A Discussion on Geopolitical Risk of Taiwan Semiconductor Industry

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Abstract

Is the semiconductor industry in Taiwan a "Silicon Shield" that deters potential military conflicts? Widely believed among business elites and the general public, the concept comes from two aspects: China's dependence on Taiwanese chips for economic growth, making war in the Taiwan Strait too costly, and the reliance of the US and its allies on chip supplies from Taiwan, prompting them to deter potential geopolitical risks. However, the "Silicon Shield" concept has flaws. Neither liberalist nor realist theories guarantee a causal relationship between interdependence and peace, with liberalists ignoring realists' concerns about vulnerability issues and realists downplaying the restraining force of international trade on aggressiveness. The naive expectation of balancing also presents a flaw. Debunking this myth requires reviewing Copeland's (2015) "trade expectation theory" and hedging strategies from Southeast Asian studies. The author argues that despite the tight linkage between the US and China in the semiconductor value chain, negative expectations of trade wars and further technology restrictions may result in militarized conflicts. Hedging studies suggest that states without immediate security threats may choose to offset potential risks rather than resort to hard balancing. The US and its allies build their own domestic foundries instead of risking their soldiers' lives. The "trade expectation theory" and hedging studies show that the expectation of the "Silicon Shield" concept is overly optimistic, and a sudden trade cutoff of semiconductor products from the US may lead to militarized conflict in the Taiwan Strait.

Keywords: Taiwan, China, US-China trade war, tech war, semiconductor

"Never in the field of human conflict was so much owed by so many to so few." — Winston Churchill

Introduction

The idea of the "Silicon Shield" is widely accepted by both political elites and general publics. The concept of the "Silicon Shield" refers two inferences of how semiconductor industry in Taiwan fight against China's aggressiveness toward Taiwan. First, the "Silicon Shield" argument claims that China relies on chip supply from Taiwan to maintain its economic growth, the opportunity cost is too high to wage a war for unification. Second, Taiwan's semiconductor industry, same as oil in the 20th century, is the hub of the global value chain, the US and its allies would defend against China's hostility to protect their interest in the region(Addison 2001). Mark Liu, the Chairman of Taiwan Semiconductor Manufacturing Company (TSMC), affirmed this idea in a press interview (Stahl 2021). Yet, the idea of "Silicon Shield" of Taiwan is defected. Experts in thinktanks warmed that potential geopolitical risks remain high since the more intense US-China competition and China's ambition on Taiwan (John Lee and Jan-Peter Kleinhans 2020).

There are two aspects should be probed before we assert that the semiconductor industry can protect Taiwan from the military threat of China. The concept of "Silicon Shield" consists both realist and liberalist perception of interdependence and war. The first aspect is the causal relationship between the interdependence and interstate conflicts. This aspect discussed whether semiconductor industry in Taiwan directly cause the cross-strait conflict. Studies on interdependence and war remains uncertain since liberalist and realist perceive interdependence differently. Liberalist studies argue that interdependent reduces the possibility of conflict because of opportunity cost, while realists claim that vulnerability increase the possibility of conflict as well (Barbieri

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1996; Gartzke and Li 2003; Maoz and Russet 1993). Therefore, the first aspect of analysis discusses in what extent that China may utilize its military power to resolve its vulnerability problem. The second aspect is indirect and passive. It discussed whether the third pary would choose balancing or hedging strategy to the geopolitical risk of semiconductor value chain. Do states ally against the common threat, or they tend to save their own skin? The alliance theory suggest that states tend to balance the threat rather than bandwagon. However, recent studies indicated that states hedge risks because the security commitment of balancing may be too hostile to the potential threats.

Strategic Choices under Modern Bipolar System

Does Economic Interdependence Cause Conflict?

Whether economic interdependence contributes to the reduction of armed conflicts remains a contested subject. Scholars in the liberalist tradition have argued that severing trade flow could be a potent signal of resolve, compelling an opponent to reconsider and potentially avoid conflict (Morrow 1999). However, states often resist such trade cut-offs, given the significant opportunity costs involved (Barbieri 1996; Gartzke and Li 2003). These opportunity costs may be influenced by external factors such as climate change, which could escalate the likelihood of armed conflicts (Roche et al. 2020). Such exogenous factors, altering the calculation of costs, undermine the explanatory power of opportunity cost theory. Furthermore, uncertainties regarding the future can shift present evaluations of opportunity cost, rendering it an insufficient factor in the reduction of international conflict (Spaniel and Malone 2019; Malone and Spaniel 2021).

Another issue in evaluating the effect of economic interdependence on armed conflict is the asymmetry in interdependent relationships. Keohane and Nye (2012)have observed that asymmetrical interdependence may facilitate power through control over resources or the potential to affect outcomes. Such asymmetrical gains from economic interdependence may bolster military potential for one party, intensifying perceptions of a power transition (Fearon 2018; Nakano 2016). The less dependent state may exploit this asymmetry to coerce and threaten its partner, thereby heightening the risk of conflict onset (Goldsmith 2013).

Dale C. Copeland (1996; 2015) has provided a more nuanced understanding through the trade expectation theory, elucidating the complex causal relationship between interdependence and militarized conflict. This theory acknowledges the liberalist perspective that states seek economic gains from trade and are reluctant to forfeit such interdependence for conflict. It illustrates how trade agreements can diminish potential conflicts by fostering positive expectations of mutual benefit (Hegre, Oneal, and Russett 2010; Mansfield and Pevehouse 2000). Conversely, the theory also recognizes neorealists' concerns that a state's dependence may be exploited as a means of coercion (Waltz 1979; Mearsheimer 1992). It portrays economic interdependence as a potential source of both relative gains and risks, such as trade cut-offs or coercion (Copeland 1996; 2015; Goldsmith 2013). In essence, vulnerability diminishes a state's resilience to sudden changes (Keohane and Nye 2012), and the greater this vulnerability, the more insecurity a state may perceive in future international trade (Copeland 2015, 34).

In conclusion, although rival powers with strong economic interdependence may perceive negative future implications due to relative gains and vulnerability issues, interdependence can also lessen the probability of armed conflicts between rivals, owing to the substantial opportunity costs involved. This article posits that rising powers may fear trade cut-offs more than existing powers, especially if the former depends on high-tech supplies from the latter for economic growth. Consequently, any restrictions on industries such as semiconductors, imposed by the existing power, may be perceived as coercion and a threat to the security of the rising power.

