‘All People Must Make Semiconductors’: Analysis of the Chinese Government and Semiconductor Industry’s Response to US’s Weaponization of Semiconductor Trade Interdependence

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Abhishek Chadha

List of Abbreviations

AI	Artificial Intelligence
AMEC	Advanced Micro-Fabrication Equipment Corporation
ASL	Anti-Foreign Sanctions Law
ATP	Assembly, Testing and Packaging
BIS	Bureau of Industry and Security
CFC	Central Financial Commission
CSTC	Central Science and Technology Commission
DAO	Discrete, Analog and Other
DRAM	Dynamic Random Access Memory
ECL	Export Control Law
EDA	Electronic Design Automation
EUV	Extreme Ultraviolet Lithography
FDP	Foreign Direct Product
FYP	Five-year Plan
GVC	Global Value Chain
ICs	Integrated Circuits
IDM	Integrated Device Manufacturer
IP	Intellectual Property
IR	International Relations
JCET	Jingsu Changjiang Electronics Technology
nm	nanometer
NSA	National Security Advisor
NSC	National Security Council
OSAT	Outsourced Semiconductor Assembly and Testing
PUEL	Provisions on Unreliable Entity List
R&D	Research and Development
SME	Semiconductor Manufacturing Equipment
SMEE	Shanghai Micro Electronics Equipment Company
SMIC	Semiconductor Manufacturing International Corporation
TSMC	Taiwan Semiconductor Manufacturing Company
YMTC	Yangtze Memory Technology Company

Table of Contents

1 Introduction

May 2019 marks a significant moment in time when Chinese technology champion and a Fortune 500 global company Huawei was sanctioned by the US Commerce Department's Entity List, impacting its ability to source and produce advanced semiconductor chips for its smartphones and telecommunication equipment using US-based technology inputs (Bown 2020). Huawei's sanctioning was significant as it marked a turning point in the thinking within the US government that the interdependence with China which had been fostered to promote innovation and economic growth since the 1990s had become less consequential than the threat of conceding technological supremacy to its arch geopolitical rival (Segal 2021).

Even prior to Huawei's sanctioning, officials in the US National Security Council (NSC) had concluded that the future of the US-China competition in critical dual use technology rested on the 'cornerstone of semiconductor mastery' (Miller 2022, 300). Semiconductors are considered essential because nearly all electronic devices used in households, industries and militaries depend on them for performing different kinds of functions such as data processing and computation (Varas et al. 2021). In the age of emerging dual use technology such as Artificial Intelligence (AI), data is considered the new oil which is processed and stored using semiconductors (Miller 2022, 24).

Unlike oil however, these semiconductors are produced by a handful of specialized companies diversified across the world and connected through hierarchical supply chains, which makes their production prone to disruptions and political interference (Miller 2022, 25). The hierarchical order in semiconductor supply chains is defined by the firms' dominant positions in the most technologically complex and higher value-added steps in the manufacturing process (Chen 2022). Due to this, global value chain (GVC) is sometimes used interchangeably with the supply chain to describe the asymmetric order of semiconductor production. Commanding higher positions in the value chain not only generates greater revenue and market control for dominant firms but also serves as a source of power in the international system (Lee 2023). Huawei was targeted by harnessing the same structural power inherent in global supply chains. Beyond blocking the access to advanced semiconductor chips from the US market, the US government also leveraged the privileged positions of American firms in the semiconductor value chain to constrict the flow of technology used for manufacturing them.

Acknowledging the asymmetric power held by dominant players in semiconductor technology, Chinese government policies since the mid 2000s have sought to target the innovation capabilities of domestic semiconductor firms in a bid to push them up the value chain (Chen 2022). As tensions with US rise, it is only logical to assume that the drive for indigenous development in China would intensify (Li 2021), inviting additional backlash from other states in the supply chain such as South Korea and Taiwan whose export led economies are dependent on the sales of semiconductors in China (Miller 2022, 252). The trend of decoupling initiated through US's sanctions and China's efforts at insulating its long-term ambitions vis a vis the local semiconductor industry therefore carries repercussions for the future of interdependence, international balance of power as well as for the global security environment.

Huawei's sanctioning set forth a series of US export control measures culminating in the most restrictive measures announced in October 2022 when US leveraged its asymmetric power in global supply chains again to strangle China's entire semiconductor industry by withholding advanced semiconductor chips and the components used for their production. US based firms' dominant position in critical production inputs such as the semiconductor manufacturing equipment (SME) and design software called Electronic Design Automation (EDA) was used to enact chokepoints against the Chinese semiconductor industry, cutting their access to the global supply chain of semiconductor production (Allen 2022).

The underlying phenomenon describing such use of economic networks like the global supply chains for coercive ends was termed in literature as weaponization of interdependence and the framework of 'Weaponized Interdependence' was put forward by scholars Henry Farell and Abraham Newman to explain its operationalization (Farell and Newman 2019). Some scholars have since applied this framework to analyze the sanctioning of the Chinese semiconductor firms but have mostly looked at it from the point of the weaponizing actor US, which limits the framework's utility to static interpretation of the US government's actions and its dominant firms' capabilities. Further, as the export control measures levied by the US government on China are an ongoing phenomenon with interactive effect, the findings offered by the work done so far are only provisional, requiring periodic re-evaluation as and when new data becomes available.

Following from above, the aims of this thesis are twofold. With respect to the utility of the case, the thesis aims to analyze and interpret China's response to US's sanctioning measures against its semiconductor firms as the other half of the action-counteraction dynamic which is relatively less addressed in academic literature. In any contemporary discussion on the ongoing weaponization phenomenon, it becomes imperative to also include the strategies of Chinese semiconductor firms who are active agents in the process, both as targets and beneficiaries respectively of the US and Chinese government policies. For the larger literature on Weaponized Interdependence, this thesis will aim to contribute to the original framework by addressing its shortcomings pertaining to the omission of target state response and the role of non-state actors within it. In line with these aims, the thesis will attempt to answer the twofold research question:

"How has China's government and corporate sector responded against US's export control measures on advanced semiconductor technologies? And, What does this imply for the framework of 'weaponized interdependence'?"

The plan for answering the above research question is divided into different sections. The first section offers a literature review of the academic literature on economic interdependence, economic sanctions and the application of weaponized Interdependence for analysing the US-China technology competition. Subsequent sections discuss the methodology and case overview, leading into the case analysis. The analysis of the case is built around two phases of the export control measures, one covering the initial measures introduced by under the Trump administration from 2018 to 2020, followed by their intensification from October 2022 to the present year 2024 under President Biden. The penultimate section discusses and interprets the findings and leads to the final section which concludes the thesis with the summary of the project, its limitations and prospects for future work.

2 Literature Review

2.1 Economic Interdependence as a Source of Conflict or Peace

Economic interdependence as a topic of research in International Relations (IR) has its roots in liberal theory (Silva and Selden 2020). Drawing from a long list of thinkers from the enlightenment era, such as Adam Smith, Immanuel Kant and David Ricardo, and interwar era scholars such as Norman Angell, liberal IR theorists have long postulated that growing interdependence between states reduced the likelihood of conflict (Keohane and Nye 2012; Rosecrance 1986; Copeland 1996). Thus, the democratic peace thesis within liberalism talked about how the Kantian triad of democratic states, international organizations and economic interdependence would create a pluralistic security community where no state would have the incentive to initiate a war (Drezner 2023, O'neal et al. 2003). Following a similar logic, the commercial peace thesis highlighted that higher opportunity costs of trade disruptions would restrain state leaders from waging wars even when they had the incentive to do so (Drezner 2023; Silva and Seldan 2020). Attracting both, support and critique, the liberal view on interdependence has been a focal point of debate in IR theory. The principal opposition to the liberal view came from Neorealism and the Marxist theory, especially through the latter's derivatives such as the Dependency and World Systems theory. While the derivatives of the Marxist theory saw the monopolistic asymmetrical character of the capitalist world economy, reinforced through an international division of labour and subordination of erstwhile colonized (peripheral) economies as a source of conflict rather than peace (Martins 2022), proponents of the former approach such as Kenneth Waltz contended that more interdependence created vulnerability which states would like to control or escape by initiating conflicts (Waltz 1979, 106). Calling out the 'myth of interdependence' he further suggested that states were unequally dependent on each other and therefore unequally placed to leverage their economic power for the pursuance of national interests in an anarchical international system (Waltz 1979, 157–158).

