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US-China Competing Interests in the Global Semiconductor Market: Where do the Key Players Stand?

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Abstract

The advent of deep learning models and the proliferation of the Internet of Things (IoT), computing power has become a pivotal factor influencing overall technological development, especially in the current age of AI. In this age of generative models and quantum computing, a competitive landscape has emerged, particularly between two global superpowers: the West, spearheaded by the United States, and China. This rivalry, driven by the desire to outpace and dominate the other's technological progress, has ignited a strategic competition with far-reaching consequences.

To counter China's ambitions, the United States has enforced a ban on the export of essential chip manufacturing and production tools to China. China, in turn, has responded with measures of its own. This paper seeks to offer a comprehensive analysis of this situation, focusing on the current standing of stakeholders in the ongoing chip war.

Keywords: US-China, Chip war, Semiconductors, Taiwan, Japan, South Korea, India, Advanced Semiconductor Materials Lithography

Introduction

According to Moore's Law, *"The number of transistors on a microchip would approximately double every two years, leading to an exponential increase in computing power and a decrease in cost per transistor"* (Britannica, 2023).

Artificial Intelligence, Machine Learning and Deep learning have been around for some time, with 2023 witnessing new language models, some famous ones being: -

- Generative Pre-trained Transformer 3 (GPT-3) developed by Open AI (Pilipiszyn, 2021).
- Bidirectional Encoder Representations from Transformers (BERT) developed by Google (Jacob Devlin et al, 2018).
- Robustly Optimised BERT Pretraining Approach (RoBERTa) developed by Facebook (Facebook, 2019).

While the above are for public consumption and give a minor glimpse into what the machine learning model has to offer to the world, the implications of machine learning models are far more than search engines and chatbots; today, generative models are used for the automation of tasks, data analytics, and even military technology, and this is where the latest semiconductors come into play. The primary reason why the US and China are trying to dominate the chip market, especially of the 7nm, 5nm, and smaller nodes is simply that whoever has the higher computing capability can develop advanced technology in machine learning models and

artificial intelligence and would have the upper hand in its application ranging from military application to a nations logistics to enhancing their economy. Later, China was able to develop its own Kirin 9000s 7-nanometer processor (Li, 2023) independently from the current chip giants viz.US/Taiwan/South Korea. As evidenced from the 20th National Congress CPC Report (MFA China, 2022) The People's Republic of China (PRC) aims to take significant measures to modernise the PLA.

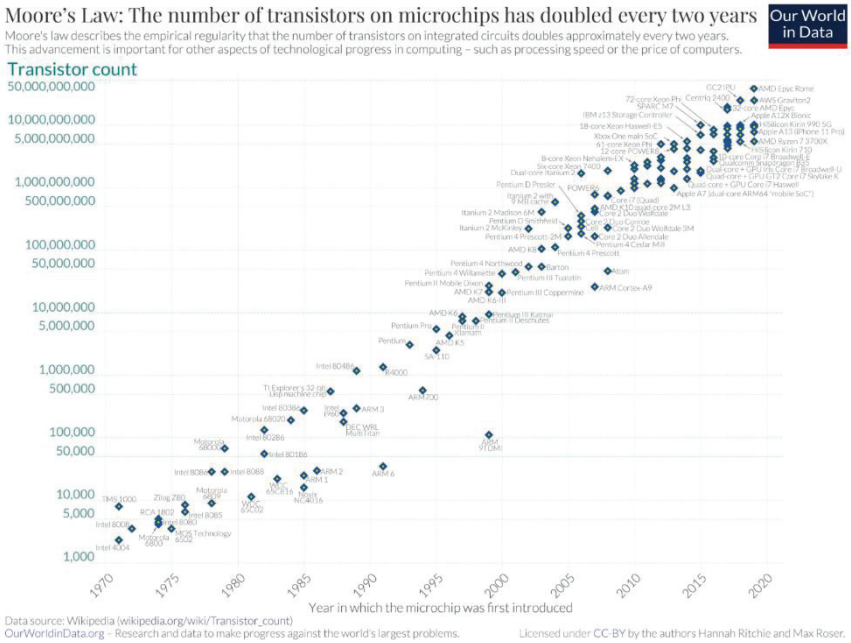
Recent sanctions imposed by the United States on China, prohibiting the sale of equipment and chip technology, may indeed mark the onset of an AI race. For years, China has heavily relied on the export of foreign chips for advanced equipment manufacturing rather than developing them domestically. However, a significant shift occurred in August 2022 when China's leading chip maker, Semiconductor Manufacturing International Corporation (SMIC), reportedly achieved a breakthrough by developing a 7nm chip comparable to those of the US and Taiwan (Pan, 2022) This development raised concerns among the Western-led front, suggesting the potential for China to produce its versions of advanced chipsets and challenge the existing US-led monopoly in the chipset industry.