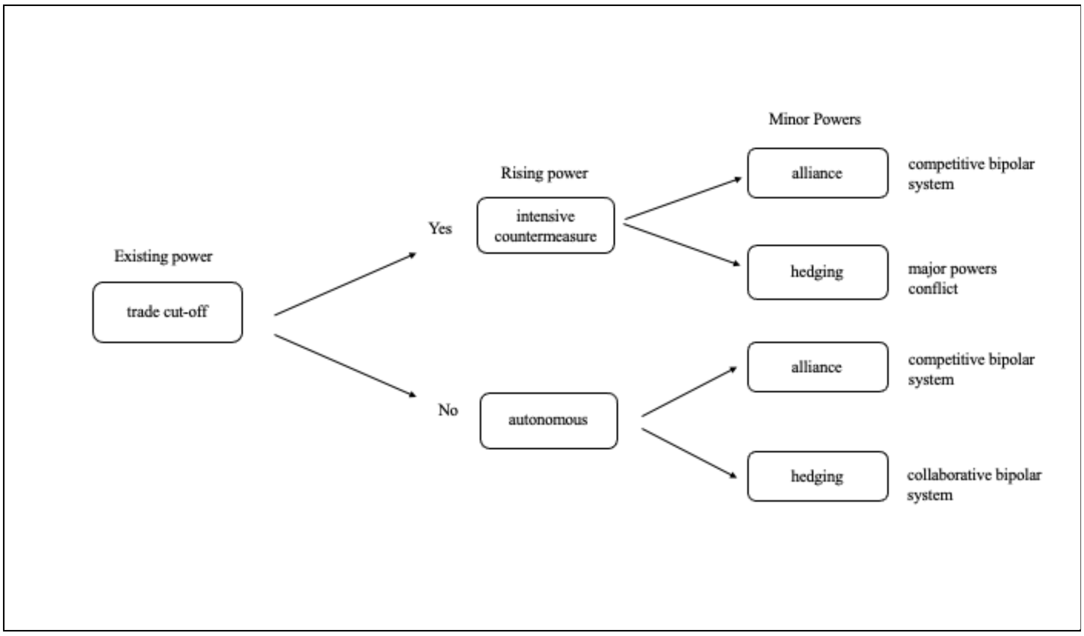

Figure 1. Major Powers' Strategic Choices

Figure 1. Figure 1 illustrates the strategic choices of emerging powers. When the established power severs trade relations with an emerging power, this action sets a negative expectation, compelling the emerging power to implement vigorous countermeasures. However, these countermeasures alone are not enough to instigate a major power conflict. This is because the established power might form alliances with minor powers to counterbalance the perceived threat. If such alliances between the established power and minor powers succeed, the likelihood of a major power conflict diminishes. This is due to the emerging power's inability to garner resources from the minor powers, ultimately leading to a competitive bipolar system. Conversely, if the minor powers employ a hedging strategy—trading with both major entities—the emerging power can amass ample resources from international trade, posing a

significant challenge to the existing power.

Maintaining trade relations between the existing power and the rising power might not inherently foster a liberal system. This is because feelings of vulnerability and negative expectations might prompt the rising power to strive for a more autonomous economic system. If the existing power forms alliances with minor powers to prevent the rising power from accessing resources and technology through international trade, a competitive bipolar system could emerge. This is due to the rising power's lack of resources, rendering it unable to challenge the existing power independently. Conversely, if the existing power fails to forge alliances with minor powers, trade relationships with the rising power would persist, and the likelihood of escalating conflict diminishes. However, the underlying vulnerability and the looming threat of potential trade disruptions might encourage the rising power to engage in trade with minor powers, thereby reducing its reliance on the existing major power.

Minor Powers: Alliance or Hedging

Alliance and Hedging are common strategies when states encounter common threats. Walt's balance of threat theory (BTT) provides a theoretical framework of alliance formation: states ally or against the most threating power, the greater the threat is, the greater possibility of alliance formation. Neorealists expect that minor powers are forced to bandwagon a major power for security under the international anarchy. BTT introduced threat perception as intermediate variables to determine which side minor powers would ally with (Walt 1985). According to BTT, minor powers typically align with the power they perceive as less threatening in order to counterbalance the more threatening power, as depicted in Figure 2. While BTT delineates a basic causal relationship between perceived threats and alliance formation, it does not fully account for the profound economic interdependence that characterizes the post-Cold War international system. Despite the uncertainties introduced by events like the US-China trade war and the Covid-19 pandemic, China remains the primary semiconductor consumer for the US, accounting for 32.82% of the US's chip exports. Additionally, China maintains significant economic ties with regional and minor powers, including Britain, Germany, and Japan. These countries provide China with cost-effective products, while simultaneously marketing their value-added products and services to the vast Chinese domestic market.