2.2 Neorealism versus Neoliberalism on Asymmetric Interdependence

The neorealist and Marxist stress on unequal dependency foreshadowed the concept of asymmetric interdependence which some liberal scholars acknowledged but saw differently. For liberals, asymmetric interdependence made the more dependent state less likely to initiate conflicts since it had more to lose from breaking economic ties (Copeland 1996). This idea resonated in the work of later liberal scholars or neoliberals such as Robert Keohane and Joseph Nye who considered asymmetrical interdependence as a source of resource power and a potential influence on the outcome of events, but not its sole determinant (Keohane and Nye 2012, 9–16). Therefore, unlike the neorealist view which considered asymmetric interdependence as a source of vulnerability and conflict because of the structural condition of anarchy, the neoliberal view saw it as a condition which could be restricted through mutual awareness of the potential gains and losses between actors (Keohane and Nye 2012, 26). In the difference of emphasis on benefits versus costs between liberals and realists, the former seldom recognized the downsides of interdependence. Even those events which led to conflicts despite strong interdependence were attributed by liberals, not to the limits of interdependence in inducing peace, but to misjudgments by political leaders in analyzing the extent of interdependence and losses in opportunity costs (Copeland 1996). Thus, when Keohane and Nye came up with their ideal type of complex interdependence where states and non-state actors were connected through multiple channels of contact with limited utility of military power, the restriction on the abilities of statesmen to manipulate asymmetric interdependence was a recurrent theme (Keohane and Nye 2012, 16, 28).

Progressing forward, neoliberal scholars saw complex interdependence through the lens of globalization and argued that 'networks of interdependence' would flatten hierarchies and fragment state power (Keohane and Nye 2012, 26). Even when US's centrality in some of the networks of interdependence was conceded, they cautioned that this preponderance would eventually erode as the asymmetries in structural holes are filled with time (Keohane and Nye 2012, 253). The perceived shift in US's structural power to 'power with' allies instead of 'power over' adversaries (Slaughter, 2017, 172) threw weight behind this conception of a new era with less scope of economic coercion and more opportunities for economic growth and interdependence. This benign outlook on the potential dispersion of structural power across networks caused them to overlook the coercive potential of network structures brought in by globalization (Drezner 2021). Notwithstanding the criticism on their optimism however, neoliberal theorists also failed to effectively conceptualize interdependence on a structural level and limited their theorizing on the bilateral level of states, stressing on the power resources of actors instead of structural factors (Wagner 1988; Drezner 2021).

2.3 Asymmetric Interdependence and Economic Sanctions

On a parallel track, the consensus between neorealist and neoliberal positions that asymmetric interdependence had important consequences for power and event outcomes (Knorr 1977,102 cited in Wagner,1988; Keohane and Nye, 2012; Waltz 1979) inspired research on its coercive effect through the literature on economic sanctions. As such, the nature of interdependence influenced who could impose sanctions and how such sanctions would work (Ozdamar and Shahin 2021). Further, as wars became costlier, economic sanctions became a viable coercive tool for states, where power derived from economic interdependence could be used for achieving strategic objectives (Silva and Selden 2019, Drezner 2024). Early scholars weighed in on the effectiveness of these sanctions both theoritically (Baldwin 1985 cited in Lenway 1988; Drezner 1999) and empirically (Hufbauer and Schott 1985 cited in Lenway 1988; Pape 1997) and paved the way for future work on the new pathways for economic coercion, sanctions and statecraft after globalization (Drezner 2024). Drawing from the network theory of IR (Hafner-Burton et al. 2009), some of these later studies focused on the consolidation of US's centrality in the financial networks since globalization (Oatley et al. 2013) and its impact on the effectiveness of sanctions (Drezner 2015). Most of the work done on economic sanctions however focused on the efficacy of sanctions for economic statecraft and like the neoliberal contributions on economic interdependence, characterized power bilaterally between the coercer(s)and the target(s) as the market access denying power of the coercer, exercised unilaterally or in alliance with other states. It overlooked the changing aspect of structural power due to globalization by missing out on the structures which made these sanctions effective in the first place (Farrell and Newman 2019).

2.4 Global Economic Networks based Coercion or 'Weaponized Interdependence'

Farrell and Newman's work on 'Weaponized Interdependence' sought to counter the benign view of economic interdependence held by liberal scholars and contributed further towards the literature on economic sanctions by addressing its shortcomings. Challenging the neoliberal position, Farrell and Newman demonstrated how economic relations and institutions which were designed for market efficiency and reducing the transaction costs could be used for coercion. Contrary to Keohane and Nye's assumptions that globalization would lead to a flat or fragmented world with diffuse power relations, Farrell and Newman argued that increased globalization had altered the structure of global economy by creating economic networks of interdependence which were hierarchically structured (Farrell and Newman 2019, 48). Within these networks, some states or firms acted as the central nodes or hubs on which all other actors or nodes were asymmetrically dependent (Farrell and Newman 2019, 48–49). In highlighting this altered structure of the global economy, they also conceptualized structural power differently from the types of power addressed by the literatures on economic sanctions and interdependence. This new form of power which stemmed from centrality in the global economic networks was different from the market power, derived from a state's domestic market size or GDP, and the bilateral power of dependence which stemmed from the inability of states to go to war with one another due to the risks of shocks and disruptions from bilateral interdependence (Farrell and Newman 2019, 52).

2.4.1 Strategies for Weaponized Interdependence- 'Panopticon' and 'Chokepoints'

The structural power, which was derived from economic networks, allowed some states to weaponize interdependence on the level of the network itself. Farrell and Newman explained two channels through which states could weaponize interdependence- panopticon and chokepoints. In the former strategy, states which had physical access or jurisdiction over hub nodes could use their influence to extract information flowing through the network for surveillance and intelligence gathering. In the second channel called chokepoints, states could use their influence on hub nodes to cut their adversaries off from the global economic networks (Farrell and Newman 2019, 52–53).

The use of SWIFT interbank payment system by the US serves as a good example of both the panopticon and chokepoints strategy. Shortly after the 9/11 terrorist attacks, US was successfully able to compel SWIFT, which hosted its data centre in Virginia to provide US intelligence agencies with sensitive financial data regarding terrorist operations, co-conspirators and planning, consequently becoming the rosetta stone for counterterrorist operations in the US. Later, in 2012, US and its European allies used SWIFT for enforcing the sanctioning regime against Iran by enacting chokepoints in the international payments system and cutting Iran off for its alleged role in using the system for developing its nuclear program and terrorist financing. The use of chokepoints in the financial messaging system crucial for bank operations was made possible due to the location of SWIFT headquarters in Belgium and the necessary laws which were enacted first by the US and later by EU (Farrell and Newman

2019, 64–66). Therefore, while private actors such as SWIFT were instrumental in both the strategies of panopticon and chokepoints, the decision to do so was made by states in the exercise of economic statecraft.

To give effect to either strategy, Farrell and Newman delineated two necessary conditions. First, only those states which had physical or legal jurisdiction over hub nodes could successfully exploit weaponized interdependence against their adversary. Second, states having this influence on networks must also be supported by appropriate domestic legal and regulatory institutions. Thus, for example, even when the states and commercial internet provider firms with their headquarters and servers in EU had influence over network hubs of internet traffic, they could rarely exploit weaponized interdependence. The lack of domestic institutions and wider scope of privacy laws prohibited their ability to collect user data which could be used for panopticon strategies (Farrell and Newman 2019, 54–55). These same conditions have sometimes restricted US from exploiting its structural power for weaponization (Fuller 2022).

