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**A JAPÁN KORMÁNY SZEREPE A FÉLVEZETŐK KUTATÁSÁBAN ÉS
FEJLESZTÉSÉBEN**

**THE ROLE OF THE JAPANESE GOVERNMENT IN
SEMICONDUCTOR RESEARCH AND DEVELOPMENT**

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Abstract

Semiconductors are coming to be regarded as a one of the most crucial commodities as they power the majority of modern technology, however this extremely complex and costly technology requires specialization across the value chain; therefore, national economies are increasingly reliant on each other for the smooth acquisition of this key product. Due to the vulnerability of this supply chain, countries are heavily investing in their own domestic industry to mitigate shocks as much as possible. Because a technology that is so essential is at stake, governments have taken it upon themselves to form strategies to promote their chip industries, despite government intervention being a contested phenomenon, as some argue that only the free market is capable of allocating resources efficiently. This why my research aims to examine the essentiality and efficiency of government semiconductor strategy through the theoretical framework of the developmental state model, taking the case of Japan, a former semiconductor leader.

With a special focus on the R&D process of the industry, by utilizing qualitative research methods including SWOT and policy analysis which are supplemented by the examination of industry reports as well as expert opinions, I have come to the conclusion that government intervention is indeed necessary in order to facilitate R&D in the semiconductor industry, as while I identified flaws in the strategies and initiatives that have been developed, including a lack of measures targeting structural problems such as demographics, overall the policy and projects accurately addressed the weaknesses the industry faces, furthermore they highlight and promote their strengths while simultaneously preparing to take advantage of future opportunities. This research is relevant as it takes a comprehensive and critical approach to the Japanese government's steps, something that there is a great shortage of in English-speaking academia.

Keywords: Japan, semiconductor industry, research and development, political economy, developmental state, technology policy, innovation

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1. Introduction

The age of the unipolar world order has come to an end – or so it is said, and hegemonic conflict has once again come into the forefront of geopolitics. The United States is now facing its most formidable opponent since the Cold War, and that is China. This new adversary has set off alarm bells in Washington, where policy makers are rushing to counter Beijing's ambitions both in the Pacific and globally (W. Harold, 2019). As economic tensions mount, one sector stands out: semiconductors, also known as chips. This critical technology is at the center of the U.S.-China rivalry due to the fact that it forms the basis for nearly all other modern industries, such as the automotive, computing, communications, or artificial intelligence (AI) industries – basically, the seamless functioning of modern society rests on the availability of these chips (Shein, 2023). Additionally, key defense capabilities of states also rely on semiconductors, since nearly all state-of-the-art military technology requires these devices, therefore in the context of hegemonic contest, technological dominance also translates to military strength (Schuman, 2022).

Where national security is at stake, often the free market is deemed as no longer sufficient in furthering these sectors, as the interest of private actors do not necessarily reflect the broader national interest. The need to secure semiconductor supply chains was made clear by the disruptions caused by the Covid-19 pandemic, to which governments reacted by implementing policies to ensure the security of the complex chip supply chain (Mohammad, Elomri and Kerbach, 2022). However, contrastingly, there exists opposing theories which state that government intervention and industrial policy is doomed to fail, or to at least produce suboptimal results compared to the free market, as it is impossible for the state to perfectly allocate resources due to its lack of information (R. Henderson, 2023). This is exactly the debate my thesis wishes to tackle – through my research I attempt to prove or disprove the statement: 'The government is a necessary actor in the promotion of research and development in the semiconductor industry, as this sector is of such importance to economic security that the free market in itself will not produce satisfactory results.'

Japan, nestled right at the hotspot of 21st century geopolitics in the proximity of China, Taiwan, and North-Korea, serves as a fascinating case study of this dilemma of government intervention in times of crisis, not only due to its strategic location and close alliance with the U.S., but because it is a proponent of what is now known as the developmental state model. On

one hand this is the economic model that led to the unprecedented development of the country, on the other hand however, sudden liberalization that followed the regulated banking practices of the period were what eventually led to the asset bubble bursting in 1992, marking the beginning of Japan's stagnation from which it has yet to recover (Hossain and Rafiq, 2011). Knowing what followed Japan's successful state-coordinated development, it is natural to be skeptical of the renewed momentum of the state to promote specific industries that it deems as essential, however it is crucial to note that even the strongest believers of the Anglo-Saxon model of free market capitalism, such as the U.S., are developing their own federal strategies to promote their domestic industry (Siripurapu and Berman, 2021). This unusual trend is what prompted me to conduct my research, because it seems as though most developed nations share the same fear of economic vulnerability, which in turn can lead to political dependence, so much so that they are willing to partially abandon their preconceived negative judgement on state support by injecting billions of USD into the chip industry, however, are these exorbitant investments and other policy initiatives truly essential? That is precisely the question I attempt to answer by taking a closer look at the Japanese government's strategy to reinvigorate its domestic chip industry.

I am of the opinion that this research will provide a comprehensive review and examination of Japanese chip R&D that is lacking in English-speaking academia. While conducting my research I quickly noticed that most English sources only provide a surface-level look into this subject, despite the technology race being one of the main topics of modern geopolitics, with Japan playing a significant role in developing secure supply chains.

I have utilized qualitative research methods, mainly consisting of the analysis of key policies and initiatives of the Japanese government, which is supplemented by secondary source materials such as reports from semiconductor companies, associations, and consulting companies. To correctly assess the efficiency of government policy, I have conducted a SWOT analysis of the current state of the Japanese chip industry as to provide a framework through which policy measures are evaluated.

I begin my research by examining the literature within the developmental state model, including its key characteristics and significance, followed by with a brief overview of the main historical periods of the Japanese semiconductor industry in order to provide context. Then I will focus on the present-day, specifically, what is the government's current goal and strategy, which will be followed by the aforementioned SWOT analysis. Then I will focus on the specific policy instruments the Japanese government has used, including grants and funding programs,

as well as research collaboration and consortia. The final section of the research will focus on the most crucial projects supported by the government in the form of case studies.

2. Research Methodology

This chapter covers the research methods I have used throughout my study to examine the role of the Japanese government in semiconductor industry research and development (R&D) process, with an emphasis on evaluating its efficacy within the theoretical framework of the developmental state model, specifically to what extent the government is competent at identifying the key challenges of the industry. This study's core research questions are as follows:

- Is the Japanese government effective in promoting research and development, as well as technological advancement, or are its efforts misguided?
- Has the Japanese government accurately identified the key opportunities and threats regarding its domestic chip industry?
- Do the policies, as well as initiatives and investments adequately make use of the opportunities, while also mitigating the threats?

The present study employs a qualitative research design, analyzing the role of the government in semiconductor R&D through a combination of policy analysis, case studies of the most significant government projects, as well as a SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis of the industry's current state to identify the exact opportunities and threats which the case studies will delve into, including analyses of certain government initiatives, such as funding schemes, policy changes, and cooperative efforts with industry parties. The selection of qualitative research is based on its capacity to offer concrete and relevant data, as well as developments regarding the industry.

In order to assess how well government participation advances semiconductor R&D, I examined the results and effects of these projects, with the SWOT analysis serving as a means of identifying both internal and external opportunities and challenges that impact the industrial landscape to examine to what extent the government's strategy aligns with the industry's requirements. The ultimate goal of this research is to obtain conclusive findings regarding the competitive position, possible areas for improvement, and external as well as internal problems that the industry faces.

For this research, primary and secondary sources of data were gathered. Primary sources include government policy papers, business statistics, industry reports, and interviews with important players in semiconductor R&D. These sources offer direct knowledge about funding plans, government regulations, and cooperative initiatives in the sector, whereas academic journals, working papers, news pieces are examples of secondary sources, which supplement the information from primary data sources by providing further context and information into the larger semiconductor R&D scene. To extract important conclusions about government involvement in semiconductor R&D, thematic analysis is utilized to detect recurrent themes, patterns, and correlations.