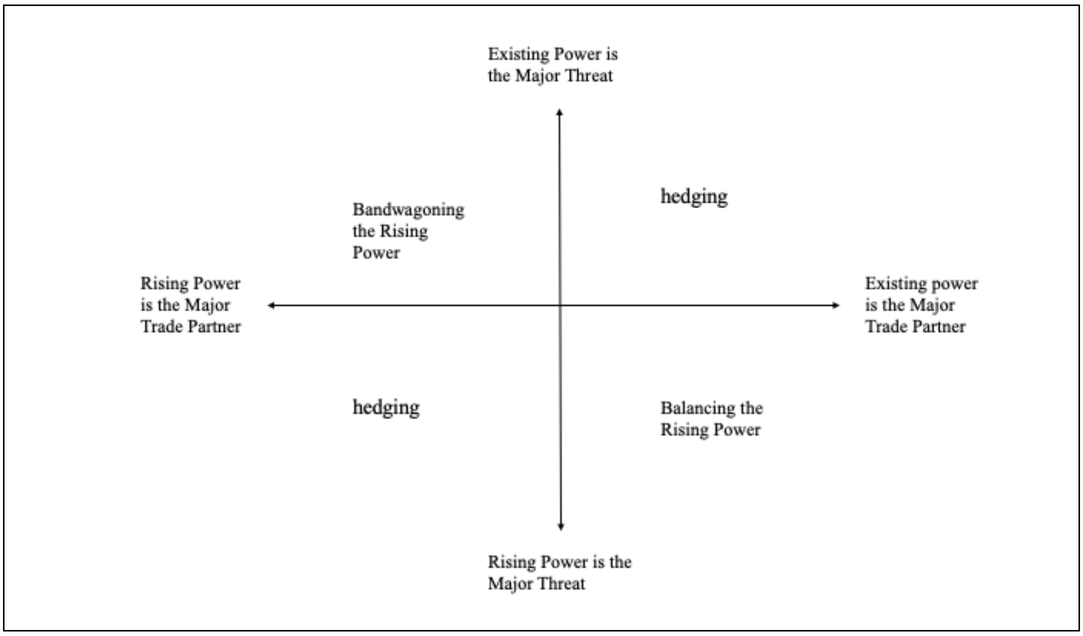

Figure 2. Minor Powers' Strategic Choices

While economic interdependence may not significantly influence the formation of alliances, it has been shown to strengthen existing alliances (D. S. Lee and Kim 2011; Skålnes 1998). This interdependence intertwines both economic and security interests among states. Major powers may be obligated to maintain security commitments to their partners, particularly if they supply essential products or commodities not found elsewhere (Brooks, Ikenberry, and Wohlforth 2012; Glaser 2013; Ikenberry 2018). Beyond these commitments, interdependence can act as a coercive tool among allies. Dominant states may employ trade with allies as rewards and use trade restrictions as punitive measures. This interdependence can also serve to solidify ties within alliances. For instance, regional trade agreements (RTAs) often restrict member states from trading with adversaries (Powers 2004). Additionally, security partnerships characterized by asymmetric interdependence are stickier; the more dependent member enjoys reduced autonomy (Sandnes 2023). As a result, economic interdependence positively impacts the robustness of an alliance; the deeper the economic ties with a less threatening major power, the stronger the bond between major and minor powers. Conversely, if a minor power has extensive economic ties with a more threatening entity, the interdependence might dilute the strength of the alliance, prompting the minor power to employ a hedging strategy.

Hedging, in international relations, is a prevalent strategy within relatively stable systems, positioned midway between balancing and bandwagoning. Unlike bandwagoning, where minor powers align with a threatening power in hopes of reaping benefits, hedging is more about risk management. Minor powers engage with both sides to establish robust cooperation, thereby mitigating the risks associated with potential conflicts between major powers (Le 2013; Kuik 2008; Roy 2005). The extent to which hedging is employed hinges on whether minor powers have alternative strategies at their disposal. States like Malaysia, Vietnam, South Korea, and Singapore operate within a more flexible strategic environment, pursuing economic cooperation with China while maintaining comprehensive security ties with the US (Ciorciari and Haacke 2019; Ji yun Lee 2017). In contrast, nations like Laos and Myanmar have limited options and tend to lean towards China due to their deep economic reliance and limited security assurances from the US (Fiori and Passeri 2015; Roy 2005; Yee and Yeung 2020). Thus, when a minor power derives both its security and economic sustenance from a threatening power, it often has little choice but to bandwagon with that dominant entity.

Semiconductor Global Value Chain

The Integrated Circuit (IC) serves as the lifeblood of the modern industrial age, encompassing electronic components found in household appliances, consumer electronics, vehicles, and aircraft. Yet, ICs cannot, on their own, be directly incorporated into these products. These chips must be integrated into electronic systems, which in turn, constitute the final products. This intricate procedure is known as the global value chain (GVC), a sophisticated production network engaging diverse actors located in multiple countries. This section offers an overview of the U.S.'s dominant role in the semiconductor GVC. The manufacturing of ICs is compartmentalized into three distinct phases: IC design, wafer fabrication, and chip assembly and testing (Figure 3). A study by the Semiconductor Industry Association (SIA) indicates that the semiconductor industry is characterized by a high degree of specialization, leveraging expertise and resources from different parts of the world.

China's information communication technology (ICT) sector, encompassing areas like artificial intelligence (AI), high-performance computing (HPC), and 5G networking, stands as a primary competitor to the US. This rivalry between the two powers transcends traditional market competition, reflecting a deeper race for strategic advantage in the future. However, the semiconductor manufacturing sector remains a significant vulnerability for China's high-tech industries. A mere 15.9% of ICs are produced domestically by local foundries (Cheng and Li 2021). China's high-tech sector heavily depends on US-designed chips manufactured by foundries in Taiwan and South Korea. While China poses competition to the US across various high-tech domains, the US continues to dominate the IC industry. Notably, 11 of the top-20 IC firms are headquartered in the US (Table 1). Moreover, pivotal components in AI and HPC servers, including the central processing unit (CPU) and graphics processing unit

(GPU), are exclusively designed and produced by US firms such as NVIDIA, Intel, and AMD. Other US high-tech giants like Broadcom, QUALCOMM, and Marvell also hold significant market shares in chips for specific applications. [1] Among Chinese semiconductor companies, only the Semiconductor Manufacturing International Corporation (SMIC) features in the top-20 list, ranking as the fifth-largest foundry service provider globally. Yet, despite its market positioning, SMIC faces challenges in wafer fabrication, primarily due to a lack of domestic expertise and technological restrictions imposed by the US government.

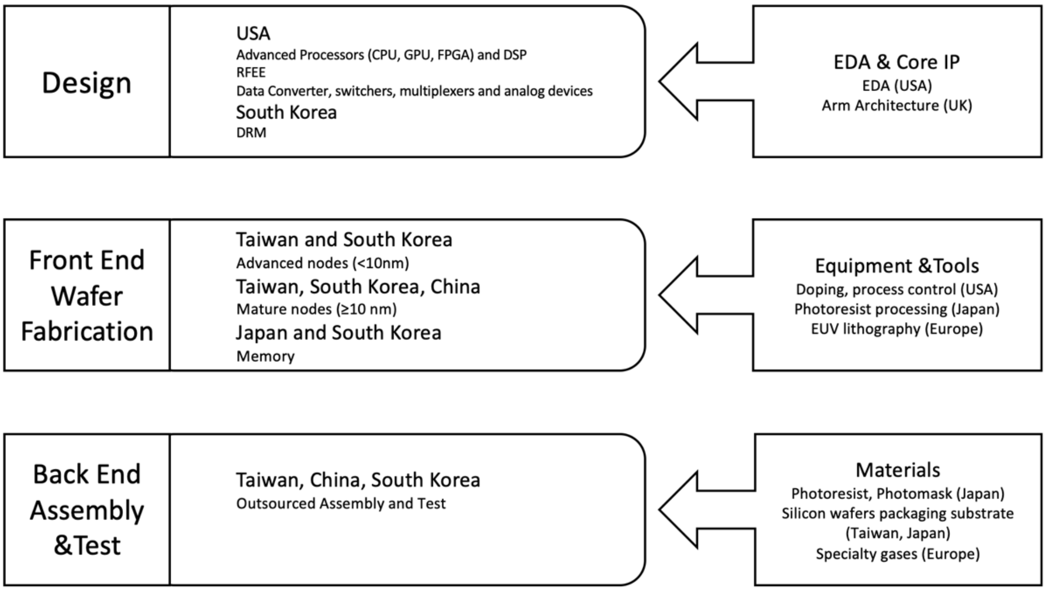

Figure 3. Semiconductor Global Value Chain

Source: (Varas et al. 2021)

[1] Chips that are tailored for particular uses are termed "application-specific integrated circuits" (ASICs). Contrary to general-purpose ICs, an ASIC is designed for a specialized function, be it data processing, high-efficiency video decoding, or digital to analog conversion.