This prompted the US to implement sanctions against China concerning the import and export of chipset equipment which are used to develop higher grade chips i.e. the 7nm, 5nm and further advanced variations.

Background

As described by Gordon E. Moore, the co-founder of Intel the number of transistors on computer chips doubles approximately every two years.

Figure 1: Moore's Law



Source: (Max Roser, 2023)

Every piece of advanced technology today utilises semiconductors, ranging from star-seeking telescopes to an individual's smartwatch. Ever since the advent of silicon-based chips, the technology has exponentially evolved over the years. The latest models' chips are the size

of fingernails, and the process of producing them is far too sophisticated, the most advanced process being the UV Lithography process wherein specialised optics and UV rays project patterns into a silicon wafer, thus enabling densely packed smaller chip components. The development of this technology has taken decades; while countries like the US, South Korea and Taiwan dominate the Chip industry, other countries end up importing the chips required due to lack of adequate fabrication facilities and raw materials for indigenous production.

China has been a large importer and exporter of semiconductors globally while investing heavily in developing indigenous chipsets. In 2020, China became the largest exporter of semiconductor devices valued at 35.8 bn, while at the same time, it imported $10.8bn worth of Semiconductor Devices (OEC, n.d.). This marker clearly shows China's capability in producing baseline chips but yet lacks proficiency in producing its indigenous models of 7nm and higher-grade chipsets; most of China's exported chips are produced using a 14nm or 28nm process.

To hinder China's research and development (R&D) capabilities, the US implemented a ban on the sale of technology and equipment used in the production of high-end chipsets. However, ASML, the leading authority in the field, appears hesitant to succumb to US pressure knowing fully well how the market would be affected if an outright ban were to be imposed. A spokesperson for the company conveyed the following to Global Times: *"Our business in China primarily focuses on mature nodes"* (Global Times, 2023). This indicates that most of ASML's transactions with China revolve around production methods for previous processing models, which involve the development of 14nm or 28nm chipsets.

The recent development of China-based Huawei's Kirin 9000s 7nm chipset, has only intensified US restrictions on China, thus pressing the Dutch government to take action— *"A licence for the shipment of NXT:2050i and NXT:2100i [deep ultraviolet (DUV)] lithography systems in 2023 has been partially revoked by the Dutch government, impacting a small number of customers in China".* The Chinese foreign ministry spokesperson condemned the action— "hegemonic and bullying behaviour from the US and ASML seems to be in a standstill" (Butts, 2024). Further, the paper analyses where each concerned parties stand.

US Invoked Sanctions

Ever since the US decided to invoke restrictions on the sale of high-end chip processing equipment to China, countries have shown mixed opinions on the matter. While some claim that it may eventually end up harming the chip market, and drive China, to develop 7nm to 5nm chips indigenously, however, China has shown its displeasure regarding the matter. This was further made clear by the Dutch Minister for Foreign Trade and Development Cooperation Liesje Schreinemacher when she said in a letter to Parliament that, the "*Netherlands will apply new restrictions on chip exports on national security grounds*", to which China's Foreign Ministry Spokesperson Mao Ning replied, "Such bullying acts seriously violate market principles and the international trade order" (Embassy of PRC Ethiopia, 2023).

Although the US ban on equipment will adversely affect China's development, however, China, in recent years, has heavily invested in more R & D to develop 7nm to 5nm chips of their own. The National Integrated Circuit Industry Investment Fund and Made in China 2025 are but some examples of China's effort to transform itself from a 'manufacturing powerhouse' into a 'high-tech manufacturing' leader and practice the "Internet Plus" strategy, which seeks to integrate internet technologies with traditional industries to drive innovation

and economic growth. However, recent sanctions on China by the West, adjoined by Taiwan, South Korea, and other stakeholders, may be detrimental to China's indigenous chip development efforts. The brief chart below **(Figure 2)** shows how countries are interdependent on these chips. (Hufbauer, 2022)

China, as it is now, lacks primarily two things: Advanced chip-making equipment and a partner who can sustain its high-end chip supply requirements.