In conclusion, this study explores the role of the Japanese government in semiconductor R&D using a qualitative research design that includes case studies, as well as SWOT and policy analysis. This study intends to offer a thorough evaluation of the efficiency of government intervention in fostering R&D within the semiconductor industry by utilizing primary and secondary data sources with the goal of producing relevant knowledge that enhances our comprehension of government-industry dynamics in semiconductor R&D.

3. Literature Review

3.1. The Developmental State Paradigm

The term ‘developmental state’ was coined by American economist Chalmers Johnson, who developed the concept in relation to the post-war ‘Japanese miracle’ – achieving unprecedented economic growth and prosperity only after a few decades after the devastations of World War II, Japan had become an enigma as well as threat to Western nations, as the methods which were utilized by the Japanese government were seen as economically ‘unorthodox’ (Johnson, 1982, p. 3).

Today, Japan lives in the general population’s mind as one of the most forward-looking and developed nations in the world – in the mid to late 20th century, American policy makers felt about as threatened by Japan as they do at this moment by China, fearing that their economic dominance might be compromised by the East Asian country (Mueller, 2023). The momentum at which Japan’s economy developed following World War II could arguably be attributed to the fact that the policies implemented at the time were at direct opposition to what

the Washington Consensus¹ would otherwise recommend developing countries (Kasahara, 2013).

The path Japan took after the war differed greatly from that of what Western countries advised: economic liberalisation and deregulation, as well as minimal state interference partnered with the absolute primacy of the free market. (Naim, 1999) East Asian nations on the other hand opted for a more statist method, which is what we now refer to as the developmental state model. The very name of this model reveals its core concept: the state is what plays the key role in developing the national economy, and politics and economy through this become substantially intertwined. Instead of relying on the free market and the invisible hand to bring prosperity, the state directly steps in and coordinates its efforts in order to further specific industries which it views as essential to achieve long-term growth, instead of being an impartial actor who merely creates the conditions for the free market to reign (Caldentey, 2008). In Japan's case, the main body of the government which planned and implemented industrial policy was the Ministry of International Trade and Industry (MITI), currently the Ministry of Economy, Trade and Industry (METI), the government body that foresaw the significance of future industries such as information technology, and subsequently allocated material and immaterial resources accordingly. (Song, 2022)

Despite achieving groundbreaking success, the Japanese miracle eventually evaporated when the asset price bubble burst in 1992, leading to a stagnation of such extent that it came to be known as the 'lost decades', with economists citing the same methods that brought about economic prosperity as the ones that led to the crisis, one which the country still grapples with today (Bayoumi and Collyns, 2000). Due to these developments, the statist approach to development is heavily contested, and has been widely deemed to be an overall ineffective model, thus paving the way for the dominance of neoliberalism and the free market – that is until recently.

According to sociologist Gerbaudo, we are currently witnessing the dawn of neo-statism, as the global Covid-19 pandemic, climate change and a surge of economic problems, all of which seem to have no market solutions, are bringing back the desire for the state to intervene and develop solutions, while guiding and even potentially limiting private enterprises. The previously prevalent belief that the state is overbearing and ineffective are coming to be

¹ A set of ten policy measures developed by the U.S. and several U.S.-led institutions, such as the IMF and World Bank, which sought to promote the development of crisis-stricken countries. The policy measures were designed in accordance with the theoretical framework of neoliberalism, that is, these recommendations aimed at promoting an intensely market-based economy with minimal state presence.

replaced by the notion that the state is indeed needed as a provider of security and direction in order to mitigate the effects of these crises (Gerbaudo, 2021).

This theoretical conflict is what primarily inspired me to conduct this research, as there exist sound evidence that support both the developmental state and the neoliberal model, however at the very least it can be deduced that a plethora of factors contribute to the success or failure of both, especially the international economic and geopolitical environment. As protectionism and economic nationalism is on the rise, I wish to examine whether or not there factually exists a need for the state to intervene in certain sectors, and whether this state intervention is more effective than the free market. As several leading economies turn to state intervention in order to further key industries in light of increasingly hostile international competition and what some would refer to as de-globalization, I believe it is crucial to objectively examine how effective these interventions are in order to determine what methods would benefit the targeted industries the best.

3.2. Innovation as One of the Driving Forces of Economic Prosperity

The reason I decided to focus on R&D in particular is because innovation is considered one of the main determinants of a national economy's competitiveness, as well as a key driver of long-term growth. As the economist Schumpeter has formulated, ground-breaking innovation is particularly vital – he introduced the concept of 'creative destruction', meaning that new ideas which can be commercialized harbour the potential to entirely disrupt and reshape markets, instead of simply introducing a slightly improved product or service. According to him, innovation gives birth to entirely new industries, while making others obsolete, causing shifts and dynamic growth in the economy (Schumpeter, 1943, p. 83-86).

In 'The Competitive Advantage of Nations', Michael E. Porter discusses the connection between technological advancement and a national economy's competitiveness, highlighting that in knowledge-based economies, the development of entirely new products, services and processes are what truly give these nation's their competitive edge, as the first player that discovers something unprecedented will be, for some time at least, the sole provider of that good, therefore gaining the upper-hand in areas such as pricing or building their customer base (Tellis and Golder, 1993). According to Porter, successful countries have a strong innovation ecosystem that fosters the development and diffusion of new ideas and technology, primarily

through the funding of R&D, and the collaboration between government, industry, and academia (Porter, 1990).

According to Aghion et al, ‘creative destruction’ promotes innovation by motivating companies to develop new technology, products, and business strategies in order to remain competitive, which in turn contributes to increased productivity, as new technology fosters increased efficiency. It also promotes economic dynamism by constantly shifting resources from less productive to more productive applications, thus resulting in the efficient reallocation of capital, labour, and other resources to industries and businesses with the highest potential for development and value creation. Overall, innovation benefits nations by productivity growth, economic dynamism, entrepreneurship, and competitive pressure, all of which promote long-term economic growth and prosperity by fostering change and adaptability (Aghian et al., 2021, p. 4-18).

3.3. R&D in the Semiconductor Industry

During the second half of the 20th century, most industrialized nations began their transition from manufacturing-based economies into knowledge-based ones, those of which’s growth is essentially based on constant innovation. While the market and private enterprises played the main role in this process, it is crucial to note how central governments implemented fostering R&D into their policies, furthermore how a number of nations, especially in East Asia, during this period viewed government intervention as critical component of furthering technological development in key sectors that would later serve as the basis of economic prosperity (Caldentey, 2008, p. 27-53).

The process of transforming creative concepts into technological breakthroughs and the capacity to produce ever-more-advanced semiconductors is known as semiconductor R&D (Goodrich et al., 2022). R&D is essential for development in all industries, however certain industries are more R&D intensive than others. According to the EU Industrial R&D Investment Scoreboard, the semiconductor industry ranked second in 2020 behind pharmaceuticals and biotechnology in average R&D spending intensity (European Commission, 2021). This large proportion of R&D spending in the industry can be partly explained by what some consider the end of Moore’s law, which states that: ‘The number of transistors on an integrated circuit will double every two years with minimal rise in cost.’ (Moore, 1965), meaning that it is becoming increasingly costly to develop and produce smaller

and smaller chips, therefore companies are looking towards innovation in other parts of the value chain instead in order to differentiate themselves from their competitors through specialized products and processes (Burkacky et al., 2022).