Table 1. Top 20 Semiconductor Companies

Company Name	Market Capitalization (Billion USD)	Headquarter	Product/Service	Company Type
TSMC	614.07	Taiwan	ICs manufacturing services	Foundry
NVIDIA	493.79	US	Logic ICs design/ Cloud Computing/ Artificial Intelligence solutions	Fabless
ASML	319.43	Netherlands	Photolithography system	Equipment & Tool
Intel	219.32	US	Logic ICs design/ Cloud Computing/ Artificial Intelligence Solutions	IDM
Broadcom	199.71	US	ICs/ Cable Converter Boxes/ Gigabit Ethernet	Fabless
QUALCOMM	166.89	US	CDMA/WCDMA chips	Fabless
AMD	136.53	US	Logic ICs design/ Cloud Computing/ Artificial Intelligence Solutions	Fabless
NXP Semiconductors	58.05	Netherlands	Automotive ICs/ Audio ICs/ Communication Infrastructure Product	IDM
MediaTek	53.84	Taiwan	Smartphone/ 5G/ IOT ICs design	Fabless
Infineon	51.50	Germany	Microcontroller/ Communication ICs	IDM
Marvell Technology Group	50.27	US	Data Process Unit (DPU)/ ASIC/ Storage	Fabless
Synopsys	44.12	US	Interphase IP/ Processor IP/ Analog IP	Fabless
SMIC	36.09	China	ICs manufacturing services	Foundry
Xilinx	36.01	US	FPGAs	Fabless
Skyworks Solutions	31.08	US	Wireless Communication Technology	Fabless
United Microelectronics	26.46	Taiwan	ICs manufacturing services	Foundry
Qorvo	21.72	US	ICs Design, GaN, GaAs foundry manufacturing and service	IDM
Renesas Electronics	21.50	Japan	Microcontroller, analog power management	IDM
ASE Group	19.87	Taiwan	Chip packaging service	Assembling and testing
ON Semiconductor	19.38	US	Power and signal management	IDM

Source: Companie Marlet Cap (2021)

IC Designs and IP core

The U.S. holds a predominant position in the IC design industry, not solely because of its world-leading IC design firms but also due to its role as the primary provider of Electronic Design Automation (EDA) tools and core Intellectual Properties (IP cores).

Both U.S. and European companies lead the charge in R&D and IP core development, accounting for 94% of EDA and IP cores and 75% of logic chip design. Chinese IC design companies, conversely, tend to specialize in semiconductor applications like the Internet of Things (IoT) and AI. However, these applications heavily rely on EDA tools and IP cores sourced from U.S. companies, which occupy 90% of China's domestic EDA tools market (Gao 2021).

EDA tools and IP cores are foundational to the IC design industry. EDA tools comprise software applications that assist IC design engineers in the creation and testing of ICs via Computer-Aided Design (CAD). Without reliable EDA tools, engineers would be unable to design functional chips, leading to significant losses for companies. Serving as the backbone of the semiconductor industry, EDA tools were often developed by U.S.-based universities and high-tech corporations, frequently supported by funding from the Defense Advanced Research Projects Agency (DARPA), a research arm of the U.S. Department of Defense (Sangiovanni-Vincentelli 2003). Two American entities, Synopsys and Cadence, dominate with market shares of 32% and 30% respectively, while the German tech giant, Siemens, commands a 13% market share (TrandForce 2022).

IP cores determine a chip's functionality. Some IP cores provide the logical blueprint for an IC, like the ARM or x86 architecture, while others impart specific features to an IC, such as AI capabilities or graphics acceleration. CPUs in personal computers and data centers primarily utilize x86 instruction set architectures, a creation of Intel from 1978. The mobile processor market is more concentrated. Major players include Mediatek, Qualcomm, Apple Inc., Samsung, and Hisilicon, a Huawei subsidiary. Yet, all mobile processors are fundamentally designed using the ARM architecture, originally developed by the British semiconductor firm, ARM.

Front-end Wafer Fabrication

Front-end wafer fabrication stands as the most critical segment of the semiconductor industry, characterized by two distinct paths: advanced nodes and mature nodes. Advanced nodes are typically employed in logic ICs, including CPU, GPU, ASIC, and FPGA, due to their superior performance and power efficiency. In contrast, mature nodes are commonly used in chips executing straightforward commands, like microcontroller units (MCU). However, they are ideally suited for power components (power ICs) due to their aptitude for high current and high voltage applications. Even though mature nodes might seem outdated for logic IC fabrication, the rising demand for electronic vehicles has led to a resurgence in the need for power ICs.