The Republic of China (ROC [Taiwan])

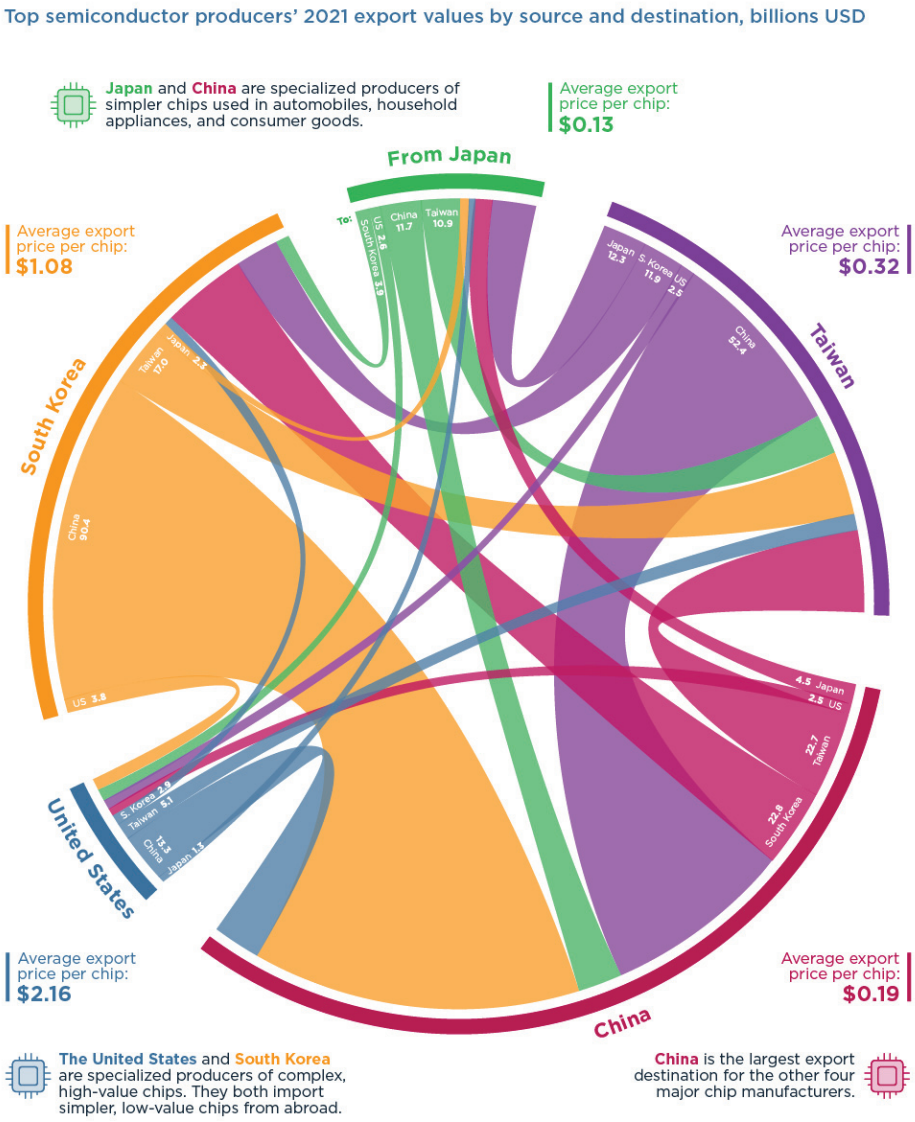


Figure 2: Top Semiconductor Producers' 2021 Exports

Source: (Hufbauer, 2022)

