1 nm is one billionth of a nanometer) from IBM in the United States and is building a factory in Chitose City, Hokkaido, with the goal of starting mass production in 2027. A subsidy of 920 billion yen has been approved for the development of the technology used by Rapidus. An additional 4 trillion yen is needed to start mass production, and the government is preparing a bill to invest in and provide a government guarantee for loans to the company. Subsidies secured for the semiconductor industry between fiscal 2021 and 2023 total approximately 4 trillion yen, but are expected to increase significantly depending on the framework of future support for Rapidus.

The movement toward large-scale support for the semiconductor industry is not limited to Japan. The US, EU, South Korea, and other countries have also launched large-scale subsidy packages in recent years. Behind this is a sense of crisis that Taiwan, home to TSMC, is a choke point in the supply chain for leading-edge logic semiconductor chips (semiconductor devices that perform calculations). High-performance logic semiconductors are key to next-generation technologies such as artificial intelligence (AI) and high-performance computing. TSMC's main factories, which account for the vast majority of the production of these semiconductors, are concentrated in Taiwan.

A series of recent events, such as the semiconductor shortage caused by the COVID-19 pandemic, Russia's invasion of Ukraine, and rising tensions in the Taiwan Strait, have created a strong sense of crisis in various countries that logic semiconductor production is over-concentrated in Taiwan, which is exposed to China's unification offensive. In Japan, interest in the semiconductor industry has increased in tandem with growing talk of a "Taiwan emergency," and semiconductors have been designated as specified critical products under the Economic Security Promotion Act (Act on the Promotion of Ensuring National Security through Integrated Implementation of Economic Measures) of 2022.

A stable supply of semiconductors is essential for the smooth functioning of the economy. However, the production of advanced logic semiconductors is an extremely competitive field in which the world's leading high-tech manufacturers have been competing fiercely for many years. Rapidus' attempt to enter this field from scratch and the government's support for it are ambitious and unprecedented in other countries' semiconductor industry policies. Is this really a reasonable option given the goal of a stable supply of semiconductors?

Regarding subsidies to TSMC, we need to calmly discuss who will benefit from the company's expansion in Japan and who should share the costs associated with the company's overseas investment.

For Japan, which is facing difficult challenges such as a rapidly declining birthrate and aging population, a decline in scientific and technological capabilities, and a worsening financial situation, the budget being invested in the semiconductor industry is huge. What kind of economic security will we be guaranteed in exchange for this amount of money being invested at the expense of other uses? This article raises questions about Japan's semiconductor support measures by examining the example of TSMC, Taiwan's king of logic semiconductor production.

The undisputed champion: TSMC

TSMC is now the leader in logic semiconductor manufacturing in both name and reality. Its share of the global foundry market was 62% in the first quarter of 2024, dwarfing second-place Samsung Electronics Co., Ltd. (13%), third-place United Microelectronics Corporation (UMC), and China's Semiconductor Manufacturing International Corporation (SMIC) (6% each) (according to data from Counterpoint Technology Market Research). In particular, the company's strength in the mass production of state-of-the-art sub-10 nanometer logic semiconductors is outstanding.[1] Its sales in 2023 were about NT$2.16 trillion (about JPY9.8 trillion). The gross profit margin was an amazing 53%.

[1] As of 2019, 92% of logic semiconductor manufacturing capacity above 10 nanometers was concentrated in Taiwan, actually in TSMC (Semiconductor Industry Association 2021).

TSMC was founded in 1987 based on the results of a technology development project conducted by the Industrial Technology Research Institute (ITRI). The company's start as the world's first pure-play foundry company, based on an idea by Morris Chang, a former vice president of Texas Instruments Inc. who was invited to become a chairman and managing director of ITRI and the first chairman of TSMC, set the stage for the company's success today.

In retrospect, the late 1980s was the perfect time to start a foundry. Shortly before, Intel had established technology leadership in the personal computer industry, and its CPUs had become the platform of the industry. Taking this chance, a large number of fabless semiconductor design companies that developed image processing and sound processing chips based on Intel products emerged in Silicon Valley. When TSMC was founded, the company expected that it would mainly receive orders from large foreign semiconductor manufacturers and Taiwanese companies. In reality, most of its orders came from American fabless companies (Chang Ju-hsin, et al. 2006).