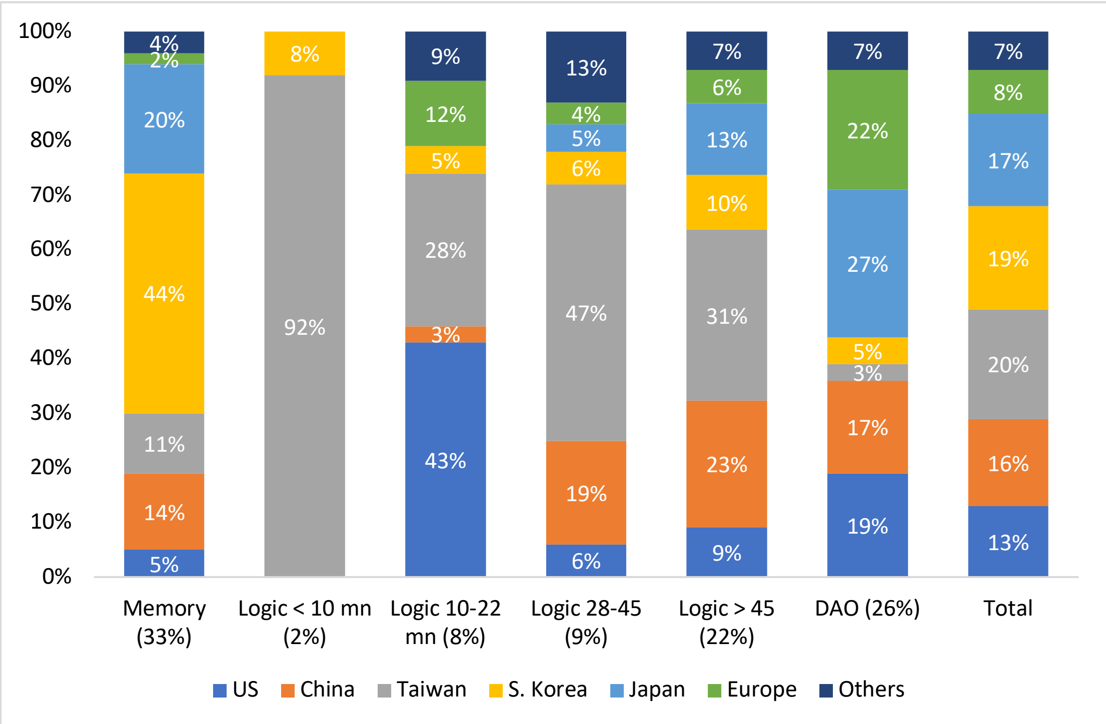

Figure 4. Global Wafer Fabrication Capacity by Region

Source: (Varas et al. 2021, 35)

In a keynote address by Lisa Su, the CEO of AMD, she highlighted that process technology accounts for 40% of performance and efficiency improvements (Su 2019)..The advanced nodes foundry industry is profoundly capital-intensive, both in terms of physical infrastructure and human resources. The market for advanced nodes reflects a unipolar structure, with Taiwan commanding an impressive lead (as illustrated in Figure 4). In 2020, TSMC's annual capital expenditure stood at 17.2 billion USD, of which 3.72 billion USD was allocated to R&D (Taiwan Semiconductor 2021). Further underscoring its commitment, TSMC has announced plans to invest 100 billion USD in advanced foundries over the coming three years, aiming to cater to the burgeoning demand for mobile chips (Yeh 2021). In comparison, Samsung is set to invest 5.28 billion in advanced nodes manufacturing, with a projected investment of 151 billion by 2030 (Hwang and Lee 2021).

Although Taiwan and South Korea dominate the production of advanced nodes, they are heavily dependent on equipment imported from the US and Europe, as well as chemicals from Japan. The foundries' value chain, much like that of chips, is characterized by global specialization. Central to advanced wafer fabrication is the extreme ultraviolet (EUV) lithography machine. Priced at 180 million dollars each, these machines are exclusively manufactured by the Dutch tech company, ASML. The creation of each EUV lithography machine involves inputs from over 5,000 specialized technology suppliers spanning Europe, the US, and Japan. Beyond lithography machines, critical machinery and technical services for advanced wafer fabrication are also supplied by US and Japanese companies. Notable among these are Applied Materials, KLA Corporation, and Canon. The role of Japan's photoresist supply in this ecosystem cannot be understated; it's as indispensable as the EUV lithography machines from the Netherlands. Four Japanese giants - JSR Corporation, Tokyo Ohka Kogyo (TOK), Shin-Etsu Chemical, and FUJI Film - collectively command a market share of 72.5%. An additional 11% of the market is held by the American chemical conglomerate, DuPont (Research in China 2021).

The semiconductor landscape reflects the technological ambitions, strategies, and political environments of the major players involved. While the United States remains a formidable force in the advanced wafer fabrication space, China is making concerted efforts to grow its domestic semiconductor industry. The US holding a significant 43% of the 10-22 nm wafer fabrication predominantly comes from Intel's production. Intel, recognized as a leader in logic IC manufacture and integrated device manufacturing (IDM), still holds sway in the x86 desktop and high-performance computing (HPC) segments, even as it grapples with delays in its 10 nm wafer fabrication (Figure 4).

China's semiconductor efforts reflect its broader technological ambitions and a drive for self-sufficiency. Though the nation holds a relatively smaller share in the advanced node space, it is increasingly gaining ground in mature nodes, with market shares of 19% in 28-45 nm and 23% in >45 nm wafer fabrications. This rise can be attributed to significant state support, evident in Beijing's policy initiatives. The policies by the Chinese government – tax reductions, low-interest loans, and direct subsidies – aim at accelerating the growth of its domestic wafer foundries and equipment suppliers.

These policies, as stated by The State Council of the People's Republic of China in 2020, underpin China's broader ambition of achieving technological self-sufficiency and reducing its dependence on foreign-made semiconductors. The massive subsidies, amounting to 211.6 billion RMB (approximately 32.5 billion USD) for over 4000 listed companies in 2020, are a testament to this effort. Notably, the state-owned IC behemoths, SMIC (中芯國際 Zhongxin guoji) and BOE Technology Group (京東方 Jingdongfang), received subsidies of 2.5 billion and 2.3 billion RMB, respectively, highlighting their critical roles in this national endeavor. As the global technological landscape continues to evolve, the semiconductor industry remains central to geopolitical strategies, economic growth, and technological innovation. The dynamics between leading nations like the US and China, in particular, will likely shape the future direction of this pivotal industry (Liang 2021).

Back-end Assembly and Test

Back-end assembly and testing, commonly referred to as packaging and testing, is an intensely competitive domain. Taiwanese firms are at the forefront of this business, with six of them featuring among the global top 10(Wang 2019). Since packaging and testing are relatively mature segments, several companies have established facilities in Southeast Asian countries, including Malaysia, Vietnam, and the Philippines (Varas et al. 2021). As advancements in node technology push transistors closer to their physical size limitations, hindering further progress in high-performance chip development, there is a growing emphasis on advanced packaging technologies. Solutions such as TSMC's 3DFabric and Samsung's X-Cube have emerged to address these physical constraints.