2.4.2 Conditions for Exploiting Weaponized Interdependence

Farrell and Newman were cautious in limiting the overstretch of the framework of 'Weaponized Interdependence' by setting its contours. Firstly, the presence of global economic networks with some level of asymmetric interdependence between different actors was crucial to the structural integrity of the concept. Further, the conditions of weaponized interdependence were only satisfied when the states effectively dominating the hubs also had the appropriate institutional capacities to manipulate them for coercive advantage (Farrell and Newman 2021, 309). In a final point of departure from the analyses focusing on market power targeting mainly economic actors and bilateral power of dependence between states accruing from asymmetric interdependence, the concept of weaponized interdependence explained coercion attempted through the global economic networks instead of dyadic pairs while stating that its final targets were political rather than commercial actors (Farrell and Newman 2021, 311).

2.4.3 Shortcomings in the Original Framework

Despite their seminal contribution to IR literature, the initial work on weaponized interdependence suffered from certain shortcomings which was acknowledged by the authors in subsequent reflections on the concept (Farrell and Newman 2021). These shortcomings mainly refer to the treatment of the concept as largely static, without incorporating the counterstrategies by targeted states and private actors which would make the concept more interactive (Jentleson 2021). Considering the interactive effects of weaponized interdependence highlights two more important omissions from the original concept. First is the treatment of firms as passive targets of weaponization without any real independent agency (Farrell and Newman 2021, 315). Second and equally important is the need to understand that economic networks are not standalone structures but devised of multiple sub-networks (Farrell and Newman 2021, 317). The interaction between different network and subnetworks is important not only in shaping their respective structure, but also in offering new pathways for weaponizing interdependence (Beaumier and Cartwright 2023).

2.5 Existing Literature on the US-China Technology War

Many scholars have since used the concept of weaponized interdependence to explain conflicts between US and its adversaries, in particular Russia and Iran, in fields as diverse as energy and gas networks (Meierding 2021) to financial networks such as the SWIFT inter banking system (Oatley 2021). With the announcement of sanctions against Chinese technology firms Huawei and ZTE beginning in 2018, the concept of weaponized interdependence has also been employed to study the operationalization and effect of US chokepoints in advanced semiconductor chip production networks (Segal 2021). Work done on the weaponization of interdependence between US and China reveals two broad lines of enquiry. First between these has looked at the effectiveness of weaponization by studying the durability of chokepoints used to cut China off from the global supply of advanced semiconductor chips. Important works under this theme include Douglas Fuller's who explained the successful application and durability of the enacted chokepoints through US firms' centrality in global value chains, preventing their displacement by Chinese firms in the foreseeable future (Fuller 2022). Another important work by Guillame Beaumier and Madison Cartwright improved the original concept by including sub-networks across the semiconductor supply chain in a phenomenon they referred to as 'Cross network weaponization'. The authors then went on to explain the success of US's weaponization of the chokepoints through its monopolistic control over the semiconductor chip design technology (Beaumier and Cartwright 2023).

The other dominant theme concerns explaining the source and change in structural power for weaponizing economic networks, due to US-China competition. In explaining the source of structural power, some have attributed it to US's dominance in technology and the extraterritorial reach of its domestic laws (Malkin and He 2024), while others have taken a narrower perspective at the level of a specific component of the supply chain, in particular design (Beaumier and Cartwright 2023). On the other hand, scholars studying change have mostly looked at the effect of weaponization on the weakening of US's hegemony in the neoliberal economic system (Mastanduno 2021; Schindler et al. 2024) and the increase in state capitalism (Rolf and Schindler 2023; Luo and van Assche 2023).

2.5.1 Gaps in the Existing Literature

Despite their relevance to the context, most of these works overlook China's counter strategies and responses which make up the other half of the dynamic of weaponized interdependence. Further, the few studies which have strived to include China's response need to be re-examined in the light of new empirical evidence which becomes available due to the fast paced nature of developments taking place in both the semiconductor sector directly as well as other critical and emerging technologies such as AI and advanced computing, all of which rely on advanced semiconductor chips for their operation (Miller 2022). This new empirical evidence, which corresponds with official government policies and key leadership statements, along with firm strategies, innovations and workarounds by some important Chinese semiconductor firms since weaponization, needs to be incorporated in the contemporary discussions on Chinese semiconductor sector's capabilities along with its adaptations to the enacted chokepoints.

2.5.2 Filling the Gaps in Existing Literature

This thesis is an attempt to address this dynamic aspect of the US-China conflict in the trade of advanced semiconductor technologies and contribute to the relatively nascent literature on weaponized interdependence. Learning from the shortcomings in the original concept, this project will be analyzing Chinese counter strategy to weaponization as an answer to the two-fold research question:

How has China's government and corporate sector responded against US's export control measures on advanced semiconductor technologies? and,
What does this imply for the framework of 'weaponized interdependence'?

As is implied from the question, the thesis will incorporate both government and corporate sector data. The purpose of including response from China's corporate sector is three folds. First, firms happen to be at the forefront of operationalizing weaponization by contributing towards both its enactment and evolution (Segal 2021; Fuller 2022). Second, the response to US's sanctions is not likely to be generated in silos, but through a cumulative effort, especially in the case of China under Xi Jinping which has been scrutinized previously for increasing the Chinese Communist Party's interference in domestic firms (Chen 2022; Pearson, Rithmire and Tsai 2022). Third, the focus on China's corporate sector also addresses the problem of sub-networks in the original concept. The semiconductor supply chains are composed of sub-networks with different firms specializing in different processes and inputs along the production of the final product (Beaumier and Cartwright 2023). Most of the firms in the supply chain therefore are associated with only one sub-network or the other which makes one country's control and efforts at localization of the entire supply chain extremely difficult. Therefore, the public and private firms constituting China's semiconductor sector are indispensable in analyzing the overall target state response to weaponization of interdependence.

3 Research Design

3.1 Research Objective

The research objective of this study is to analyse and interpret the Chinese state and corporate sector's adaptive strategies in response to the U.S.'s weaponization of semiconductor trade interdependence, focusing on how these strategies challenge, mitigate, or circumvent chokepoints imposed by U.S. export controls. In doing so, this study will assess how variations in Chinese government policies and firm strategies contribute to refining and expanding the current theoretical understandings of target state responses under the framework of 'Weaponized Interdependence' (Farell and Newman 2019). The method employed to achieve this aim is process tracing applied to a 'within-case analysis' of the export control measures on China, in particular its government and semiconductor industry.

3.2 Case Selection

The transnational character of the semiconductor supply chains represent an extreme case of asymmetrical concentration of market power within global supply chains (Lee 2023), which makes them conducive for the application of chokepoints by the dominant state to cut the target state off. In the competition between US and China, sub-networks of EDA and SME were leveraged as chokepoints by US to cut Chinese companies off from the network of advanced semiconductor chip production (Allen 2023). Such sanctioning of Chinese technology companies from advanced semiconductor production supply chains offers a good case for the application of Weaponized Interdependence.

Apart from fitting the framework, the case of export controls on China is important for analysis on two more counts. First, semiconductors are the most fundamental piece of technology which form the backbone of other dual use technologies such as AI and supercomputing (Varas et al. 2021). US's weaponization of globalized semiconductor production networks offers a new application area for the concept beyond the traditional confines of financial networks used for sanctions against adversaries, thereby expanding its scope. Second, the case addresses the shortcomings in the original framework and offers the opportunity to refine it further. For one, Farrell and Newman talk about target state counter strategies as limits to the application of Weaponized Interdependence (Farell and Newman 2019, 73) but do not develop or back these claims by adequate evidentiary data. Another lacuna corresponds with the non-inclusion of firms as actors in the original analysis. Process tracing, which seeks to establish the causal process between the independent variables and the outcomes of the dependent variables can help to identify such causal mechanisms not yet identified by the theory, contributing to theory development as much as theory testing (George and Bennett 2005, 256–271).