The dominant business model has shifted since the inception of the industry from a vertically integrated model, in which one company possesses the materials and capabilities to complete all stages of production, to a horizontally integrated one. Currently, specific companies focus on only a part of the production process. The formation of specialized players was aided by the sharp rise in technological complexity and the requirement for scale to finance large scale investments necessary to maintain the rate of innovation in both design and manufacturing (Varas et al., 2021). Consequently, in order to meet the rapidly increasing demand for semiconductors from all sectors of the global economy, it is to be expected that the industry will need to invest over 3 trillion USD in R&D and capital expenditure across the value chain over the next ten years. The development of increasingly complex circuits to power disruptive applications like AI, the Internet of Things (IoT) and autonomous vehicles would need semiconductor companies to continue spending over 90 billion USD on R&D each year, or almost 20 percent of their total revenue (Varas et al., 2021). Despite the large amounts of funds invested into R&D, breakthrough innovations usually take up to a decade or more to fully develop and commercialise. For example, ASML invested over 7 billion USD and took 17 years to develop their technology for extreme-ultraviolet lithography, including the capacity to manufacture the technology in large quantities. The high-stakes long-term investment proved to pay off however, as eventually extreme-ultraviolet lithography became a significant source of income for the company (Burkacky et al., 2022).

Basic pre-competitive engineering and scientific research forms the backbone of the industry, primarily aimed at developing the materials and chemical reactions that will serve as the foundation for innovative design and manufacturing technologies, creating the foundation for the next generation of commercial advances in computing power. Several actors collaborate in this stage from varying sectors, including businesses, academia, and government-funded labs, with the goal of minimizing costs in this lengthy and uncertain phase. This stage accounts for about 15 to 20 percent of industry R&D (Varas et al., 2021).

The chip value chain is composed of six stages, from which companies usually specialise in three or less. The most R&D intensive part of the value chain is the design of state-of-the-art semiconductors, representing around 53 percent of private sector R&D, while also providing 50 percent of the value added. At the inception of the industry, all of these activities were done by a single company, however not only did the drastically rising demand for

semiconductors since the 1990s, but also the rapid pace of innovation has made it increasingly difficult for a single firm to manage all parts of the value chain, resulting in the development in the fabless model – a company that has no manufacturing capabilities, and outsources assembly, testing and packaging in order to fully focus their resources on the R&D intensive design stage of the value chain (Varas et al., 2021). As the technology that requires advanced chips rapidly evolves and develops, the demand for semiconductors with highly specialised functions also grows, meaning that the companies that can design products which meet the needs of these customers, will significantly raise sales, and enjoy an advantageous position as being the sole player who possesses the intellectual rights to its innovative design (Bauer et al., 2020).

4. A Historical Overview of Japan's Semiconductor Industry

This chapter will focus on comprehensively analysing the very beginnings of the Japanese semiconductor industry, including what measures and circumstances led to its rise and fall as a global champion. The exact causes of how the archipelagic country lost its dominance are equally crucial as the causes of how it initially achieved its leading position. Following the historical overview, I will examine the contemporary state of the industry, as well as conduct an analysis in order to determine what its strengths, weaknesses, opportunities and threats are, so as to provide an in-depth account of the state of the industry with the goal of providing context and a clear framework for examining how the Japanese government's policy initiatives and goals fit into the current character of the sector.

From the very infancy of the chip industry, the Japanese government has played an active role in the development of the national semiconductor industry. After calling an end to Japan's total isolation in 1853, also known as the 'sakoku' policy, drastic societal and economic changes were pursued as the country strived to 'catch up' to Western powers, primarily in order to avoid becoming dominated and subjugated by them in the form of a colony (Ahmed, 1988, p. 1674-1676). From this era onwards, policy makers focused on absorbing state-of-the-art Western technology. When this goal had been achieved, and Japan had reached the developmental level of the West, it was clear that they needed to create their own technological breakthroughs to continue growing.

Following World War II, Japan did not pursue defense and military advancement as the US and the USSR, but rather the development of commercial technologies was prioritized, primarily due to Japan's pacifist constitution. The government focused on foundational

technologies, especially those that were essential inputs for consumer electronics and automobiles, such as semiconductors (Gerstel and Goodman, 2020).

4.1. Rise to Global Market Dominance

In the post-war era, the development of the country's industrial policy can be divided into four phases according to Koshiro Kazutoshi: '(1) the reconstruction period (1945-1959); (2) the period of rapid growth (1960-1969); (3) the period of qualitative consolidation (1970-1979); and (4) the period of promotion of creative and knowledge-intensive industries (1980's)' (Koshiro, 1986, p. 163-177). The focus of the government's industrial policy falls on the supply side, which manifests through the policy of support and aid for future technologies in the 1970s and 1980s. Throughout these four stages the fundamental tenet of Japan's industrial policy has been to achieve optimal resource allocation from a long-term and dynamic viewpoint, which cannot be accomplished purely by the free market (Koshiro, 1986, p. 163-177).

In 1979, the Ministry of International Trade and Industry (MITI) recognised the need for long-term strategic resource allocation into key designated industries, and thus drafted the policy strategy that Japan would become a 'technology-intensive nation' in its 'Vision for Industrial Policy in the 1980s' (Okazaki, 2017, p. 57-61). As to promote technological innovation and breakthroughs, the introduced industrial policy was based on four main programs: '(1) R&D subsidies; (2) national or public research institute establishment; (3) the establishment of industry-specific branches of the Technological Research Association; and (4) the awarding system.' (Koshiro, 1986) These specific policy measures will be further analyzed in 'The Main Policy Instruments of Semiconductor R&D' section of my thesis.

Following the formulation of this strategy, R&D funding for semiconductor manufacturing equipment increased from 2 percent at the start of the 1970s to 26 percent of the nation's overall R&D investment by 1977. Furthermore, in 1976, the six major computer companies in Japan – Fujitsu, Hitachi, NEC, Mitsubishi Electric, NTT, and Toshiba – joined forces in a joint public-private technology research project called the Super LSI Technology Research Association, which was funded by the Japanese government with an initial investment of 300 million USD. As a result, numerous groundbreaking inventions related to the design and production of semiconductors have emerged, notably electron beam lithography (EBL), which facilitated the production of unprecedentedly complex chips. Japan's dominance in the global semiconductor market was made possible by this technological leap – by 1988,

Japanese companies accounted for 51 percent of global sales (Tomoshige, 2022). Specifically, the production and design of increasingly more complex DRAM (dynamic random-access memory) is the field in which Japan gradually overtook the US in global market share (Okada, 2006, p. 39-103).

4.2. Falling from Grace: The Decline of Japan's Semiconductor Industry

After reaching its peak in 1988, the industry faced a gradual decline, one which cannot be attributed to a single factor, but an interplay of domestic as well as foreign circumstances.

The industry underwent significant structural changes in the 1990s, most notably that chips had gained the ability to store increasingly large amounts of data on an even smaller surface level, therefore reducing the need for additional storage capacity. As a result, manufacturers shifted their resources from producing function-specific chips to large-scale integrated circuits (LSI), and while DRAM functions were still in use in these LSIs, their demand plummeted (Okada, 2006).

The dominant business model of the industry also began to shift, as highly specialized companies that either designed or manufactured chips had replaced vertically integrated companies as the predominant business model for the semiconductor sector. The Japanese government pushed a number of programs intended to encourage businesses to specialize, stating that corporations should allocate their excess capacity to enhance high-value design capabilities rather than investing in redundant manufacturing facilities (Tomoshige, 2022).

Nonetheless, a vast number of Japanese semiconductor companies were either reluctant or unable to adjust to new trends in the international market, as the declining domestic popularity of consumer technology products resulted in reduced revenue, and consequently less capital available for research and development, eventually leading to a loss in global competitiveness. Furthermore, the cooperative initiatives that the Japanese government promoted helped the semiconductor sector at first, but as a result of their firms' technology standardization and convergence, the diversity among Japanese semiconductor manufacturers was ultimately reduced, resulting in the creation of an industrial structure that made it challenging for businesses to adjust to shifts in the market (Tomoshige, 2022).