The semiconductor industry's landscape has evolved over the past three decades. Generally speaking, front-end wafer fabrication operates on a hub-and-spoke model. Even industry leaders like TSMC rely heavily on machinery and technological services from European, Japanese, and American firms. The US continues to be the linchpin of the semiconductor industry, dominating in IC design and IP core sectors. Meanwhile, East Asian nations, particularly Taiwan and South Korea, have established themselves as manufacturing powerhouses since the 1990s, excelling in wafer fabrication and advanced packaging. Emerging markets, such as Malaysia, Vietnam, and the Philippines, are steadily enhancing their IC manufacturing prowess to achieve their export growth targets. Conversely, China's efforts to cultivate domestic manufacturing capabilities face challenges, especially given restrictions on advanced technology support due to concerns over its human rights record and alleged unfair competitive practices. The technological rivalry between the US and China will be explored in the subsequent section.

The Rivalry and Perception of IC Industry

China: Overcoming the Technology Restriction

Since the arrest of Meng Wan-zhou, CFO of Huawei, and the imposition of a $1.7 billion fine on ZTE by the US government, China has grown wary of potential technological sanctions from the US. This stems from the extensive dependency of the Chinese ICT sector on chip supplies and technological assistance from American firms. Recognizing the lack of domestic chip manufacturing capabilities – encompassing wafer fabrication, chemical materials, and EDA tools – China views this deficiency as a potential national security threat. To mitigate these concerns, the Chinese government has invested heavily to circumvent technological constraints imposed by the US. This section will evaluate China's potential to establish a self-sufficient semiconductor industry.

In response, the Chinese government has implemented a series of supportive measures, including tax reductions, subsidies, and recruitment initiatives to bolster the domestic semiconductor sector. For instance, foundry services can avail tax exemptions for a period ranging from one to ten years, as outlined in Table 2. In addition to foundries, the government has extended tax incentives to IC design firms, EDA tool providers, essential equipment manufacturers, and assembly and testing enterprises. Beyond these tax incentives, the state has facilitated access to long-term loans and financial derivatives via state-owned banks. Furthermore, local governments have been directed to introduce guarantee mechanisms to counterbalance the financial risks associated with these loans. (The State Council of People's Republic of China 2021).

Table 2. Tax-reduction on Foundries

Processing Nodes	Year	Tax Reduction
< 130 nm	1st — 2nd	100%
	3rd — 5th	25%
< 65 nm	1st — 5th	100%
	6th — 10th	25%
< 28 nm	1st — 10th	100%

Source: (The State Council of People's Republic of China 2021)

China has also sought to bolster its semiconductor sector through increased domestic investment. In 2014, the Chinese government set up the National Integrated Circuit Industry Investment Fund (國家集成電路產業基金 Guojia jicheng dianlu chanye jijin), commonly referred to as the "Big Fund." This initiative aims to provide strategic investments to emerging IC ventures. Available data indicates that the first phase of the Big Fund's investments totaled 96.439 billion RMB (approximately 14.92 billion USD), while the second phase accounted for a substantial 204.2 billion RMB (around 31.6 billion USD). Both phases were spearheaded by the Ministry of Finance and the China Development Bank Capital (國開金融 Guokai jinrong), in collaboration with both central and provincial state-owned enterprises (SOEs).

This state-driven initiative is discerning in its investment choices. With an objective to address the gaps in the IC industry, the Chinese government strategically channels resources into the financial sector. The chip manufacturing segment claims the lion's share, absorbing 67% of the total investment, while IC design encompasses 17% (Wang 2019). Notably, three of the top five Big Fund investments have been directed towards wafer fabrication, as outlined in Table 3. Beyond addressing existing deficits, the Big Fund also prioritizes the advancement of novel technologies. One such area of focus is the development of SiC/GaN compound semiconductors, pivotal for power management systems in electric vehicles.

Table 3. Top 5 Companies with the Big Fund Investment

Ranking	Company	Type	Scale Million USD	Percentage
1	San'an Optoelectronics	IDM	1000	4.6%
2	JCET	Package & Test	760	3.5%
3	Goodix Technology	Fabless	440	2%
4	Huahong Group	Foundry	400	1.8%
5	SMIC	Foundry	400	1.8%

Source: (Wang 2019)

The Big Fund has adopted various strategies to financially support Chinese IC firms. These include:

1. Facilitating cross-border mergers and acquisitions;
2. Enabling mergers and acquisitions through private placements;
3. Shareholder buyouts; and
4. Pre-initial public offering (IPO) investments.

Compared to domestic ventures, state-led overseas mergers have been met with some contention. For instance, JCET, a Chinese packaging and testing company, acquired STATS ChipPAC, a considerably larger Singapore-based package and test firm. This acquisition, bolstered by the Big Fund, elevated JCET to the position of the third-largest package and test company in the global market (García-Herrero and Weil 2023). Yet, even with governmental backing, the Big Fund has faced criticism for inefficiency and allegations of corruption. Despite the multi-billion dollar investments, the fund has not been successful in enhancing China's advanced semiconductor manufacturing capabilities. Furthermore, several managers of Chinese SOEs and the Big Fund's general manager came under investigation by the Central Commission for Discipline Inspection (CCDI) (Goh 2022).

The talent deficit remains a significant challenge for China's semiconductor industry. Recent reports suggest a looming shortfall of over 200,000 professionals in the upcoming years. Although more than 210,000 microelectronic engineering graduates enter the job market annually, a mere 13% opt for the semiconductor industry, primarily due to subpar compensation. University graduate salaries average around $2,194 monthly, while R&D engineers earn approximately $5,500 per month—significantly less than their counterparts in the U.S. (Yuan 2023; Liu 2019). To address this, the Chinese government has attempted to introduce policies to bolster the talent pool in the semiconductor sector. This includes the establishment of semiconductor research facilities in universities and research institutions (State Council of the People's Republic of China 2020). However, challenges persist, especially given the limited R&D investments and time constraints.

The United States: Maintaining the Leadership

The U.S.-China semiconductor trade relationship remains tense, yet the robust competition stemming from China's rise has heightened U.S. concerns regarding its global leadership and national interests. As Steve Bannon, a chief advisor during the Trump Administration, remarked, "the center core of what we believe is that we're a nation with an economy" (Sarlin 2017). The U.S. has accused China of enforcing unfair technology transfers and violating the International Emergency Economic Powers Act (IEEPA) by exporting U.S.-origin technology to Iran. While the trade conflict marked the onset, the U.S. escalated it to a strategic contestation rooted in national security concerns.