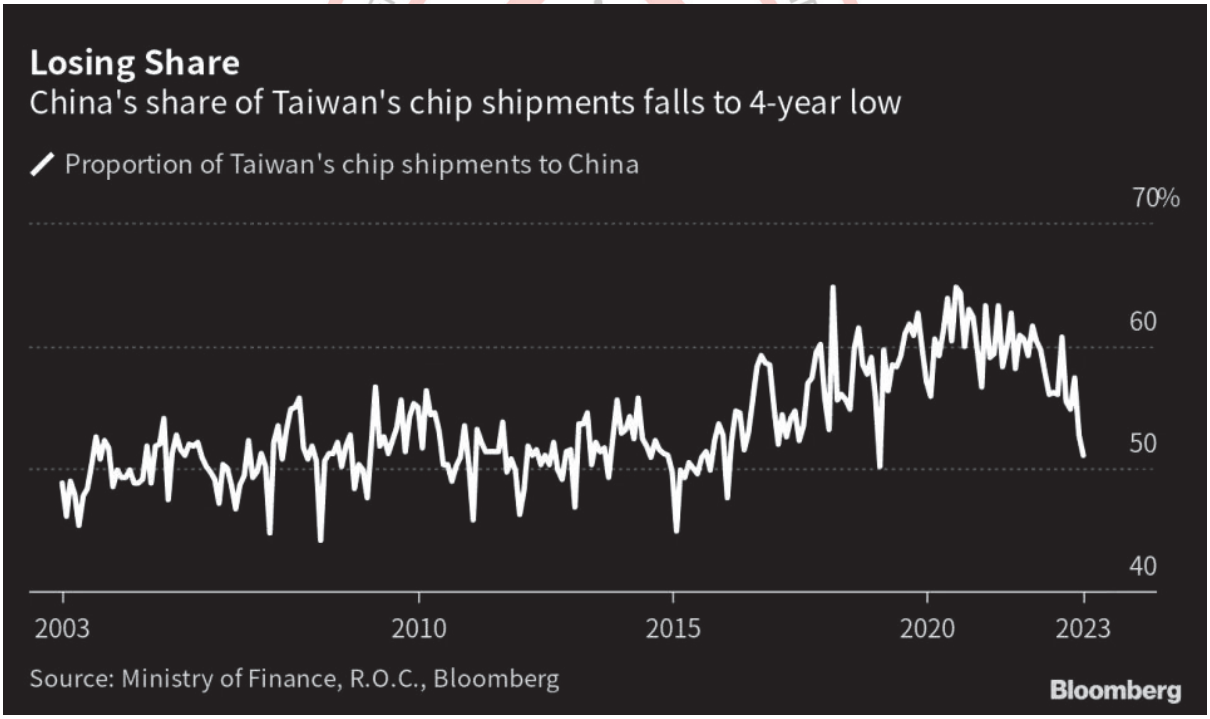
ROC or Taiwan is a critical player in the semiconductor industry, and China and Taiwan have a strenuous relationship; Taiwan's TSMC Ltd is a massive player in the semiconductor market, while China in itself has declared ROC to be a part of larger China as per its One China policy — a notion which Taiwan rejects. Taiwan's significance in the Chip industry is yet another factor as to why China is so keen on the One China policy. Despite the strenuous

relationship, in terms of the Chip industry, "China depends on the Taiwan Semiconductor Manufacturing Company (TSMC) to make up 70 per cent of the deficit. TSMC also fabricates—under contract—92 per cent of the most advanced chips designed by US semiconductor companies" (Cronin, 2022).

Although conditions have changed significantly in 2023, TSMC gains all the more importance as a key player in the production of advanced chips due to the increasing importance of AI models and deep synthesis in various industries. A steady supply of these chips is crucial for advancements in the field of information technology. Hence, the US imposing the current embargo on the sale of said chips to China is a significant decision with potential consequences on one hand, it could further deteriorate relations between China and Taiwan and on the other hand, it could provide Taiwan with greater US support against any possible military action by China. Overall, the situation is complex and fluid. It remains to be seen how these developments will play out in the long term.

In the new era where technology is becoming increasingly sophisticated, these microprocessors have become vital. A recent slump in Chip shipments to China indicates the US' influence in ROC, even more so after the recent elections wherein Lai Ching-te of the Democratic Progressive Party (DPP) was elected to be the President — a move that angered Beijing (Brian Hart, 2024).