Furthermore, the international environment showed increasing hostility to the Japanese dominance of the market – especially the U.S. began to view Japan as a competitor that needed to be restrained. American policy makers were concerned that the excessive presence of export-

subsidized Japanese consumer electronics and chips aimed to push out domestic players, while simultaneously limiting their access to the Japanese market. Pressure had started to mount on the Japanese government for what the US claimed to be unfair trade practices, and as the threat of being shut out from the American market entirely grew, Japan signed the 1986 U.S.-Japan Semiconductor Agreement. The deal increased the foreign share of the Japanese semiconductor market from 10 to 20 percent, as well as granting the U.S. government the power to set minimum fair market prices for semiconductors sold in the country (Irwin, 2007, pp.5–14). These two requirements made it possible for semiconductor businesses in the United States, South Korea, and other nations to capture the majority of the global semiconductor market share while simultaneously weakening Japan's competitiveness in both its domestic and international semiconductor markets.

4.3. Current Era: Dawn of a New Golden Age?

In the 2020s, Japan, as several other nations around the world have declared that chips are a strategic technology, indispensable for economic prosperity and military prowess. The securitisation and politization of semiconductors have prompted companies and governments to redesign and restructure their operations, with an enhanced focus on ‘near- or friendshoring’, meaning that countries are eager to either to move key semiconductor players inside of their own national borders, or to move them to political and military allies to secure supply chain security (Miller, 2024, p. 2-3).

Reacting to this shift, the Japanese government formulated the ‘Economic Security Promotion Act’, which will shift economic cooperation to political allies in order to minimize dependence on China, with the goal of securing supply chains against disruption from geopolitical disputes. This also includes developing domestic capabilities which will provide Japan with an indispensable position in the value chain of certain key technologies to increase the country’s geopolitical and economic influence, while simultaneously shielding Japan from economic dependency-based coercion tactics by other nations (Izumi Koyu et al., 2022, p. 28-55) Under this act, semiconductors have been designated a critical technology that is to be extensively promoted by government action. The updated strategy includes additional components including encouraging the creation of AI-focused chips with lower power consumption and bolstering Japan's chip manufacturing sector by drawing in foreign investment (Cabinet Office Director-General for Policy Planning , 2020).

This strategy focuses on four policy areas for economic security: first and foremost, the protection of supply chains regarding essential commodities like semiconductors; second, the guarantee of basic infrastructure security; third, in order to maintain competitiveness, government and private sector research will be done to determine the priority areas for innovation and technological advancement; and fourth, in order to safeguard important innovations, a subset of Japanese patents will be classified as confidential (Nikkei, 2022).

In accordance with this policy, the government has announced several substantial projects to promote the domestic industry, most of which fall under METI's 'Strategy for Semiconductors and the Digital Industry', which is comprised of the following key components:

- 'Jointly developing cutting-edge semiconductor manufacturing technology and securing sufficient production capability'
- 'Accelerating digital investment and strengthening the design and development of cutting-edge logic semiconductors'
- 'Promoting green innovations'
- 'Strengthening the portfolio of the domestic semiconductor industry and enhancing its resilience' (Ministry of Economy, Trade and Industry, 2021)

Furthermore, at the G7 Hiroshima Summit in May of 2023, Japanese representatives further added that promoting international cooperation in R&D for next-generation semiconductor technology is a key aspect of Japan's semiconductor strategy going forward (Tomoshige, 2023).

In the upcoming parts of my research, I will analyze the specific measures and projects outlined in the government's policy, as well as provide an overarching examination to accurately determine the current state of the industry that these policies target, as it is crucial to understand exactly the conditions in which these measures will be implemented, since their success rate is also dependent on how current policy is tailored to the actual needs of the sector.

5. SWOT Analysis of the Japanese Semiconductor Industry

5.1.1.1. *Strengths*

Despite Japan not being a global leader anymore, it still maintains a favorable position in a number of different portions of the value chain, preserving a significant portion of global

market share while possessing strong international competitiveness. Specifically, the country maintains its lead in the product categories of memory (particularly NAND), sensors (CMOS image sensors), and power semiconductors. As per the November 2022 International Trade Association report, Japan's approximate proportion of the world's supply of manufacturing equipment is 35 percent (Kaur, 2023), while the value added to this sector is 27 percent according to the Statista Research Department (Statista, 2024). Not all Japanese chip giants fell into obscurity following the decline of the domestic industry, therefore with their noteworthy experience and expertise, they still constitute the most internationally competitive players in these sections – one of the reasons Japan continues to be strong in the area of materials and equipment used in semiconductor manufacturing (Shindengen). For instance, SCREEN Holdings has a huge stake in particular processes like cleaning equipment, and Tokyo Electron still maintains a high share in coating and development equipment (Tsumura, 2023). Japanese companies also control a sizeable global market share of 56 percent in materials, a category that is essential to the development of state-of-the-art chips. (Tochibayashi and Kutty, 2023). Additionally, the nation also possesses a relatively large portion of the discrete, analog, and other (DAO) semiconductor markets, all of which are within the industry's R&D-intensive segment (Statista, 2024).

Regarding R&D, Japan is still a leading player, spending around 20.7 trillion JPY on R&D in the fiscal year of 2022, which is about a 5 percent rise compared to the previous year. When examining the makeup of the total R&D expenditure, private companies have regularly spent more than 70 percent on competitive research to develop new products and value chain processes, while tertiary education institutions have spent about 20 percent on pre-competitive basic research (Statista, 2024). In 2022, Tokyo Electron Ltd. was the leading company in the number of patents registered in the semiconductor industry, standing at 498 individual patents (Statista, 2024). Globally, Japan is in second place for the total number of US-granted patents, with 40.960, followed by China and South-Korea, while the US maintains the top position with 162.557 granted patents (Singer, 2024).

To summarize, Japanese companies hold a dominant 56 percent share of the global semiconductor materials market, making it one of the strongest players in post-processing, while also remaining competitive in key semiconductor product categories like memory and sensors. Additionally, the country's strong presence in manufacturing equipment, with a 35 percent global supply share, further supports its resilience. Increased R&D spending, reaching 20.7 trillion Japanese yen in 2022, reflects Japan's commitment to innovation, with companies

like Tokyo Electron Ltd. leading in patent registrations and reinforcing Japan's position as a key semiconductor R&D player.

5.1.1.2. Weaknesses:

The weaknesses of the industry can be identified in the major reasons for its eventual decline. In order to ensure their products function without fail for a prolonged period of time, Japanese manufacturers heavily prioritized quality, however, as the price and lifespan of consumer electronics gradually decreased, demand soared for cheaper and passing quality chips – East Asian nations like China, Taiwan, and South Korea managed to capitalize this shift with the assistance of their respective governments, having massively expanded their semiconductor industry, whereas Japan lagged behind due to the inability to adapt to the changing demands of the market (Shindengen). Many of the country's leading semiconductor manufacturers were actually simply branches of larger general electronics companies, rather than solely specializing in semiconductors, therefore making it not unusual for upper management to lack knowledge of the semiconductor industry. As a result, according to certain experts, Japan is about 10 years behind the global industry standards in manufacturing (Shindengen).

It should also be acknowledged that Japan is severely handicapped when it comes to product development because it lacks modern semiconductor production facilities, making it much more challenging to utilize the opportunities granted by the green revolution and digitization. Specifically, in cutting-edge logic chips (CPU, GPU), Japan heavily relies on American corporations like Intel, AMD, Qualcomm, and Nvidia. With the goal of taking advantage of the heightened demand for advanced chips due to the rise of AI technology, Japan is conducting research and development on chips needed for this sector, however in order to prototype and produce cutting-edge semiconductors (28 nm and beyond), Japanese businesses and research organizations still have no choice but to rely on foreign foundries in countries like Taiwan, South Korea, or the U.S., as Japan has very meager manufacturing capabilities. Foreign companies, on the other hand, either own or operate cutting-edge manufacturing facilities within their domestic affiliates (Global Research and Innovative Solutions, 2018).