U.S. sanctions targeted major Chinese tech companies like Huawei and ZTE, alleging that these military-affiliated tech giants not only relayed sensitive information to the Chinese Communist Party but also bolstered the Chinese military capabilities through their 5G technologies (Brustein 2019; King, Bergen, and Brody 2019; Vergun 2019b; 2019a). The Trump administration also urged the Dutch government to revoke China's €150 million EUV equipment procurement, aiming to hinder its IC manufacturing capabilities (Alper, Sterling, and Nellis 2020). Beyond technology restrictions, U.S. law enforcement agencies clamped down on alleged illicit Chinese recruitment and corporate espionage, viewing such actions as threats to the U.S.'s economic interests and national security. Since 2015, the U.S. Department of Justice (DOJ) has charged numerous scholars with tax and grant fraud (United States Department of State 2021). Building upon Trump's policies, the Biden Administration intensified the competition with China. Beyond continuing the EUV prohibition, they sought to deny export licenses for Deep Ultraviolet (DUV) lithography machines to China, a technology typically used for >7nm nodes (Shin et al. 2021).

Post the COVID-19 pandemic, perceptions of economic and political security have grown increasingly negative. First, U.S. semiconductor industry leaders cautioned the Biden Administration about the vulnerabilities of the U.S. chip sector, notably evident during the pandemic-induced chip shortages. They advocated for enhanced investment in semiconductor manufacturing to preempt future challenges and to sustain industry leadership. The chip scarcity not only jeopardized the modern weapon systems but also stifled innovation and job creation potential (The White House 2021). Second, China's ambitious Made in China 2025 (MIC) initiative was perceived as a challenge to U.S. supremacy, largely due to alleged unfair competition. The U.S. criticized the MIC 2025 and other Chinese policies for ostensibly favoring Chinese firms, disrupting global trade and investment flows, broadening China's global influence, and enhancing its technological and military prowess (Sutter 2020).

To fortify supply chain resilience, President Biden issued an Executive Order to bolster the domestic manufacturing sector, earmarking $50 billion for semiconductor research and production in the $2 trillion infrastructure investment package. This bill, swiftly backed by Congress and the chip manufacturing industry, facilitated the CHIPS Act which allows U.S. governmental support for domestic semiconductor R&D and production. For instance, the U.S. Department of Defense granted $30.4 million to Lynas' light rare earth projects in Australia and Malaysia, which collectively account for nearly 25% of the global rare earth element supply (U.S. Department of Defense 2021). Departing from Trump's "America First" approach, the Biden Administration aims to forge robust collaborations with allies, emphasizing shared values to collectively strengthen economic and national security (The White House 2021).

Despite the consensus between U.S. policymakers and business leaders on asserting technological dominance over China, the semiconductor interdependence between the two countries remains significant. U.S. IC exports to China soared to an all-time high in 2021, with imports remaining consistent. Even amidst strategic tensions, American firms are reluctant to relinquish the lucrative Chinese market. Companies specializing in AI, such as Nvidia and Intel, have tailored products for the Chinese market to circumvent U.S. export restrictions (Nellis, Stephen and Lee 2023; Kaur 2023). Intensifying sanctions against China poses challenges for the U.S., given the substantial revenues U.S. firms garner from the Chinese market. Remarkably, in 2022, approximately 70% of products on the U.S. Department of Commerce's Entity List received export approvals to China (Shepardson 2023). Broadly, the U.S.'s strategy hinges on bolstering IC manufacturing prowess while adeptly navigating the intricacies of U.S.-China competition.

Table 4. US–China Integrated Circuit Trade (billion USD)

Year	Export	Import
2013	3.89	2.01
2014	4.48	1.82
2015	5.01	2.00
2016	5.18	2.23
2017	5.29	2.75
2018	6.10	3.20
2019	8.15	1.58
2020	10.16	1.80
2021	12.27	2.36
2022	9.42	2.61

Source: UN Comtrade (2022)

Does the "Silicon Shield" Work?

Bob Work, the former Deputy Secretary of Defense, asserted, "We believe we are just 110 miles away from losing access to the majority of cutting-edge microelectronics, which are integral to numerous enterprises and our military" (Harper 2021). The technology rivalry between the U.S. and China appears inevitable, given that the U.S. perceives China's military capabilities and intentions as threats to its economic security. For smaller powers, the decision to either balance or hedge is contingent upon the immediacy and intensity of security threats.

Japan

In the context of East Asian Countries (EACs), balancing emerges as a predominant strategy, primarily because these nations, which are vital to semiconductor manufacturing, view China as a significant security concern. For instance, Taiwan has perennially faced threats from thousands of ballistic missiles and rockets, especially since Beijing has yet to renounce its objective of a "peaceful unification" via militarized means (Murray 2008; Zhao 1999). Japan, a pivotal player in the Information and Communication Technology (ICT) sector and semiconductor manufacturing, perceives an increasing threat from the hegemonic contest between the U.S. and China. During a meeting in Washington between President Biden and Japanese Prime Minister Yoshihide Suga, both nations pledged to collaborate on the development of innovative semiconductor manufacturing technology (Nekkei Staff Writers 2021). The Japanese government is actively seeking alliances with regional counterparts to counterbalance China's ascent. As part of its latest semiconductor strategy, Japan intends to channel $1.8 billion towards fortifying its domestic supply chain. Furthermore, Japan is keen on fostering collaborations with foundries and research institutes in the U.S., Europe, and Taiwan to spearhead advancements in areas like 3D packaging and innovative material technologies (METI 2021, 16–17).

South Korea

While China is viewed by South Korea as a regional concern, the two countries have maintained a more cooperative stance, particularly on the issue of North Korea. Yet, the ongoing U.S.-China rivalry has prompted a strategic recalibration in South Korea's approach. U.S. Secretary of Commerce Gina Raimondo and South Korean President Moon Jae-in have proclaimed an enhanced industrial partnership, encompassing sectors such as pharmaceuticals for Covid-19 vaccines, electric-vehicle batteries, and semiconductor production. This bilateral arrangement has been characterized as mutually beneficial. In exchange for a stable supply of Covid-19 vaccines from the U.S., top South Korean conglomerates have committed to a collective investment of $40 billion in the U.S., targeting areas like electric vehicles, batteries, and semiconductor foundries (Leonard 2021; Song and White 2021).

Furthermore, South Korea is bolstering its domestic supply chain resilience through the "K-Semiconductor Belt Strategy" (KSBS), slated for completion by 2030. Under this ambitious strategy, South Korea envisages an investment of $440 billion (equivalent to 510 trillion KRW) to be channeled into semiconductor manufacturing, research, financial backing, and infrastructure development. The KSBS aims to secure a competitive edge in futuristic domains like Artificial Intelligence (AI), power semiconductors, advanced fabrication, and 3D packaging technologies.