TSMC's development with fabless companies as major customers during the rapid growth period of the personal computer industry has formed the foundation of its competitiveness to this day. First, by targeting fabless companies, which had limited management resources and were competing in the huge personal computer market, TSMC was able to establish a comprehensive technical customer support system early on. Specifically, since the late 1990s, the company has expanded its IP block (reusable circuit block) library and provided reference flow to support customer product development, and has deepened its partnerships with IP block vendors, electronic design automation (EDA) tool vendors, and OSAT (outsourced semiconductor assembly and test) vendors to create an environment that allows customer companies to focus on their core business (Kishimoto 2017[2]).

This technical support system has proven to be effective in making customers dependent on the company and securing continuous orders. In particular, the abundant IP blocks that TSMC has accumulated based on customer needs have been very attractive to fabless companies and have become an entry barrier that competitors cannot easily overcome.

Second, the fact that the company started its operation during the period of rapid growth of personal computers laid the foundation for the high-speed management style that is the company's strength. Technological changes in the personal computer market are rapid and product life cycles are short. By working with its customers to bring their products to market in a timely manner, TSMC has honed its "fast follower" skills (Tseng Sheng-Wen 2009[3]), a characteristic of Taiwan's semiconductor industry that involves hard work and tight schedules.

Since the 2000s, the demand for semiconductor chips for mobile phones and smartphones has exploded, driving TSMC's growth in technology and volume production. In addition to high functionality and low cost, semiconductor chips for smartphones must also be small and energy

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[2] For the history of Taiwan's semiconductor industry, see 張如心・潘文淵文教基金會（2006）『矽説台灣ー台灣半導體産業傳奇』天下遠見出版 (Chang Ju-hsin and Pan Wen Yuan Foundation, 2006, *The Legend of Taiwan's Semiconductor Industry* [Taipei: Commonwealth Publishing Group]), Sato Yukihito (2007), *Taiwan Haiteku Sangyo no Seiseito Hatten* (The creation and development of Taiwan's high-tech industry) (Iwanami Shoten), and for TSMC, see Kishimoto Chikashi (2017), *Taiwan Handotai Kigyo no Kyoso-senryaku—Senryaku no Shinka to Noryoku Kochiku* (Competitive strategies of Taiwanese semiconductor companies: Evolution of strategy and capability building) (Nihon Hyoronsha), edited by Hayashi Hirofumi and Nozuru Tsuyoshi, translated by Makitaka Hikari (2024), *TSMC Sekai wo Ugokasu Himitsu* (TSMC's secret to moving the world) CCC Media House, etc.

[3] Tseng Sheng-Wen (2009), 《快速跟隨、產業聚落與社會鑲嵌：以台灣 IC 設計產業為例》(Fast follower, industrial cluster, social embeddedness, Taiwan, IC design industry), Doctoral thesis, Graduate Institute of Development Studies, National Chengchi University

efficient. The development of microfabrication technology, which is the key to achieving these conditions, became the focus of competition, and a fierce R&D race broke out among first-tier semiconductor manufacturers. The price of production equipment rose sharply, and only a handful of top manufacturers who could continue to make huge investments were able to advance in the race to develop the next generation of process technology.

UMC, a pioneer in Taiwan's semiconductor industry and once a good rival of TSMC, gradually dropped out of the miniaturization technology development race since the late 2000s and began to focus its foundry business on production using mature processes. In the first half of the 2010s, Intel, Samsung, and TSMC engaged in a fierce R&D race, but in the late 2010s, TSMC became the frontrunner in technology development. Since then, TSMC has maintained an unassailable position as a high-volume manufacturer with an overwhelming share of the logic semiconductor market and as a technology leader.

In establishing microfabrication technology, TSMC also achieved a speed that stunned its competitors. In order to increase the speed of recovery from huge investments, it is necessary to establish mass production technology before other companies and climb the learning curve as quickly as possible to increase yield rates. Even Samsung, the long-standing king of semiconductor memory, lags behind TSMC in improving the yield rate of logic semiconductors (Yoshioka 2024[4]). One episode that made TSMC's organization culture famous was the "Nighthawk Project" in 2014, which Morris Chang personally led. Dividing the 24-hour period into three shifts, more than 400 engineers performed non-stop relay process development, competing with rival companies in the speed of developing a 10-nanometer process. The success of this project not only solidified the company's dominance, but also made its extraordinary work ethic widely known.

Since 2020, AI chips have become a new growth driver, with NVIDIA Corporation and Advanced Micro Devices, Inc. (AMD) joining Apple as top customers of TSMC. In addition, as the physical limits of miniaturization approach, advanced packaging technologies are becoming increasingly important, and TSMC is honing its capabilities in this area as well.