Despite the usefulness of this case for the 'Weaponized Interdependence' framework however, a single case research design may fall prey to over-generalization of the findings (George and Bennett 2005, 110). Since the sanctions on Chinese technology companies represent a sub-type or subclass in the weaponization of interdependence phenomenon, findings from this case might be less generalizable to other kinds of weaponization such as those of the financial or energy flow networks. Also, due to the fast paced changes in technology driven by innovation, profitability and the zero sum logic, strategies and counterstrategies against weaponization of trade in advanced technologies also evolve rapidly which necessitates re-examining the new evidence as and when it becomes available. This not only makes the project challenging but also adds to the uncertainty in the final findings.

3.3 Scope and Focus

Being mindful of these limitations, this study will analyse the actions of Chinese government and the semiconductor industry firms between 2018 and 2024. While it can be argued that the chokepoints in EDA and SME were explicitly implemented only in October 2022, sanctions on Chinese firms such as ZTE and Huawei, preventing them from accessing advanced semiconductor chips for dual use technologies had already been put in place since 2018 by the Trump administration (Allen 2023). As per trade expectations theory, a state which perceives restrictions to trade by another state is driven to reduce its vulnerability by taking preventive and sometimes offensive measures (Copeland 1996). Stockpiling of advanced semiconductor chips and diversification of suppliers of essential equipment indicate a similar trend in China after 2018. Thus, 2018 marks the threshold year for interpreting the variation in the behaviour of the Chinese state and domestic semiconductor industry. Inclusion of 2024 acknowledges the contemporary nature of the export control measures.

3.4 Data Selection

3.4.1 Primary and Secondary Sources for Chinese Government's Response

The data used to study the Chinese government's and corporate sector's behaviour will be gathered through both primary and secondary sources. In the case of the Chinese government, which refers to the Chinese National Government unless specified otherwise, overall directives for the industry, specific decisions for the semiconductor sector and speeches by key leaders on the issue serve as good sources of data. Primary sources of these data such as the English transliterations of the official policy documents available on the Chinese government affiliated websites or published by state-backed news agencies will be utilized for this study. However, official announcements of subsidy schemes in China often omit the scope and scale of state support, implying limits to measuring government policy through official announcements alone(Garcia-Herrero & Schindowski 2024). Primary Chinese government publications will therefore be supported through the analyses made by foreign newspaper reports, international think tanks and scholars as additional sources.

3.4.2 Primary and Secondary Sources for Chinese Corporate Sector's Response

For the corporate sector, response will be measured by observing any variation in firm strategies and capabilities of key Chinese firms involved in the semiconductor production process. These include Chinese telecommunications major Huawei and its chip designing subsidiary HiSilicon, China's largest semiconductor manufacturing company SMIC (Semiconductor Manufacturing International Corporation), leading chip designing software firm Huada Empyrean, semiconductor equipment firm SMEE (Shanghai Micro Electronics Equipment Company), additional equipment suppliers Naura and AMEC (Advanced Micro-Fabrication Equipment Corporation), semiconductor packaging and testing firms JCET (Jingsu Changjiang Electronics Technology), Tongfu Microelectronics, and Tianshui Huatian and memory semiconductor firm YMTC (Yangtze Memory Technology Company). The criteria for selecting these firms is threefold. First, these firms are the most important Chinese firms in their subsectors by annual revenues and market shares (Li 2021). Second, most of these firms were targeted by US's export control measures and therefore have been actively working their strategies around supply chain disruptions. Third, these firms cover mostly all subsectors of the semiconductor supply chain, including the chokepoint hubs targeted by the US government.

Taken together, the selected firms offer a good horizontal and vertical spread of the Chinese semiconductor industry, making them conducive for analysing the corporate sector's response. The secrecy around China's semiconductor industry makes it difficult to gather any official sector-wide data to assess and measure the progress made by Chinese firms (Triolo 2024a). As a result, this thesis will mainly rely on primary data in the form of industry reports, public discourse in English newspapers, opinions of industry experts and think tank publications.

3.5 Data Limitations

It is important to acknowledge the limitations of both the primary and secondary data prior to undertaking the study. Primary data related to technology related developments in China has become difficult to source, partially due to the backlash received by Chinese Industrial policies (Triolo 2024a). For those made publicly available, it is equally challenging to sift meaningful data from state-backed propaganda. This challenge is partially overcome by supplementing the primary data with inputs from industry insiders and subject matter experts. Addition of these secondary sources makes the analysis prone to any cognitive biases the authors might have while collecting the data. Corroboration and cross validation through multiple other secondary sources, however, diminishes the impact of cognitive biases and makes this study a worthwhile enterprise to pursue.

4 Case Analysis

Case analysis will proceed in three parts. The first part introduces semiconductor chips and products establishing their importance for the phenomenon of weaponization of interdependence. This would be followed by an explanation of the semiconductor supply chain, highlighting its asymmetric character and the potential for enacting chokepoints. Process tracing of events is applied to explain the operationalization of the weaponization phenomenon in the third part by classifying it under two broad phases. These phases cover the most significant export control measures taken till date, from their initiation under President Trump (2018-2020) to their intensification under President Biden (2022-2024). Chinese policies and firm strategies have been analyzed as responses to the US's export control measures under the two phases. The interregnum period from 2021 to September 2022 represented the transitional phase in the US government and was accompanied by relative reorganization of the state-backed investment funds in China owing to corruption scandals. This was hence a period of relative dormancy on both sides, reflecting the continuation of policies and strategies underway since the first phase until more concrete measures were announced by the Biden administration in October 2022.

4.1 Semiconductor Geopolitics and the US-China Technology War

Semiconductors are miniature components which are used to power electronic devices, helping them process, store and transmit data. Most of the semiconductors today, which are only a couple of atoms thick, consist of billions of tiny electrical devices such as diodes, transistors and capacitors interconnected to each other on a wafer of silicon. Due to this, semiconductors are mostly referred to as Integrated Circuits (ICs) or simply as chips (Varas et al. 2021). Apart from being indispensable to consumer electronics including home appliances and daily-use devices, semiconductors form the basis for all dual use technology such as AI and quantum computing (Khan et al. 2021). Their importance to the modern economy has often generated comparisons with oil. When used as a comparative metric in the case of China, the importance of semiconductors can be gauged from the fact that China's imports of semiconductors have consistently surpassed its imports of oil since the early 2000s (Miller 2022, 245).

Based on their type, semiconductors can be classified into three broad product categories- Logic, Memory, and Discrete, Analog and Other (DAO) (Varas et al. 2021). Logic chips serve as the 'brains' of computing and are classified based on the technology processes used to manufacture them as advanced (or leading-edge node) and legacy (or mature node). Logic chips produced using sub-14 nanometer (nm) technology processes are generally classified as advanced (Ezell 2024). Due to the precision offered by below 14nm production sources, advanced chips pack greater number of components on a single chip making them capable of performing complex operations for technologies such as AI. Legacy chips which are manufactured using a thicker wavelength of light are common in automobiles, household appliances and aerospace products (Ezell 2024). Memory chips are used to store data and have two subtypes-DRAM (Dynamic Random Access Memory) and NAND, based on their ability to do so with or without being connected to a power source (Varas et al. 2021). Memory is a highly competitive segment requiring constant innovation and upgrading. Therefore, unlike the logic chips, it does not have any advanced or legacy nodes (Triolo 2024a). DAO chips are used for a range of operations such as converting analog sounds into digital data but are relatively less important segments for cutting edge technologies like AI and market revenues compared to logic and memory. The process used to manufacture all semiconductors products is highly globalized through a network of specialized firms and their suppliers dispersed in different geographies.

While semiconductors were invented in the US, their manufacturing was outsourced to other parts of the world, mainly to East Asian countries like Taiwan, South Korea, Japan and China in the early 1990s to accrue the benefits from globalization. Overtime, this has produced an inherently skewed global supply chain of semiconductor production, with most of the revenue and value-added functions being retained in the US or 'friendly' countries which are dependent on it for territorial and economic security (Lee 2023). These countries include Taiwan, South Korea, Japan and the Netherlands, all advanced economies whose semiconductor industries grew through close collaboration with the US chip industry and are deeply integrated with it to remain profitable (Miller 2022, 252). With the growth in the global semiconductor industry's revenue, the disparities in the semiconductor supply chains became even more entrenched. (Bown 2020).