Despite having numerous strengths in R&D, there is one area where Japan significantly lags behind: global collaboration in patent development (GCP). GCPs constitute the most high-

quality and innovative patents due to the many benefits of international cooperation, and despite Japan's share of GCPs increasing over the past two decades, it is still much lower than that of nations like the U.S. and Germany, resulting in a large gap in the level of collaboration that Japanese inventors have with the international scientific community. While roughly 10 percent of all patents in the United States and 25 percent of all patents in Germany are classified as GCPs as of 2015, the percentage of GCPs in Japan is still quite low, sitting at just 3 percent (Bahar et al., 2021).

Briefly, the main shortcomings that plague the Japanese semiconductor industry include the fact that domestic manufacturers have historically prioritized quality, but the market's shift towards cheaper, lower-quality chips has left Japan at a disadvantage compared to other East Asian competitors like China, Taiwan, and South Korea. Many Japanese semiconductor companies are subsidiaries of larger electronics firms, resulting in a lack of specialized industry knowledge at the management level, and the country's outdated manufacturing facilities hinder its ability to develop cutting-edge semiconductor products, forcing reliance on foreign foundries for production. Additionally, Japan's collaboration in global patent development is lacking compared to countries like the U.S. and Germany, with a low percentage of high-quality patents produced through international collaboration.

5.1.1.3. Opportunities:

The emerging digital and green revolutions will provide the most significant opportunities for the Japanese chip industry to revive and become a leading global player once again. We can already witness the green revolution's effect on the industry, as environmentally friendly technology will lead to a rise in the demand for extremely energy-efficient semiconductors, such those required in the assembly of electric vehicles (EVs). Additionally, the need for carbon-neutral semiconductors will also rise globally, creating a massive new market that Japanese companies can break into (Wakabayashi, 2024).

In accordance with Japan's competitive advantage in the production of manufacturing equipment and the post-process phase of the value chain, a growing number of foreign manufacturers have established facilities in Japan in order to take advantage of these strengths. The most notable example is the Taiwan Semiconductor Manufacturing Co., Ltd. (TSMC), which in 2022 established a high-tech packaging development base in Ibaraki Prefecture (Tsumura, 2023). Additionally, it has been declared that Samsung Electronics plans to invest

around 30 billion yen in Yokohama to build a prototype production line centered on research and development duties, which is also anticipated to concentrate on post-processing (Tsumura, 2023).

As the application of AI grows, major semiconductor manufacturers are vigorously expanding their production capabilities, for example the largest semiconductor foundry in the world, TSMC was reportedly considering constructing a third plant in Japan. It is anticipated that the further development of AI will present a chance for Japan's semiconductor sector to flourish, as the manufacturers producing ultra-high purity semiconductor-related parts and manufacturing equipment would see a considerable increase in earnings. Growth in the semiconductor sector is anticipated, and Rapidus, the Japanese government's most ambitious endeavor, which plans to produce 1-nanometer chips in the future, is one company that will greatly benefit from this growth (President, 2023).

As geopolitical tensions and pressure from China mount, Taiwanese TSMC has made it its strategic priority to diversify risks and create a reliable chip procurement structure for itself and its client companies. Apart from geopolitical strain, on the island nation there is a growing lack of water, electricity, and human resources as a result of the industry's explosive growth, putting into question the corporation's ability to further expand its capacity in its homeland. Potential expansion into its closest political ally, the U.S., also poses a number of challenges, including growing labor and material prices which will most likely cause a delay in the opening of factories (President, 2023). These difficulties shed a favorable light on Japan, who has bolstered its security system, providing a stable environment in which the Taiwanese enterprise can expand into, as it is becoming increasingly crucial to avoid growing geopolitical dangers. Furthermore, North Korea is stepping up its military provocations on the Korean Peninsula, one example being the test launch of an intercontinental ballistic missile, which has prompted Samsung Electronics to set up an R&D development system in the secure environment of Japan (Makabe, 2023).

The growing importance of international cooperation also provides opportunities, as the United States proposed Taiwan, Japan, and South Korea create the 'Chip 4 Alliance' in order to restrain the growth of the semiconductor industry in mainland China. Chip design constitutes the U.S.'s most significant strength, and advanced chip fabrication capabilities are possessed by Taiwan and South Korea, while Japan has an edge in semiconductor packaging and testing technology, raw materials, and precision production equipment. As a result, the government and opposition parties in Japan are of the opinion that this is a 'once-in-a-lifetime' chance to

revitalize the country's semiconductor sector through making use of Japan's special position in the supply chain (Lee, 2023).

In light of these international and domestic developments the Japanese chip industry is poised for a significant revival, insofar as they are able to capitalize on opportunities presented by the emerging digital and green revolutions. Demand for energy-efficient semiconductors, driven by green technology and the widespread use of EVs, creates a promising market. Simultaneously, foreign manufacturers, like TSMC and Samsung, are establishing facilities in Japan to leverage its competitive advantage in manufacturing equipment and post-process value chain phases, while strategic investment in Japan also reflects aims to diversify risks amidst geopolitical tensions and resource constraints. This indicates a positive trajectory for Japan's chip industry, with potential benefits for companies like Rapidus aiming to produce advanced semiconductor chips. Overall, Japan's semiconductor sector appears poised for growth and collaboration, leveraging global trends and strategic partnerships for success.

5.1.1.4. Threats:

Despite the plentiful opportunities that have arisen in recent years, there is also no shortage of threats, both internal and external, which could potentially squander the government's efforts in revitalizing the chip industry.

Japan is projected to have an acute shortage of talent in the near future, as demonstrated by a study conducted by McKinsey & Company, according to which merely 28 percent of participants believed that their organizations could draw in and keep top engineering talent. Additionally, only 24 percent of those employed by international corporations stated that their organizations would choose Japan as the preferred location for research and development projects rather than other countries (Chokki et al., 2020). This issue is partially demographic, since the number of persons of working age is predicted to decrease from 75 million in 2018 to 69 million in 2030 due to a rapidly aging population and declining birth-rates. Consequently, companies are finding it increasingly challenging to replace senior R&D professionals (Chokki et al., 2020).

The rapid speed in which new technological developments are taking place also poses a challenge to the acquisition of talent. There is currently a projected 240,000 skilled IT worker deficit in the nation; by 2030, that number is predicted to approach 600,000. It is becoming more difficult to fill traditional mechanical or electrical engineering roles since high-potential graduates are drawn to trending fields like AI. Japan, meanwhile, is not very enticing in the

eyes of foreign talent – when it comes to attracting highly trained personnel, the nation is ranked 20th out of 38 OECD countries (Chokki et al., 2020). Therefore, it can be stated that the most significant obstacle in advancing the industry is the acquisition of human capital, particularly ‘on-site human resources’. Production engineers, personnel in the manufacturing process, and even maintenance engineers are among the human resources on site that are in great demand (Mitsubishi Research Institute, 2023).

The ongoing trade war between the U.S. and China also negatively affects the government’s ambitions, as Washington urged Japan to tightly regulate its exports of key semiconductor manufacturing equipment to China. While Japan does view China as a security threat, thus wishing to hinder its further military advancement, it still remains the fastest growing and largest export market for manufacturing equipment. Consequently, the government faces the tough balancing act of deciding to what extent exports should be limited to China so that it does not sabotage the domestic chip industry (Suzuki et al., 2023, p. 19-24).

From its inception, the ‘Economic Security Promotion Act’ eliminated the idea of exporting Japanese semiconductors to China – its current biggest consumer – raising concerns of whether the drastic expansion of domestic manufacturing capabilities will be matched with a similar level of demand (Japan Enterprise (China) Research Institute, 2023). After automobiles, semiconductors are Japan's second largest export and its top export to China. In 2022, Japan was China's top exporter of machinery used in chip manufacturing, however in the first quarter of 2023, as trade frictions rose, Japan's exports to China fell by 20 percent, resulting in an 11.5 percent decline in overall bilateral trade. (Global Times, 2023).