Figure 3: Taiwan's Dropping Chip Shipments to China



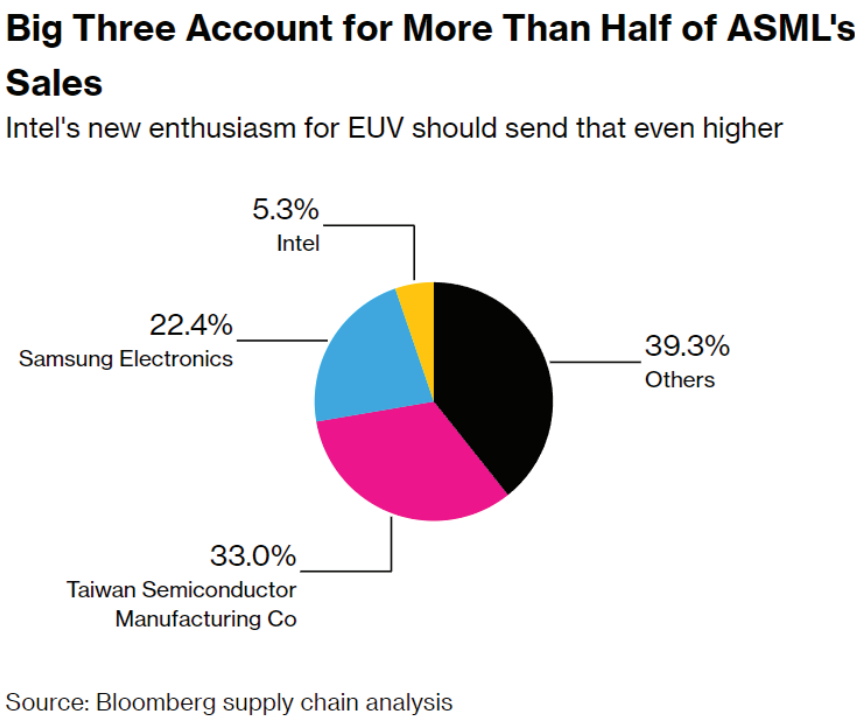
Source: (Sato, 2023)

Relevance of ASML and Lithography Machines

Advanced Semiconductor Materials Lithography (ASML) is a Dutch company specialising in fabricating Lithography machines. The equipment utilised for the fabrication process is provided by ASML; globally, their method of utilising extreme ultraviolet (EUV)

light to create intricate patterns of silicon wafers enables the production of increasingly smaller and energy-efficient microchips. After the imposed ban on chip sales, ASML has only increased its share in the semiconductor industry. The recent development of semiconductors globally relies heavily upon this Dutch company, as they are the single entity which provides optical EUV lithography systems. The following graph shows the big three, which make up the majority of ASML sales.

Figure 4: Major Stakeholders of ASML Sales



Source: (Cagan Koc et al, 2023)

The bulk of the semiconductor industry has been pushed to decouple from PRC-based fabricators and companies. Further, the Dutch government has also introduced policies to be implemented every year:

The Dutch government plans to announce new regulations with a licensing requirement for the top tier of ASML's second-best product line, deep ultraviolet (DUV) semiconductor equipment (Freifeld, 2023)

While the US is working towards introducing licenses to export equipment to about a half dozen Chinese facilities, including a fab operated by SMIC— China's largest chipmaker, the new rules may well be in effect. These steps would further work towards crippling China's access to the latest semiconductor technology and, in turn, crippling the development of advanced technology. However, many Dutch lawmakers have questioned the unilateral decision of the US to restrict chip exports to China. The trade minister Liesje Schreinemacher responded with the following "The Cabinet was not opposed to the new US rules affecting Europe's largest tech firm but this should be tackled in a much more European way" (Reuters, 2023). Furthermore, US officials reached out to ASML to block a shipment inbound for its Chinese consumer in the latter half of December 2023, further mounting pressure on Beijing's requirement for advanced chipsets. (Cagan Koc, 2024).

Japan

While Japan and South Korea's semiconductor industries are not as large as Taiwan's TSMC, however, they are crucial players in the semiconductor market the Japanese government has taken steps that will add advanced semiconductor manufacturing equipment to its list of regulated exports. Japan's Foreign Exchange and Foreign Trade Act regulates the export of equipment or goods which can potentially be used in military applications or weaponised. Japan's new export list, which had marked 23 items for export regulations, includes Etching and EUV lithography equipment, essentially prohibiting exports to countries deemed non-friendly Beijing responded with the following statement "The move is an abuse of export control measures and a serious departure from free trade rules and international economic and trade rule" (Xinhua, 2023).