By 2019 China, along with the US, had become the largest semiconductor market due to its growing consumer market and manufacturing capabilities (Varas et al. 2021). At the same time, most of the intellectual property (IP) in the technology needed for semiconductor manufacturing was held by US and other countries like Japan and the Netherlands. High market entry barriers and limited indigenous capacity in semiconductor manufacturing meant that Chinese technology companies remained heavily dependent on the technology provided by foreign entities to remain viable (Miller 2022, 244–245).

The concern for China' s asymmetrical dependence on foreign entities for semiconductor chips was evident in the multiple speeches made by Chinese President Xi Jinping since 2016, the central theme of which revolved around achieving urgent breakthroughs in core technologies, including semiconductors (Miller 2022, 248). Chinese policies such as the National IC guidelines in 2014 and the Made in China 2025 plan launched in 2015 further set targets of reducing China's dependence on foreign entities through import substitution backed by massive government funding (Lee 2023).

Chinese self-sufficiency targets coupled with state-backed subsidies and announced timelines threatened to upend the globalized semiconductor supply chains and the profitability of the major beneficiary states (Miller 2022, 253–254). As concerns grew around the nature and size of Chinese subsidies to domestic firms, Chinese policies became the target of the Trump administration's trade war against China beginning 2018 when tariffs were imposed on Chinese imports including semiconductors (Bown 2020). More importantly, due to their criticality in dual use technology, control of semiconductor chips and their production was considered crucial in maintaining US's military and strategic advantage over China by the national security bureaucracy within the US government. Looking through the zero-sum lens, statements issued by US government officials in the Congress and the NSC made it evident that China's technological growth was seen as a national security threat which could only be abated with China's slowing down. Exploiting Chinese technology firms' dependence on US chips served as an important next step to achieve this objective (Miller 2022, 311–316).

To explain how semiconductor supply chains came to be weaponized using chokepoints, it is important to first understand how semiconductors are produced in the most complex and geographically distributed supply chain networks.

4.2 Semiconductor Supply Chain

Semiconductor supply chains represent one of the most extreme forms of asymmetric globalization. The entire process of semiconductor production is organized hierarchically into transnational production networks or vertically integrated global value chains, with the hierarchical order defined by the position of the firms in the value chain. Higher placed or upstream firms control the technology on which the downstream firms are dependent for their functions, thereby commanding more revenue and bargaining power from the semiconductor manufacturing activity.

In its present form, the semiconductor production ecosystem is a multistage manufacturing process, transforming critical inputs into the finished assembled form used in products such as smartphones, computers and telecommunications hardware. This process can broadly be classified into three stages: design, front-end manufacturing (wafer fabrication) and back-end manufacturing (assembly, testing and packaging) (Khan et al. 2021). Each stage of the production process involves high degree of specialization and complexity requiring substantial investment and technical know-how, supported through years of research and development (R&D) funding by governments and firms. The capital-intensive nature of the process thus poses high market entry barriers for new entrants leading to a concentration of key firms and states around each stage (Bown 2020). The supply chain can be visualized as shown in **Figure 1**.

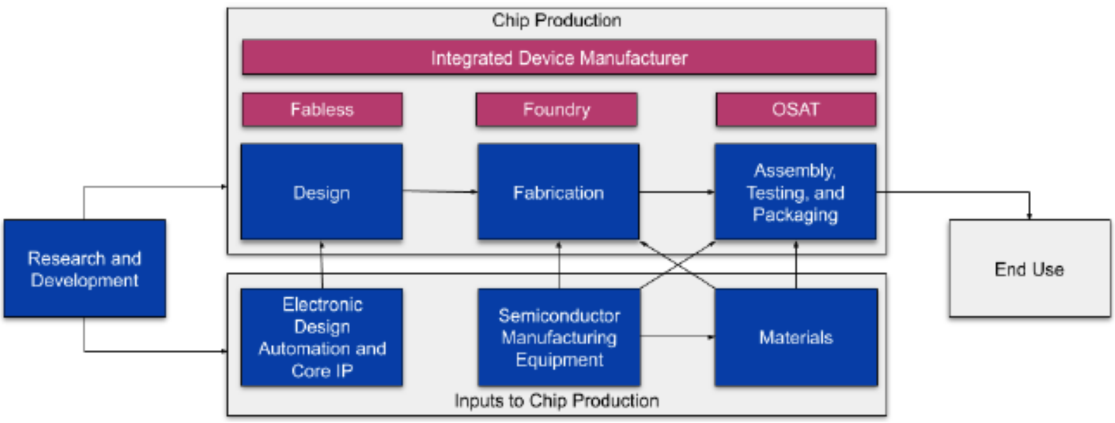

Figure 1: Semiconductor Supply Chain. (Source: Khan et al. 2021, Pg. 5)

There are two models of semiconductor production namely the foundry model and integrated device manufacturer (IDM) model. In the foundry model, fabless firms design the chip and outsource fabrication to another firm called a foundry. Individual chips from the foundry are then further supplied to an Outsourced Semiconductor Assembly and Testing (OSAT) facility which assembles, tests and packages these chips into end-use electronic products. In contrast to the foundry model, IDMs vertically integrate designing, manufacturing and assembly functions under one firm which sells the chips. Both foundries and IDMs require critical inputs from separate firms in the form of design software EDA, SME and specialized chemicals and materials, to manufacture semiconductors (Khan et al. 2021). The three stages of semiconductor production are summarized below.

4.2.1 Design

The first stage called design includes software and intellectual property used in the manufacturing process. The software used for designing semiconductors is called Electronic Design Automation (EDA) which works on the Intellectual property architecture or Core IP for chips, provided by firms such as Intel and UK based ARM. Design is the most knowledge-intensive sector which accounts for more than half of the semiconductor industry's R&D expenditure and its added value (Beaumier and Cartwright 2023). More than 95% of the global market share in EDA is controlled by three firms- Cadence Design Systems (US), Synopsys (US) and Mentor Graphics (Germany) while US and UK based companies own about 93% share of the market for core intellectual property, making this stage of production an oligopoly of US based firms and its security allies in Europe (Varas et al. 2021). Nearly every chip in the world relies on the IP provided by these firms (Miller 2022, 315) which makes the domination of design a credible weapon in the US's arsenal.

4.2.2 Wafer Fabrication

The second stage of production called wafer fabrication involves several steps culminating in the printing of ICs on silicon wafers. Steps within wafer fabrication include oxidation and coating, lithography, etching, doping and process control, with every step requiring its own special equipment, chemicals and materials. Like the oligopolistic EDA market, the markets for semiconductor manufacturing equipment as well as chemicals and materials are highly concentrated. Most prominent and indispensable equipment for manufacturing semiconductors is the photolithography machines which use high intensity light source to print patterns on silicon wafers (Bown 2020). More than 96% of the global market share in photolithography machines is captured by two companies ASML (Netherlands) and Nikon (Japan), with the former holding an absolute monopoly on the most advanced versions called Extreme Ultraviolet Lithography (EUV) machines without which advanced semiconductor chips used for AI and other complex operations are impossible to produce at scale (Beaumier and Cartwright 2023). Specialty chemicals and materials are used in combination with the photolithography machines to treat the silicon wafers, enabling the printing of intricate IC designs. Firms specializing in these materials and chemicals are scattered across different regions including US, China, Taiwan, South Korea and Japan. US based firms such as Applied Materials, Lam Research and KLA-Tencor enjoy a near monopoly over additional etching, doping and process control tools which are indispensable to the manufacturing process (Bown 2020). In both EDA tools and SME, China lags far behind the global leaders and is heavily dependent on them for its domestic need (Fuller 2021).