High barriers to entry for new players

TSMC's competitive advantage is supported by a variety of strengths, including: (1) outstanding research and development capabilities for cutting-edge technologies, (2) a comprehensive technical support system for customers, and (3) "economies of scope" created by more than 500 diverse customers. Behind this are organizational capabilities such as the presence of a large number of talented engineers willing to work hard, the management ability to organize them into a cohesive team while stimulating their competitive spirit and ambition, and the know-how to manage relationships with customers and suppliers. It also has close working relationships with manufacturers of production equipment. Another strength of the company is that over its long history of operation, it has built a wide array of production capacities, covering the latest processes to mature processes.

The historical background of Taiwan has also contributed to TSMC's competitiveness. One example is the deep ties Taiwan has built with Silicon Valley in recent decades through "brain circulation."

[4] Yoshioka Hidemi, *Keizai Anzenhosho Jidai no Handotaisangyo no Kadai* (Challenges for the semiconductor industry in the era of economic security), World Economic Review, Sept. / Oct. Issue, 2024

Taiwan is also home to a cluster of fabless companies, including MediaTek Inc., large contract manufacturers of various electronic products, and equipment and material suppliers. Engineers frequently choose to change jobs between these companies and TSMC, and information is widely shared. As a result of these factors, TSMC's competitive advantage as a logic semiconductor foundry is now so overwhelming that even Samsung and Intel are unable to compete.

What lies ahead for Rapidus

More than a quarter of a century after TSMC's founding, Rapidus has taken on the mission of establishing a manufacturing base for next-generation semiconductors and contributing to economic security, and aims to enter the advanced logic semiconductor foundry market with the goal of starting production in 2027. The company will not compete directly with TSMC, but will target customers who want speed in manufacturing.

There are customers who are dissatisfied with TSMC in terms of price and delivery time. From the customer side, it is not desirable for TSMC to win alone. There is a potential demand for "suppliers other than TSMC." But even if such demand were to accumulate, would the volume of orders be sufficient to justify the initial investment, which is estimated to be at least 5 trillion yen, and would such orders be expected to continue? Although both Samsung and Intel have struggled in the foundry business, each has already established a production base for advanced logic semiconductors, so perhaps they are better positioned than Rapidus to meet demand that TSMC cannot. Even if the development of 2-nanoparticle process technology, which is being carried out with an investment of about 900 billion yen, is successful, a difficult road lies ahead in which they will have to launch mass production, continue to expand orders, recoup their initial investment, and continue huge research and development and capital investment for a long time. It is estimated that another 4 trillion yen is needed to start mass production of Rapidus. It is fine if private companies that see sense and potential in the company's business decide to take the risk on their own. However, the government is reportedly preparing a bill that would allow government guarantees to be attached to loans to the company. If the government is to invest large amounts of public funds in any form, such as investment or government guarantees of loans, it must provide a clear outlook with concrete evidence that this will succeed as an independent business, survive fierce market competition in "peacetime," and contribute to "economic security" in the event of a serious supply chain disruption.

Rather, it is much more realistic to expect TSMC to expand its fabs in Japan from the perspective of ensuring a stable supply of state-of-the-art semiconductors in Japan and securing supply chain resilience for advanced semiconductors. JASM's first fab will use 20-nanometer and 10-nanometer process technologies, while JASM's second fab, which is expected to be operational by the end of 2027, will produce 6-7-nanometer process products. A third fab is also reportedly under consideration.

However, the subsidy policy for JASM needs to be considered calmly. In recent years, Taiwan's semiconductor industry has suffered from the "five shortages" of electricity, water, land, production workers and engineers. TSMC's enormous size has grown to such an extent that Taiwan cannot contain it.

In Japan, the company's entry into Japan is often discussed from the perspective of responding to a "Taiwan emergency" (a military offensive by China) and cooperating with Japan's economic security

policy. However, the company's entry into Japan is based on the strategy of solving the "five shortages" and business calculations to respond to customers' requests to disperse production bases. Japan, as an investment host country, is not the only stakeholder to benefit from the dispersion of TSMC's production bases through the establishment of JASM. TSMC's customers, who can hedge against the risk of supply disruptions, and TSMC, which finds new opportunities in new production sites, also see long-term benefits. As Japan is increasingly recognized by TSMC as a favorable investment destination, it is necessary to have a frank discussion about who should share the costs associated with the company's overseas expansion and how, without being swayed by the competition to attract companies from Europe and the United States.