In brief, Japan is facing a significant talent shortage in its semiconductor industry, exacerbated by its demographic crisis, and increasing competition for skilled workers. The country struggles to attract and retain top engineering talent, hindering its ability to replace senior professionals. Additionally, the rapid pace of technological advancements further complicates talent acquisition, with a projected deficit of skilled IT workers and challenges in filling traditional engineering roles. Moreover, Japan's role in the ongoing trade war between the U.S. and China adds complexity, as the government must balance national security concerns with the need to maintain export markets for semiconductor manufacturing equipment.

6. Main Policy Instruments in Semiconductor R&D

Considering the costs and the prolonged period needed to commercialise R&D investment, the government's main task is to support these endeavours financially and institutionally in order to take significant burden off private enterprises, while simultaneously encouraging them to take bold risks in hopes of discovering ground-breaking innovations which would improve their position relative to competitors (Goodrich et al., 2022). The existence of market failures connected to R&D activities, such as a lack of private sector R&D supply because of high investment risk, provides economic reason for the public sector to support R&D. Typically though, the anticipated spillover effects exceed the intake. Businesses in a competitive market are less likely to invest in R&D to the socially optimal level because of these kinds of market failures (Leyden and Link, 2013).

National and local governments also have an interest in investing in these activities, as well as providing the most suitable legal, institutional, and financial environment for R&D to flourish. Their interest lies not only in creating or preserving their own unique position in the value chain, but also in the positive multiplier effect semiconductor R&D investments have on almost all industries, such as automotives, defence or communications. As an increasing amount of government funds are invested into basic research, this also greatly pushes advancements in computing, nanotechnology, and advanced manufacturing processes, since the fundamental scientific and engineering research of these fields overlap (Ravi, 2020).

As previously mentioned, Japan has outlined its main policy measures in its 'Economic Security Promotion Act' and 'Strategy for Semiconductors and the Digital Industry'. In the following sections, I will introduce and analyse the two main policy measures applied to foster R&D in the industry to gain a deeper understanding of what the Japanese government views as the most essential aspects of R&D in need of government support.

6.1. Grants and Funding Programs

Government grants and funds are a key part of the strategy devised by the Japanese government to revitalize the country's chip industry, as the government is allocating billions of JPY to support large-scale R&D facilities in conjunction with investment from private companies. The funds are primarily used to support long-term, uncertain, yet potentially ground-breaking research that may not reach profitability for years. Given the nature of this process, the government is committed to elevating the financial burden and risk of companies, hoping to increase the boldness and ambition of their R&D.

The most notable institutional initiative in this area is the establishment of the Public-Private Cooperation Council (PPCC), which authorizes Ministers ('R&D Ministers') to grant funds to R&D projects related to Designated Critical Technologies (DCTs). Through the PPCC, the government may actively fund R&D projects, while also providing assistance that could take the following forms: providing researchers with important data for R&D projects, such as the demands of the public and private sectors for the technology, as well as promoting societal implementation by commencing the required legal adjustments or deregulations. In addition, the act requires PPCC members to safeguard confidential data in accordance with their agreements (Cabinet Office Director-General for Policy Planning, 2020).

Besides institutional reforms, the government has increased the amount of subsidies it provides in order to lure in foreign companies. According to a statement made by the local government of the city of Yokohama, Samsung Electronics would invest around 40 billion JPY (280 million USD) over the course of five years in an R&D centre specialising in improved chip packaging, which the Japanese government will support with subsidies of up to 20 billion JPY (132 million USD) (Nussey and Lee, 2023).

In total, the government of Japan is planning to provide approximately 2 trillion JPY (13 billion USD) to fund initiatives aimed at growing its chip industry. A significant amount of the funds, set aside in a supplemental budget for the fiscal year of 2023, is anticipated to go towards supporting TSMC, which recently opened a new fab and a chip foundry venture called Rapidus, aiming to develop and produce state-of-the-art chips in Hokkaido (Nagao, 2023). Eight of the top Japanese businesses, including Toyota Motor Corporation and Sony Group, invested a combined 73 billion JPY (about 48 million USD) into this project, that is devoted to the mass manufacturing of next-generation chips for uses like AI and autonomous driving. The government pledged an additional 590 billion JPY (3.9 billion USD) in funds through the supplemental budget for the 2023 financial year (Tochibayashi, 2023).

Another 19 billion JPY (126 million USD) subsidy was authorized for TSMC's new R&D facility in Ibaraki Prefecture, which will be used for advanced semiconductor packaging and testing (Togashi, 2022). The chip industry allocation is a component of the 13 trillion JPY in expenditure pledged by the Prime Minister in the additional budget for 2023–2024 that his administration adopted, funded by issuing bonds worth about 9 trillion JPY (59.8 billion USD) (Kajimoto and Nussey, 2023).

In its venture to diversify and expand manufacturing capabilities, TSMC is reportedly much more enthusiastic about investing in Japan than in the U.S., considered by some as one of the first major successes for the Japanese chip industry. Competition in the bid for TSMC's

cutting-edge facilities is becoming increasingly heated, as other governments of leading economies are also aiming to grow their national chip industry. With TSMC, Japan possesses a strong advantage compared to the U.S. or Germany, citing the country's network of suppliers of chip equipment and materials, similar work cultures, and geographical proximity. TSMC has also stated that the Japanese workforce, renowned for its long workweeks and steadfast dedication to their employers, are more inclined to tolerate harsh schedules and work overtime. Contrastingly, in Arizona labor unions are lobbying against the company's plans to relocate and hire Taiwanese workers (Saxena, 2023).

Additionally, attracting such an immense amount of foreign investment will lead to increased competition between key domestic players like Rapidus, TSMC and Samsung. This diverse set of companies active in Japan will likely assist the domestic industry in avoiding the mistake it made back in its prime: the cooperative initiatives that the government promoted in the past helped the semiconductor sector at first, but as a result of technology standardization and convergence, the diversity among Japanese semiconductor manufacturers ultimately reduced, resulting in decreased competitiveness (Tomoshige, 2022). Tokyo will have to carefully balance the weight domestic and foreign companies pull in the revitalization of the industry: on one hand, the aforementioned risks of standardization, inflexibility and the reliance on domestic demand plague Japanese companies and collaboration, while on the other hand, the supremacy of foreign entities that are for-profit will always have their own interests in mind, making them more unreliable in the long-term, especially when the grand goal is to support the national economy.

Takashi Yunogami, director of the Microfabrication Research Institute, explains that the government is making the same mistake that led to the decline of the domestic semiconductor industry in the past, as he puts it bluntly: 'Wrong diagnosis, wrong prescription'. Through his analysis, he declares that only 20 to 30 percent of the 55,000 wafers produced each month at the TSMC Kumamoto plant can increase Japan's market share, even with subsidies. Furthermore, Kioxia's Yokkaichi and Kitakami plants supply just 50 percent of Japan's contribution, while Micron's Hiroshima factory contributes zero percent. Therefore, the overall share of Japanese semiconductors will only increase by a few percentage points even if the Japanese government injects billions worth of subsidies into TSMC Kumamoto Factory, Micron Hiroshima Factory, Kioxia Yokkaichi Factory, and Kitakami Factory in accordance with the policy drafted by METI. What makes the situation even more dire according to Yunogami is that TSMC's Kumamoto plant was supposed to leverage the

global shortage of 28 nm logic chips, however the shortage has already been resolved (Yunogami, 2023).

6.2. Research Consortia and Collaborations

The formation of research consortia and research collaborations, be it domestic or international, are key to the enhancement of the technological prowess of the Japanese chip industry, as different companies and institutions possess strengths and know-hows in different areas of the development process, therefore by collaborating they can pool resources, expertise, and different perspectives to foster innovation (Palma, 2022).