4.2.3 Assembly, Testing and Packaging (ATP)

The last stage of the production process falls under back-end manufacturing and includes the assembly, testing and packaging (ATP) functions. After the manufacturing facility, called fabs, produces a semiconductor wafer, it is transferred to another facility which assembles, tests and packs the individual semiconductors from the wafers and ships them to end user firms, mostly in the electronics and automobiles sector. This stage of production generates significantly lesser revenue than the other two stages and is labor intensive. Chinese firms such as JCET, Tongfu Microelectronics, and Tianshui Huatian Technology have an edge in this segment despite lacking in certain cutting-edge equipment, the supply of which is controlled by US and Japan (Khan et al. 2021).

4.3 Weaponization of Semiconductor Interdependence

4.3.1 Initiation of Weaponization under Trump Administration (2018-2020)

The weaponization of global semiconductor production networks by the US and its allies had its origin in the Trump administration's allegations of unfair trade practices by the Chinese state. In the wake of these allegations, Chinese companies were investigated and two prominent ones, telecommunication firm ZTE and memory chip maker Fujian Jinhua were slapped with sanctions in 2018. While ZTE was punished for flouting the sanctions regime on Iran, Jinhua was held guilty of stealing IP from US memory firm Micron's factory in Taiwan. As part of the sanctions on ZTE, it was cut off from access to any semiconductor chip sold by US based firms which were used in its telecommunication equipment. Jinhua on the other hand was cut off from buying US equipment for manufacturing its memory chips. Both ZTE and Jinhua had been heavily dependent on technology supplied by US firms, devoid of which they were crippled to the point of bankruptcy (Segal 2021). Recognizing its vulnerability, the Chinese government did not react aggressively against these measures. It imposed retaliatory tariffs on some US exports but refrained from including semiconductor chips and capital equipment (Bown 2020).

4.3.1.1 Use of SME and EDA as Chokepoints for Targeting Huawei in 2019

Next year in May 2019, Chinese technology champion Huawei was targeted on fears that its critical 5G infrastructure equipment could be used for spying by the Chinese state and army and put on the US Commerce Department's Bureau of Industry and Security (BIS) Entity List (Fuller 2022). The Entity List prevented US based firms to trade with companies placed on that list without government license (Bown 2020) and had been used effectively to force ZTE and Jinhua to cease operations. Huawei was dependent on several US firms for a range of chips in its smartphones and telecommunication equipment. With its inclusion on the Entity List, it lost access to these semiconductor chips produced in the US market. Further, the BIS restrictions prevented the supply of US origin hardware or software to Huawei or any of its listed subsidiaries, including products made outside the US in which US origin IP constituted more than 25% of product value (Chen and Myers 2023). This restriction hit at Huawei's ability to even fabricate or design its own chips using SME and EDA tools, the global market for both of which was controlled by US based firms.

<u>Chinese Government's Reaction to Huawei's Sanctioning</u>

Huawei's sanctioning elicited a more proactive response from the Chinese government compared to its lukewarm retaliations against the sanctioning of ZTE and Jinhua earlier. In July 2019, the Chinese central government announced funding for semiconductor capital equipment and EDA tools via the second tranche of the National IC Industry fund or the Big Fund which had been operational since 2014 (Fuller 2021). Adding to the investment of $21 billion in the first round, the second funding earmarked another $29 billion (Marukawa 2023). Shadowing the central government, local governments in China established 15 semiconductor funds, contributing an additional $25 billion (Allen 2023). Traditionally, the Big Fund and other government backed funds at the provincial and local levels had focused on domestic design and ATP firms, largely ignoring manufacturing equipment and EDA software both of which required repositories of knowledge developed over half a century and substantial capital investments (Fuller 2019). This shift in emphasis of government subsidies from the most profitable market opportunities earlier towards potential chokepoints (Allen 2023) signaled the Chinese government's prioritization of the domestic semiconductor sector and its vulnerabilities.

<u>Huawei's Survival through Loopholes in the Entity List</u>

For its part, Huawei survived the onslaught through loopholes in the Entity List regulations. (Fuller 2021). The Entity List rules had been written prior to the era of globalized value chains and only covered EDA software and equipment containing 25% of US origin IP. Therefore, if the manufacturing equipment was mostly produced outside the US in offshore foundries, it could be used to bypass the export control restrictions. American firms like Qualcomm and Xilinx could still design the advanced chips for Huawei and outsource their fabrication to foundries such as Taiwan Semiconductor Manufacturing Company (TSMC) (Chen and Myers 2023). Huawei could also continue to buy the advanced chips from other IDMs such as Samsung which could design and manufacture these chips for Huawei using US origin IP (Fuller 2021). Thus, this iteration of export controls mostly affected Huawei's ability to design its own chips using US based design software, which marginalized the profits of its chip design subsidiary HiSilicon but kept the multisegmented Huawei afloat (Bown 2020).

4.3.1.2 Plugging the Loopholes in May 2020 Export Controls

To close these loopholes, Huawei's supply of chips through third countries was also restricted by the application of US Foreign Direct Product (FDP) rules in the May 2020 update to the export control regulations. This legislation barred any manufacturing firm, US or foreign based and using any US-origin components from supplying to Huawei and other Chinese firms on the Entity List (Bown 2020). Since all advanced manufacturing facilities or fabs around the world rely on either US technology or components in some measure (Allen 2022), such an extraterritorial application of domestic laws ensured that US was effectively able to choke Huawei's access to advanced chips for the time (Segal 2021). These measures were followed by additional inclusions in the Entity List in December 2020 which included China's largest foundry SMIC (Semiconductor Manufacturing International Corporation) amongst others (Bown 2020). Earlier in July 2020, the US government had successfully persuaded the Dutch government to ban the sales of advanced EUV machines sold by Dutch company ASML to SMIC under the FDP rules (Alper, Sterling and Nellis 2020).

Chinese Government's Response to US's use of SME and EDA Chokepoints

Shortly after the May 2020 export controls, the Chinese government doubled down on the support for domestic semiconductor firms through a series of government fundings and tax incentives. State Circular 8 released in August 2020 promised tax exemption to semiconductor projects producing advanced nodes at 28 nm or below (Fuller 2021). Lesser exemptions were also provided to those producing between 28 and 65 nm. Similarly, other firms in the semiconductor manufacturing segments such as those in design software (EDA), semiconductor materials and ATP were also relieved from paying corporate income taxes for two years (Triolo 2021).

China's model of economic planning and the new regulatory framework also reflected the Central government's prioritization of the semiconductor industry. The 14th five-year plan (FYP) (2021-2025), which was adopted in October 2020 declared semiconductors as one of the seven frontier technologies targeted for breakthroughs. It also highlighted the role of innovation in modernization and technological self-reliance as the path to achieve economic growth (Xinhua 2020).

Between September 2020 and June 2021, China passed a series of legislations signifying its intent and resolve through the domestic legal system (Wang 2024). These included the Provisions on Unreliable Entity List (PUEL), Export Control Law (ECL) and the Anti-Foreign Sanctions Law (ASL) amongst others, containing punitive and retaliatory clauses against any foreign state, legal organization, entity or individual discriminating against Chinese companies, causing them material damage and threatening China's national security in the process. They also granted extraterritorial jurisdiction to Chinese authorities to prohibit or restrict the supply of dual-use items to any entity outside Chinese territory (Bogdanova and Wang 2023).

Huawei and SMIC's Strategy against Chokepoints

In the corporate sector, Chinese technology companies, especially those directly targeted by sanctions, such as Huawei and SMIC started stockpiling advanced chips and manufacturing equipment (Bloomberg 2021). In less than a week after being squeezed further by the May 2020 restrictions, Huawei revealed that it had imported about $23 billion worth of advanced chips, components and materials in 2019, up by 73% compared to the previous year (Li and Ting-Fang 2020). It also increased the investments into domestic companies across chokepoints in semiconductor production through its investment units (Fuller 2022).

After its inclusion in the Entity List, SMIC realigned its focus to domestic customers, selling and generating more revenue from its sales in China and Hong Kong, compared to supplying globally (Chiang 2022). Backed disproportionately compared to other domestic firms by the Big Fund (Marukawa 2023), SMIC expanded its foundry business by announcing future projects in Shenzhen and Beijing. Unable to freely import advanced EUV machines, it stuck to older equipment, remaining profitable throughout 2021 by producing chips below the technology frontier for electronic devices such as smartphones, biomedical devices and electric vehicles (Chiang 2022).