What is "economic security" for semiconductors?

The companies that make up the global semiconductor industry are highly interdependent. TSMC is at the choke point of advanced logic semiconductor manufacturing. However, when looking at the entire supply chain, advanced semiconductor manufacturing is not the only choke point. TSMC's microfabrication technology would not be possible without the Extreme Ultraviolet Lithography (EUV) exposure system, which is exclusively supplied by ASML Holding N.V. In addition, as a natural consequence of the contract manufacturing business model, top customers have a strong influence on TSMC. The fact that the United States was able to attract TSMC to Arizona in early 2020, despite the high investment and operating costs, was a manifestation of the strong influence that the United States, a market that accounts for 60% of sales, has on TSMC.

Given that the semiconductor supply chain is based on complementarity among companies with advanced technological capabilities and those with the ability to create new markets through innovation, in order to ensure a stable supply of semiconductors, it will be important for companies and governments to work together across borders, rather than relying on a nation-centered, defensive approach associated with the term "economic security."

Logic semiconductors are intermediate goods that companies input into production and are strongly use- and customer-specific in nature. "Economic security" cannot be achieved if companies are unable to obtain semiconductors with the specifications required for their products.

In the event of a sudden emergency, as faced by automakers around the world, including Japan, during the COVID-19 pandemic, there will be a scramble for production capacity from chip users. To hedge such risks, customer user companies have invested in JASMA and TSMC's German fabs. At the corporate level, efforts are already underway to secure advantage in the event of a crisis by investing in and strengthening relationships with highly competitive foundries. Individual companies, who are more aware than anyone of the need for a stable supply of semiconductors, should play the main role in strengthening the supply chain.

There are some initiatives that only governments can take. In recent years, efforts have been made to strengthen cooperation among countries concerned with strengthening the semiconductor supply chain through the US-led Indo-Pacific Economic Framework (IPEF), the high-level meeting between Japan, the United States, and South Korea, and other such efforts. The government is expected to play a role in efforts to increase the effectiveness of such international cooperation.

What is the goal of Japan's semiconductor policy?

Since 2020, a series of events have occurred in rapid succession, including a semiconductor shortage and disruption of the global supply chain due to the COVID-19 pandemic, Russia's invasion of Ukraine, and rising tensions in the Taiwan Strait. Semiconductors have come to be seen as strategic materials directly linked to national security, and have become a target for huge subsidies to promote domestic production. With major countries providing huge subsidies to the semiconductor industry, there are strong voices saying that Japan cannot be the only one to fall behind the trend.

But why is it necessary to create a brand-new advanced logic semiconductor manufacturing company to achieve the goal? Is this the only solution to improve semiconductor supply chain resilience?

As Yoshioka (2024) points out, citing Saito (2018), the occurrence of a crisis distorts people's perceptions and sometimes creates a tendency to justify countermeasures against risks that ignore cost-effectiveness. [5] The same problem exists with the economic security policies surrounding semiconductors.

In addition, there is a problem with Japan's current semiconductor policy in that the banner of economic security is intertwined with an industrial policy aimed at reviving domestic semiconductor manufacturing, a field in which Japan was once a leader. However, it is necessary to separate the two policy goals and deal with them separately.

To improve the competitiveness of Japan's semiconductor industry, it is realistic to further enhance the strengths that Japanese companies already possess in some semiconductor products and materials.

If the government holds a firm belief that establishment of a new domestic advanced logic semiconductor company is the only solution to enhance supply chain resilience and secure semiconductor procurement for domestic firms in case of emergency, it is necessary that we can foresee a future in which the subsidized companies can survive the fierce competition in the global market and grow sustainably. However, judging from Taiwan's experience, the hurdles are extremely high. If the government is to provide further public support to Rapidus, it must clearly explain how it plans to overcome these hurdles.

Japan faces many economic and social challenges. By investing trillions of yen that could have been used for other purposes, what kind of "security" and future will we be guaranteed for the semiconductor industry ? Even if we try to look at the future with Taiwan as a guide, the outlook remains hazy.

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5 Yoshioka (2024), Saito Makoto (2018) *Kiki no Ryoiki — Hi-zero-risuku Shakai ni okeru Sekinin to Nattoku* (The territory of crisis — Responsibility and acceptance in a non-zero risk society) (Keiso Shobo)

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