Established in 2021, the JOINT2 project aims to expedite the technological advancements required for the production of next-generation semiconductors. Participating firms include material and equipment makers, and the project's main objective is to jointly develop and assess next-generation packaging materials for usage in post-processes in semiconductor production. In order to expedite the shipment of materials, enterprises participate in this project by jointly developing products and manufacturing processes, while they allow access to their unique technology and share their expertise (Asia Tech Observer, 2023).

In August 2022, METI launched the most ambitious and crucial project of the government's chip strategy: the establishment of Rapidus Corporation, a consortium of Japanese companies collaborating with the U.S.-based IBM Research to develop 2 nm semiconductor technology. The first fab, scheduled for construction in Hokkaido, aims to start operations by 2026–2027. Rapidus, led by veteran Japanese semiconductor executives, is built on the cooperation of leading Japanese companies like Toyota, Sony, NTT, and Softbank. Additionally, the consortium has partnered with Belgium-based IMEC to further its research endeavours (Makabe, 2023).

Collaboration with one of their closest allies, the U.S., is seen as imperative to revive the domestic chip industry. The two nations decided to collaborate on R&D in critical technologies during a July 2022 meeting of the U.S.-Japan Economic Policy Committee, during which the establishment of the Leading-Edge Semiconductor Technology Center (LSTC) was declared, a public research organization designed to be modeled after the U.S. National Semiconductor Technology Center (NSTC). Furthermore, the two states are members of the U.S.-East Asia Semiconductor Supply Chain Resilience Working Group (commonly referred to as the 'Chip 4 Alliance'), the U.S.-led semiconductor alliance that also includes Taiwan and

South Korea. The goal of Chip 4, which convened for the first time in February 2023, is to fortify the semiconductor supply chain within the Asia-Pacific. (Shivakumar et al., 2023).

Through the establishment of these research facilities, the government does indeed address the lack of international collaboration that characterizes the Japanese R&D environment, which is expected to result in a major increase in the number of registered patents thanks to international collaboration. This form of collaboration brings together a diverse pool of talent, resources, and perspectives, leading to more innovative and cost-efficient findings (Science Europe, 2014). However, the government has neglected to take any steps in improving its attractiveness to foreign researchers and students, which puts into question just how sustainable these international collaborations will be. What is more, according to Kenichi Ohmae, foreign companies will be reluctant to send their best engineers and executives to Japan, as the regions in which the main R&D facilities are built, have little to no institutions for expats, such as international schools (Ohmae, 2023). Other societal factors also contribute to Japan's disadvantageous position, including non-competitive wages compared to other G20 countries, work-life imbalance, discrimination, and the practical impossibility to completely integrate into broader Japanese society. The consequences of major demographic decline looms over the country's economy, and while the government has laxed its immigration policy in recent years, this is simply not adequate. A plethora of comprehensive reforms would be needed in order to improve the country's attractiveness, especially in domestic working conditions and gender equality, but even then, many aspects cannot be substantially changed by top-down government policies (Harrison and Sakudo, 2023).

7. Case Studies of Crucial R&D Initiatives

7.1. Rapidus Corporation

The establishment of Rapidus, a group of Japanese businesses collaborating with IBM Research to develop 2 nm semiconductor technology in Japan, constitutes the flagship project of METI's strategy to revive the national chip industry, and simultaneously the beginning of the U.S. cooperation pillar of the ministry's policy. To take advantage of this exceptional opportunity for international collaboration, Japanese high-tech and financial companies, including as Toyota, Sony, NTT, NEC, Kioxia (Toshiba), Softbank, Denso, and Mitsubishi UFJ Bank, are members of the consortium. Interestingly, a high number of consortium

participants are major chip buyers, and it is anticipated that they would provide the consortium's initial market for its output. (Shivakumar, Wessner and Howell, 2023) Recognizing the growing demand for AI and data centers, where vast data processing is needed, these efforts should propel Japan to prominence in the world semiconductor market, particularly in innovative nanoscale techniques (Hou and Thiagarajan, 2023).

As I have previously mentioned, this project is the most essential aspect of Japan-U.S. collaboration, since the U.S. is increasingly considering Japan as a viable alternative to China for chip production, despite higher costs. This perspective is largely driven by Japan's exceptional expertise in the tools and materials essential for advanced chip manufacturing, with Japanese suppliers often leading the world in their specialized areas. These areas of specialization include but are not limited to EUV lithography, semiconductor materials and 3D chip packaging (Kaur, 2023a).

While Rapidus is positioned as a cutting-edge foundry, it does not intend to directly compete with industry giants like TSMC and Samsung in mass-producing commodity devices. Instead, it will concentrate on niche technologies that command premium prices. Its strength lies in its ability to swiftly deliver specialized devices tailored to the specific needs of end-users; therefore, the initial production volume is expected to be modest, with forecasts indicating around 50,000 wafers per month. Although details about its customer base have not been disclosed, it is anticipated that the consortium members themselves will constitute a significant market for the new foundry's chips (Shivakumar, Wessner and Howell, 2023).

The Canadian startup Tenstorrent and a Japanese government-backed semiconductor research group will collaborate on the design of the latter's first cutting-edge AI chip. Tenstorrent announced at a joint ceremony in Tokyo that it will co-create the entire chip and license its design for a portion of Japan's AI accelerator. (Rapidus, 2024) With the intention of manufacturing the jointly built AI chips at Rapidus' facilities, the Tenstorrent agreement has the ability to further these efforts. (Lee and Savov, 2024)

The international strategy of Rapidus is not limited to just North America however, as the company and the Belgian IMEC have decided to establish a wide strategic relationship on the European front. Rapidus will be a key component of IMEC's advanced nanoelectronics initiative, which is financially supported by METI and the European Commission in addition to the regional government of Flanders. The partners will concentrate on important enabling technologies, such as EUV lithography, which is crucial for semiconductor production at the 2 nm node. Additionally, IMEC has a close working partnership with the Dutch ASML, which is the only supplier of EUV equipment in the globe at the moment. For its Hokkaido facility,

Rapidus has already obtained a commitment for ASML EUV tools (Shivakumar, Wessner and Howell, 2023).

After thoroughly examining several possible locations throughout Japan, Rapidus decided to situate its manufacturing in Chitose, which is on the northern main island of Hokkaido. The ‘Hokkaido Valley’ concept is widely supported, as it is viewed as a center for the convergence of domestic and foreign businesses to further the development of Japan's technology sector. Rapidus expects the ‘Hokkaido Valley’ to draw in foreign investment and act as a catalyst for long-term economic development in a number of different industries, which is in line with the Hokkaido regional government's efforts to draw in enterprises from the digital industry (Japan External Trade Organization, 2024).

The government’s flagship project however is not void of criticism, as Kenichi Ohmae has stated that foreign companies are taking advantage of the country’s willingness to subsidize their expansion, consequently taking on their risks, which will eventually result in enormous losses. IBM, for instance, according to him, would invest in their own equipment to produce 2 nm chips if it was truly profitable, but by outsourcing manufacturing to Rapidus Corporation, they can avoid the commitment and the potential risks. He also elaborates that IBM and other foreign companies will be reluctant to send their executives and engineers to Japan, due to a variety of factors, even though Japan is facing a shortage in skilled STEM-related labor (Ohmae, 2023).

7.2. Leading-Edge Semiconductor Technology Centre (LSTC)

The Leading-Edge Semiconductor Technology Centre, or LSTC, which was founded in December 2022 as a coordinating body for semiconductor research in Japan, will facilitate the Rapidus endeavor. LSTC's research themes closely correspond with the Rapidus plan of action, furthermore, several of Japan's public research institutions will fund LSTC, including the University of Tokyo; Riken, a sizable government-funded scientific research facility, and the National Institute of Advanced Industrial Science and Technology (AIST). LSTC is also serves as a platform to foster international research collaboration (Shivakumar, Wessner and Howell, 2023).