Taiwan

Contrary to Japan and the US, Taiwan has reaped benefits from both the global semiconductor shortage and the U.S.-China technological rivalry. In 2020, Taiwan's semiconductor exports to China amounted to $146 billion, marking an increase of 237.8% since 2008 (see Table 5). While the Taiwanese semiconductor sector has profited from its economic interdependence with China, Taiwan continues to grapple with Chinese military threats. Over 1,000 ballistic missiles are strategically positioned by China as a deterrent to pro-independence movements in Taiwan. Beyond conventional security threats, Taiwan faces heightened challenges from mainland China. In a bid to bridge their technological gap, several Chinese tech enterprises have set up head-hunting agencies in Taiwan, aiming to poach talent from Taiwanese tech corporations, raising security alarms (Zhang and Liang 2021). In response, Taiwan's Ministry of Labor has mandated manpower agencies to cease listing job vacancies from China (Wu and Liang 2021). Furthermore, Taiwanese law enforcement authorities have taken action against a Chinese entity involved in illicit recruitment activities (New Taipei District Prosecutors Office 2021).

Table 5. Taiwan ICs Export to China

Year	Total Value (Billion USD)	YoY (%)	Percentage (%)	YoY (%)
2011	76.37	17.69	20.77	-0.10
2012	77.44	1.40	24.54	18.14
2013	78.48	1.35	25.26	2.91
2014	94.81	20.81	30.58	21.07
2015	96.43	1.71	31.64	3.47
2016	97.02	0.62	32.15	1.61
2017	109.08	12.43	31.98	-0.51
2018	119.77	9.80	33.91	6.02
2019	120.06	0.24	28.17	-16.93
2020	146.00	21.61	29.70	5.44

Source: (Bureau of Trade–Trade Statistics 2021)

In response to challenges posed by China, the US and Taiwan entered into a trade pact aimed at bolstering the resilience of their supply chains. TSMC announced a commitment of $12 billion towards an investment in Arizona, projected to have a capacity of 20,000 wafers per month and anticipated to create 1,600 high-tech professional positions (Taiwan Semiconductor 2020a). Taiwan and the US formalized a memorandum of understanding (MOU) focusing on their semiconductor partnership. Through TSMC's investment, the US envisions an augmented collaboration in semiconductor manufacturing. The discourse between both nations also extends to future cooperations in 5G and AI technologies (American Institute in Taiwan 2020). Beyond Arizona, TSMC is considering the establishment of an R&D center in Japan to innovate in 3D chip packaging technology (Taiwan Semiconductor 2022)

Facing immediate security threats from China, Taiwan is in search of fortified security assurances from the US and other like-minded partners. Even though these investments in the US and Japan might entail additional business costs, they serve to strengthen the ties among Taiwan, Japan, and the US. On June 22, 2021, representatives from Taiwan, Japan, the US, and the EU convened for a Forum on Tech Supply Chain Partnership. During this forum, the participants concurred on the idea that "no economy can produce everything it needs" and emphasized the shared interest in ensuring resilience in their supply chains (American Institute in Taiwan 2020).

Europe

While the EU isn't in direct competition with China, the semiconductor shortage during the Covid-19 pandemic adversely impacted the European automotive industry. This has prompted the EU to contemplate developing its own semiconductor supply. In 2020, due to the chip shortage, automotive production saw a staggering decline of 67%. Consequently, firms across Europe called for increased investments in domestic semiconductor R&D and production capabilities. Addressing this, the European Commission unveiled the "European Chip Act," which is dedicated to enhancing the resilience of the domestic supply chain. This ambitious initiative seeks to elevate Europe's stake in global semiconductor production to 20% by 2030, possibly through investments from industry giants like TSMC or Samsung (Clarke 2021; Drozdiak and Fouquet 2021). Technological advancements have paved the way for enriched collaborations between European and Asian nations. Emerging trends in advanced driver-assistance systems (ADAS) and smart cockpits are prompting European chip manufacturers to integrate more sophisticated fabrication technologies for enhanced data and graphics processing. A notable partnership was announced in 2020 between TSMC and NXP, wherein NXP has chosen TSMC's 5nm process for its next-generation automotive platform (Taiwan Semiconductor 2020b). This increasing demand for cutting-edge fabrication technology implies a deeper alliance between European semiconductor companies and their Asian counterparts.[2]

[2] TSMC, in collaboration with Bosch, NXP, and Infineon, has declared the formation of a joint venture aimed at producing advanced semiconductors within Europe. This joint endeavor anticipates a production capacity of 40,000 12-inch wafers monthly, employing TSMC's 28/22 nm and 16/12 nm technology platforms (Taiwan Semiconductor 2023).

Conclusion

The concept of the "Silicon Shield" warrants scrutiny. The ongoing US-China semiconductor rivalry confirms what many IR and IPE scholars have argued: heightened interdependence and trade volumes often lead to increased disputes and potential conflicts (Barbieri 1996; Goldsmith 2013; Krustev 2006). In line with Copeland's (2015) projections, negative interactions and the anticipation of trade disruption have exacerbated disputes between the US and China. These pessimistic expectations about future trade dynamics drive policies leaning towards economic nationalism. Both superpowers, for reasons tied to national security, are keen on bolstering domestic manufacturing capabilities. Empirical data reveals that Taiwan's prowess in semiconductor manufacturing does little to deter rivalry between major powers; in fact, this dependence serves to heighten mutual insecurities.

In examining the second dimension of the "Silicon Shield", one can observe that Taiwan's semiconductor industry indeed fosters alliances and partnerships grounded in economic security. However, contrary to neoliberalist emphasis on economic interests, these partnerships primarily stem from a drive to balance or neutralize shared threats to national economies. Such partnerships focus on enhancing domestic manufacturing capabilities and fortifying the resilience of global supply chains. This provides fresh empirical evidence supporting studies in economic nationalism, which posit that nations can bolster economic security through liberal means like free trade.

In conclusion, this paper critically evaluates the shortcomings of the "Silicon Shield" theory. While Taiwan's semiconductor sector might enhance partnerships with allies sharing similar values, it fails to mitigate major power rivalries. Worse still, should there be a severance in interdependence, this industry could very well be the catalyst for intensified US-China conflicts.

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