Persistence of Chinese Vulnerabilities

Between 2020 and 2022 the demand for semiconductor chips grew in China and globally. In 2021, China imported about $378 billion worth of semiconductor chips while only 16% of its demand was being met through domestic foundries (Lee 2023; Warren and Bartley 2023). Being a late follower in global value chains, China's semiconductor firms faced high market entry barriers and remained confined to less revenue generating functions like assembly and testing (Lee 2023). Despite the steps taken after Huawei's sanctions therefore, the Chinese state and firms' dependency on foreign firms remained very high. For example, in EDA, 90% of the market in China was captured by the oligopoly of three US firms Cadence, Synopsys and Mentor Graphics (Kleinhans 2022). Similarly in SME, Chinese firms' market share was less than 6% in 2020 (Ezell 2024).

At the same time, corruption charges against Big Fund's top executives revealed the inefficiencies in the government's Industrial Planning and funding mechanisms (Branstetter and Li 2024). Despite the incremental progress made by Chinese firms since the May 2020 export controls, they remained vulnerable for further restrictions imposed by the subsequent iterations of export control measures.

May 2020 export controls against prominent Chinese firms served as a precursor for further restrictions on the supply chain chokepoints against the Chinese state and semiconductor industry, preventing not just the global sourcing of advanced chips by China based entities but also the ability to manufacture them within China. By effectively using the indispensability of US firms to the semiconductor fabrication process, the US government was able to cut Huawei and other prominent Chinese firms off from the global semiconductor supply chains producing advanced semiconductor chips. Subsequent instalments of export controls expanded the scope of these measures beyond restricting the supply of advanced chips to Chinese firms, leveraging chokepoints in the semiconductor production process to bring the Chinese semiconductor industry to a halt.

4.3.2 Strengthening of Chokepoint Controls under Biden Administration (2022-2024)

The first concrete measures after 2020 were announced on October 7, 2022, followed by an update in October 2023. The October 2022 export control measures were significant as they targeted China as a geographic location beyond the Chinese firms already listed on the Entity List (Lee 2023). Officials in the Biden administration such as National Security Advisor (NSA) Jake Sullivan who coined the phrase ‘High Fence, Small Yard’ to define the narrow focus of the export controls on advanced chips and critical inputs for their manufacturing, made it evident that US’s intentions were not just to maintain its lead but degrade China’s existing capabilities in the long run (Mark and Roberts 2023).

4.3.2.1 Extending Denial through Chokepoints to China as a Jurisdiction

The export controls announced by the US Department of Commerce’s BIS in October 2022 attacked the Chinese semiconductor industry on four fronts. First, they put a blanket ban on the sourcing of advanced semiconductor chips crucial for AI development by any entity in China including even the US companies operating an AI data centre in China (Allen 2022). On the manufacturing front, the 2022 export controls leveraged US’s dominance in chip design software and semiconductor manufacturing equipment as chokepoints against China. The FDP rules were invoked again in prohibiting fabs outside the US from manufacturing advanced AI and supercomputing chips designed by Chinese fabless designers. For the Chinese organizations on the Entity List, any kind of manufacturing by overseas fabs relying on US origin technology, software or hardware had already been banned since May 2020 (Allen 2022). Like it had done with the Netherlands earlier, the US government used diplomacy and persisted in convincing Japan to set thresholds for the most critical photolithography equipment used for manufacturing advanced semiconductor chips (Shivakumar et al. 2024). Following this, the sales of advanced semiconductor manufacturing equipment and its components was denied to all of China (Mark and Roberts 2023). Moving beyond material supply, the October 2022 export controls also put license restrictions on any US personnel, resident or green card holder working in any advanced manufacturing facility within China (Branstetter & Li 2024). This meant that leading US toolmakers like Applied Materials, KLA and Lam Research were forced to pull out their personnel from facilities run by Chinese semiconductor companies such as SMIC and memory maker YMTC (Reinsch et al. 2024).

Updates to the October 2022 export controls in 2023 decreased the thresholds for advanced chips as well as the equipment used for manufacturing them in a bid to squeeze the Chinese semiconductor industry further. Along with this, the Entity List's coverage was expanded to additional 43 countries to prevent stockpiling of advanced chips by Chinese firms through subsidiaries and shell companies abroad (Harithas and Schumacher 2024).

4.3.2.2 Chinese Government Strategy since the 2022 Export Control Measures

The Chinese government responded to US enacted export controls by increasing its financial support to the domestic chip sector. Throughout 2022, the Central government granted nearly $12 billion in subsidies to 190 domestically listed semiconductor firms. SMIC was the largest beneficiary of these subsidies which included other prominent firms such as Naura Technology in the SME segment, Tianshui Huatian in the packaging sector, and YMTC in the NAND memory segment (Cao 2023b). Similarly, Jiangsu province committed $74 million each year for the next three years while Guangzhou municipal government pledged $21 billion in 2023 for semiconductor projects by domestic chip firms (Cao 2023a; Che and Liu 2023).

Along with the increased financial support, the priority of the government has shifted towards ironing out the inefficiencies in the funding mechanism. While this process had begun earlier in 2021 through investigations of wasteful expenditure and graft charges against the Big Fund's top-level executives, it gained momentum in the aftermath of the October 2022 export control measures against Chinese firms. After significant readjustments, the Big Fund was revived again in February 2023. Together with other state-backed investors, it provided about $7 billion to the recently sanctioned YMTC and $2 billion to China's second largest founder company Huahong Semiconductor (Pan 2023). At the administrative level, two Party-led bodies: Central Financial Commission (CFC) and Central Science and Technology Commission (CSTC), were formed for coordinating and directing investments towards major science and technology projects in need of financial support. This was done to reduce wasteful spending and realigning the focus of the Industrial Policy on core technologies such as semiconductors which required longer time planning and investment (Triolo 2024a).

Compared to the previous investments targeting chokepoint vulnerabilities, the pattern of investment since 2022 export controls has covered mostly all segments of the value chain, putting into action the government's goal of promoting indigenization of the semiconductor supply chain (Allen 2023). Calls for self-reliance in science and technology, emphasizing innovation in core technology as a survival mechanism against intense international competition had surfaced frequently in the articles and speeches made by President Xi since 2018 (State Council 2023, Chen and Myers 2023). Reducing reliance on foreign inputs was also a key feature of the dual circulation strategy underlining the 14^{th} FYP (Bown 2020). To give effect to this strategy, a nationwide system for science and technology development was envisioned (Chen and Myers 2023) and used shortly after the US government increased its restrictions on the Chinese semiconductor industry. The top-down push for public-private collaboration against US enacted export controls was evident when in 2023 five private and public sector firms, all important players for working around chokepoint technologies, namely Huawei, SMIC, YMTC, Nauru and AMEC were given preferential access to state backed research in basic semiconductor R&D (Triolo 2024a).

4.3.2.3 Chinese Corporate Strategy since October 2022 Export Controls

Devoid of access to cutting edge fabrication, SME and EDA tools from foreign vendors, Chinese firms have increased their collaboration with other domestic firms in the sector. Huawei for example increased its investments and involvement with domestic firms in all subsectors of the production process (Chen and Myers 2023). Its investments in EDA startups, underway since 2020 are not only fulfilling its own chip design needs but also helping domestic packaging firms like JCET and Tongfu by providing them the EDA tools specific to the packaging process. In late 2023, Huawei's investment vehicle Hubbel Technology assisted Chinese lithography equipment maker SMEE in successfully developing a 28nm lithography machine (Triolo 2024a). Other niche specific companies such as memory chip maker YMTC are also collaborating with domestic equipment makers Naura and AMEC for replacement parts in the wake of US personnel and firms pulling out from China contributing to an increase in the latter firms' revenues, domestic market shares and capabilities (Triolo 2024b; Reinsch et al. 2024).