South Korea

While South Korea is host to companies like Samsung and several others, which are huge players in the semiconductor and tech industry, due to its relatively economical and business-oriented model, South Korea is somewhat reluctant to enforce restrictions on the sale of its goods. While 40% of South Korea's chip exports go to China (Reuters, 2023), South Korean companies like Samsung & SK Hynix have production plants in China that essentially dominate the Dynamic Random Access Memory (DRAM) market.

In a trade-dependent economy, where 70% of the economy is dependent, China and Hong Kong account for more than 60% of South Korea's chip export market. In comparison, the US share is only 7.7% (Seong-ho Sheen, 2023). As a game of tit-for-tat, China banned Micron— a US company. China's cyberspace regulator said on May 21 that:

"Micron, the biggest US memory chip maker, had failed its network security review and that it would block operators of key infrastructure from buying from the company" (Lawder, 2023).

This, however, had a direct impact on South Korea as the US had specifically approached South Korea, before the ban, not to provide supplementary chips to China. (Sevastopulo, 2023).

US-China

The US-China chip war has been steadily escalating wherein Beijing and Washington are constantly at odds with each other due to the sanctions imposed by the USA; China has also chosen to curb the export of precious metals utilised in computer chips' "China produces around 60% of the world's germanium. It produced180 metric tons in 2022, and over 90% of the world's gallium" (Reuters, 2023). China has cited security concerns in its decision and US intends to hamper China's indigenous chip development. However, companies like US-based Nvidia had developed their version of advanced Chipsets i.e. the A800 and H800 chips; Nvidia then developed for the Chinese market which were later banned in October 2023 (Baptista, 2024).

India & Semiconductor Market

India stands to gain immensely from the ongoing Chip war the Western front aims to choke China collectively and stakeholders like South Korea have already affirmed to the US to solve the matter concerning exports to China. India is seen by the West as an emerging alternative for Semiconductor production, as evidenced by the statement released by the White House where several points of cooperation were discussed, including terms of semiconductors. It was reiterated that "Microchip Technology, Inc., to invest approximately US$300 million in expanding its research and development presence in India and Advanced Micro Device's announcement to invest US$400 million in India over the next five years to expand research, development, and engineering operations in India" (White House, 2023). In addition, US chip-making giant Micron has started construction of a $2.75 billion semiconductor factory in Ahmedabad in partnership with Tata Project and has signed an MoU with the government of Gujarat The venture is in alliance with the private as well as the government of Gujarat (Tripathi, 2023). Current investments and future projections clearly show that the West as a whole is planning to build India as an alternative Chip supplier; for example, the semiconductor plant of Micron is expected to be ready by December 2024. Owing to its strategic position, India has secured and acted upon the common interests of countries and ventured to make itself a hub for the global semiconductor market (Kushal Dev Sharma, 2024).

Conclusion

The US-China chip war is drawing the entire world into chaos that could have grave implications for the semiconductor industry; while Japan and South Korea are making efforts to put an end to this chip war, the rivalry between the US and China seems to be escalating with no common meeting ground in sight. This situation also poses the danger of China succeeding in mass-producing of 7nm chip, capturing the bulk of the chip market. While the US still dominates the market, thanks to companies like IBM unveiling its 2nm chip models and its ongoing relationship with companies like TSMC, the China factor is crucial. If China intends to encroach on Taiwan, there will be a change in the status quo. The final wild card in the ongoing tussle may well be India since, currently the US tech giants are investing heavily in Chip production plants in India. If India does deliver and seize the opportunity, then it will become a contender to China, which is a crucial exporter, and the present demand for chips may well be filled up by India.

One thing, however, is inevitable in the ensuing age of language models, machine learning and AI. The keystone which makes or breaks a path in this information age is the processors, which are integral for deploying and researching such vectors and whichever nation holds even a portion of the semiconductor industry will undoubtedly be a key player in times to come. If India were to yield results as a production hub for mass-produced chips, it would have an unquestionable role in global geoeconomics and geopolitics.

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