As a global center for scientific research and development, LSTC will provide new technologies for next-generation semiconductors to meet the demands of both the domestic and international market. Furthermore, it is anticipated that IMEC and LSTC would work together

on cutting-edge semiconductor technology (Tomoshige, 2023). The research and development center will focus on developing advanced semiconductors that are even more precise than the 2 nm semiconductors that Rapidus plans to produce. Additionally, the center will work on developing chips for AI, which can instantly process vast amounts of data and images, such as in autonomous driving and robotic applications. The center will collaborate with Tenstorent as well in the field of AI (NHK – Japan Broadcasting Corporation, 2024).

In 2024, LSTC was chosen by METI to be the organization in charge of implementing the ‘Post-5G Information and Communications System Infrastructure Strengthening Research and Development Project.’ The development of advanced semiconductors for the 2 nm generation and beyond will get funding from the Ministry totaling 45 billion JPY (297 million USD). More precisely, LSTC will be focusing on two research themes: ‘Beyond 2 nm Generation Semiconductor Technology Development’ and ‘2 nm Generation Semiconductor Chip Design Technology Development’. From the total of 45 billion JPY, METI would allocate 28 billion JPY in support to the former and 17 billion JPY to the latter (Asai, 2024).

Other than promoting international research collaboration, LSTC will also serve as a facilitator for academic and professional exchange, as young Japanese graduates and researchers will be sent to several key companies or universities abroad, like IBM in New York City or IMEC in Leuven (PingCode, 2023). This project is key in developing the high-value human resources of Japan, however whether or not there will exist an adequate amount of such young talent in the long-run due to Japan’s demographic crisis remains to be seen.

7.3. Jisso Open Innovation Network of Tops 2 (JOINT2)

The JOINT2 consortium, consisting of 12 companies that create semiconductor packaging materials, substrates, and equipment, began operations on October 1st, 2021, and is based at the Showa Denko Materials Packaging Solution Center in Kanagawa Prefecture, with the goal of establishing next-generation semiconductor packaging technologies, including 2.5D and 3D packaging, as well as evaluation technologies (Resonac, 2021). JOINT2 is part of the ‘Post-5G Information and Communications System Infrastructure Strengthening Research and Development Project/Development of Advanced Semiconductor Manufacturing Technology’ – a project funded by the New Energy and Industrial Technology Development Organization (NEDO) (Murao, 2023).

The consortium was launched by Resonac, a new company that was established by incorporating Resonac Holdings, the controlling firm, Showa Denko, and Showa Denko Materials (previously Hitachi Chemical). By merging, together they possess the largest global market share for specific semiconductor materials (Eguchi, 2023). Due to the ongoing partnerships amongst semiconductor manufacturers, the business environment is changing to a degree that mergers and acquisitions in the materials sector are required. Currently, Resonac is in a position to lead in terms of sales volume thanks to the merging of Showa Denko and the former Hitachi Chemical. As per the findings of the June 2022 survey ‘Current Status and Future Outlook of the Semiconductor Materials Market in 2022’ conducted by Fuji Keizai, the global semiconductor materials market, comprised of 30 items, is expected to expand at a compound annual growth rate of 5.2 percent until 2026 (Murao, 2022). This growth is to be taken advantage of by the JOINT2 consortium, which’s goal is to make Japan an indispensable player in the post-processing section of the value chain.

JOINT2 aims to strengthen the country’s post-processing position, however when we analyze the international structure of the value chain, it can be concluded that for instance, the U.S. possesses the ultimate goal of creating its own domestic chip ecosystem, no matter how precarious, therefore in the future it cannot be ruled out that it will no longer rely on Japan for equipment and materials (Chiang and Jingyue, 2023). Exports to China do not even come into question since they were regulated or entirely prohibited from the very beginnings of the ‘Economic Security Promotion Act’, therefore Japan will have to remain vigilant in order to remain a leader of post-processing, the only segment of the value chain which it currently has a competitive advantage in.

8. Conclusion: Will These Exorbitant Investments Amount to Anything?

The legitimacy and efficiency of state intervention into certain key industries is a heavily contested topic, however in recent years it can be said that geopolitical as well as natural threats have led to a renewed need for targeted industrial policy in key sectors. Due to the fact that most modern technology runs on semiconductors, these microchips have been deemed a crucial resource, one that is to be protected from supply chain shocks. Furthermore, as technologies of the future will demand even more complex chips, whoever manages to develop certain breakthroughs will gain a substantial upper hand in the global market. Economic and political

power are intertwined in the international chip competition; therefore, state support of the industry is to be increasingly expected. Despite this, not all state support necessarily leads to the improvement of industries, which is why, taking the case of Japan, I concluded that the government is a necessary actor in the fostering of semiconductor R&D.

In a time of extreme competition for the expertise of leading semiconductor companies, such as TSMC or IBM, I have concluded that the government is in fact a necessary actor in fostering R&D in the chip industry, as by nature these investments are high-stakes and demand a prolonged period to commercialize, thus the financial safety net as well as incentive the government provides is a key determinant of R&D performance. It is important to note that while the intervention is not nearly as invasive or comprehensive as it is in the developmental state paradigm, it is still a key factor of the success of an industry which even allied countries are competing for dominance in.

As I have previously examined through each case study, the Japanese government's grandiose efforts to support its domestic chip industry have not gone without criticism, as Yunogami and Ohmae have observed that the mega-projects being pursued with a combination of foreign investment and billions of taxpayer money will not bring about the success wished for by the government. While the government does address the issue of Japan's lacking position in international collaboration, according to my research it has not directly designed policies that tackle the structural problems which constitute the main threats to the revitalization of its chip industry, namely the talent shortage and demographic crisis. Even though these problems are not specific to the semiconductor industry, not taking drastic measures to improve these conditions will result in the long-term unsustainability of the government's ambitions.

Furthermore, it is important to note that the primary cause of Japan's semiconductor industry's three-decade decline has been the ongoing deterioration of consumer demand of electronics, and the country is still far behind in the development and commercialization of modern technology, such as EVs, 5G or AI, in addition to the relatively weak domestic demand for these products. (Japan Enterprise (China) Research Institute, 2023). Partnering this with the directive found in the 'Economic Security Promotion Act' stating that export to China will either be limited or entirely banned, long-term demand for the products Japan plans to develop are uncertain, especially considering that other countries are taking similar measures to boost their own industry.

In spite of there being circumstances that are not addressed by the government according to my research, the strategy and initiatives still accurately recognize the strengths that differentiate Japan from other nations. By promoting the aspects of the value chain which

they already possess a competitive advantage in, Japan can secure its indispensability, while also becoming the sole provider of certain specialized chips. As they are already one of the leaders of R&D, remedying their greatest weakness, international collaboration, through heightened cooperation with foreign firms and research institutions, as well as the establishment of joint facilities will lead to an increase in global cooperation patents, resulting in overall higher quality patents.

All in all, it can be concluded that in such a key industry, government support is indeed necessary, as the market failures and risks that arise from such uncertain endeavors that are required to reach breakthroughs in semiconductor R&D discourage businesses from allocating finances towards this process. While according to some, this vast number of sums are ill advised and are fated to go to waste, however without them Japan's industry would not receive the push it needs to become a robust player in this increasingly competitive market.

Despite reaching this conclusion, I must acknowledge the obstacles which I have encountered during my research, which resulted in certain limitations that this thesis possesses. Mainly, finding Japanese data, documents and reports are what posed the most significant challenge, primarily due to the language barrier. Even though I strived to use as many Japanese sources as I could find, there is a possibility that I have not covered all key reports and opinions which would clarify the situation of the industry even further. Further limitations include the fact that certain projects are still being developed, and while it is possible to speculate on the future success or failure of these endeavors, only a limited amount of data and information is available, coupled with the impossibility to predict future developments, it would be sound to re-examine this research after one decade or so, when most of the initiatives have been set into motion and have produced quantifiable results.

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