With the tightening of the US government's stranglehold on critical components, Chinese firms' access to key technology for chip production has become increasingly dependent on the pace of innovations around the chokepoints (Triolo 2024b). The strategies adopted to promote innovation differ for different firms depending on the gap in their existing capabilities and the technological breakthrough needed. In SMIC's case, innovative techniques such as multi-patterning were used to produce leading edge chips at 7nm for Huawei's smartphones in 2023 using older lithography equipment for making 14nm and 28nm chips (Chen 2022). According to some source, the US Commerce Department's decision to extend restrictions on the sales of older lithography equipment to China was premised upon SMIC's breakthrough in advanced chipmaking in 2023 (Goujon and Reynolds 2024; Harithas and Schumacher 2024). Huawei has also followed suit by patenting novel techniques and investing massively in open-source R&D to bypass the chip design and manufacturing equipment bottlenecks (Ezell 2024; Reinsch et al. 2024). By 2023, it was leading the development of open-source RISC-V architecture in China as an alternative to the core IP in chip design provided by foreign firms such as Intel and ARM (Triolo 2024b).

Anticipating further restrictions and uncertainty around foreign supplies, Chinese firms are also seeking to diversify the domestic supply chains away from US and foreign suppliers wherever possible. From January to August 2023, local manufacturers of key equipment won 47% of all machinery equipment tenders from Chinese foundries. In the same year, China's share of domestically produced SME nearly doubled year over year to reach 40 percent from about 21 percent in 2022 on the back of US equipment makers' sliding sales in the mainland. Chinese toolmaker firms Naura and AMEC which were major beneficiaries of this diversification, grew in revenue by 32% and 50% respectively in 2023 owing to domestic sales (Reinsch et al. 2024).

In the EDA sector, leading Chinese firm Empyrean has made strides in filling the gaps left by the pull-out of American firms Cadence and Synopsys, realizing a sixfold increase in its revenues between 2018 and 2023 (Varadrajan et al. 2024). Huawei's subsidiary HiSilicon is also working with domestic EDA companies in localizing the EDA tools for trailing edge chips above 14nm. Compared to other firms, the drive to remove American firms from production lines is more explicit in YMTC's intent to indigenize memory semiconductor supply chains within China under a series of code-named projects such as Wudang Mountain (Triolo 2024b).

4.3.3 Present Challenges for the Chinese Semiconductor Industry

Due to these changes brought about by the tightening grip of the US export control measures, semiconductor indigenization has been completed to the point that Chinese companies have presence in every segment of the value chain. However, this presence is limited at 28 nm (Warren and Bartley 2023) which is far below the level of leading-edge chips at 2nm to 3nm currently being produced by foundries such as TSMC (Ezell 2024; Shivakumar et al. 2024).

Despite the policy support provided by the Chinese government, it will be difficult to replace foreign equipment and software which are generally at a higher level of sophistication and quality than their Chinese counterparts (Triolo 2024a). As discussed in the previous sections of this thesis, Chinese firms still lag foreign firms in almost all segments or sub-sectors of semiconductor production. Especially in segments such as SME and EDA which require years of co-development and transfer of knowledge between firms to develop and perfect, Chinese capabilities will remain years behind the technology frontier for the foreseeable future, forcing Chinese firms to remain integrated with the global supply chains (Lee 2023). Further, China would have to increasingly meet its self-sufficiency targets by relying on second tier domestic equipment and secondhand products from foreign manufacturers in a very hostile international environment (Triolo 2021), which will keep the Chinese state and semiconductor firms vulnerable to export control measures at least in the short to medium term.

5 Findings and Discussion

Tracing the events of the US-China tech war from 2018 to 2024 provides ample data for analyzing the Chinese state and corporate sector's response to US's weaponization of semiconductor trade interdependence.

Chinese government's response to US's sanctioning of Chinese firms was triggered soon after Huawei was placed on the US Commerce Department's Entity List in 2019 preventing it from accessing the US market for advanced semiconductor chips. Shortly after this, potential chokepoints for domestic firms were identified by the Chinese state which directed its attention and funding towards overcoming them through its primary investment vehicle into the sector known as the Big Fund. In May 2020, after SME and EDA chokepoints were leveraged by the Trump administration to punish Huawei and its subsidiaries, the Chinese government announced tax incentives for firms working to find solutions around these chokepoints.

Chinese firms such as Huawei and SMIC which were progressively targeted in 2020 resorted to stockpiling advanced chips and manufacturing equipment. While Huawei increased its investment in domestic companies working on chokepoint technologies, SMIC turned to manufacturing less advanced chips using older equipment and selling them to domestic customers in China and Hong Kong.

Despite these measures however, Chinese firms' dependency on foreign entities remained high throughout 2021 and 2022. Being late followers in the global value chains, Chinese firms lacked innovation and expertise in semiconductor production and remained stuck in the low value adding functions like packaging and testing. Owing to the increase of electronics manufacturing and an expanding domestic consumer base in China, demand for semiconductors, especially at the cutting edge of technology increased in 2021. The mismatch between production and consumption ensured that Chinese domestic firms and the state remained dependent on foreign firms for the time.

The inefficiencies of Industrial planning further made progress complicated for the state as top executives of the Big Fund were arrested for corruption in 2022, temporarily halting state investment into the sector. This dampened the progress of the semiconductor industry in China which continued to remain vulnerable against further restrictions imposed in 2022 and 2023.

Following the strengthening of export control measures in October 2022, Chinese government increased its commitment to the semiconductor sector through financial funding and subsidies to domestic firms across the semiconductor value chain. It also prioritized the semiconductor sector through better administration and ironing out the inefficiencies in the government's funding instruments like the Big Fund. The government's focus on indigenous innovation was now put to work through a top-down push for a nationwide system bringing the public and private sector closer.

Compared to prior phases in China's semiconductor industry's evolution when Chinese semiconductor firms had competed against each other at lower segments of the value chain (Chen 2022), inter-firm collaboration to fill in the gaps left by foreign firms increased after 2022.

As the access to chokepoint technologies became dependent on the speed of indigenous innovation, Chinese firms experimented with novel techniques, open-source alternatives and increased R&D expenditure to overcome the barriers. Another important shift from earlier was that domestic firms in China increasingly preferred using domestic alternatives over incumbent foreign firms to mitigate the uncertainties associated with future export control measures.

These developments suggest that the nationwide system envisioned by the 14th FYP has been brought to fruition through both a top-down support from the government and a bottom-up push from the commercial sector. Sustained pressure from Washington has made the corporate sector increasingly aligned with the state's goal of achieving indigenous innovation as early as possible, partially because the latter's own access to present and potential chokepoint nodes depends on it. The trend of diversification of established supply chains through domestic alternatives further suggests the targeted state's attempts to isolate itself from the economic network to reduce its vulnerabilities. Increase in innovation is likely to push the Chinese firms up the value chain reorienting the networks of production and the supply chains over time, upending the established order of interdependence which made weaponization possible in the first place. In the long term, both these trends threaten to sever the interdependence between the target and the weaponizing state, highlighting the limits to the phenomenon's future leverage.

For the framework of Weaponized Interdependence, the findings from this thesis contribute to improving the original framework by making it more interactive through incorporation of the target state's response. As the competition between US and China for progress in dual use technology has intensified, Chinese firms have been the leading agents for finding workarounds to the US enacted chokepoints and in the process have found themselves to be closely aligned with the Chinese state's policy goals. Even in the case of China which has been accused of 'steering' its domestic firms through excessive meddling in corporate governance, it cannot be assumed that Chinese firms will always go along with the state's directives (Chen 2022, Triolo 2024a). The thesis' findings to the contrary therefore justify their inclusion in the weaponized interdependence framework.

Further, the pace of production and upgrading using cutting-edge innovation within the semiconductor industry is not uniform but spread across different subnetworks of production stages represented by a different set of firms with varying degree of technology specialization and bargaining power in the market. Identifying that the interaction between different networks can lead to new strategies of contention and economic coercion, the original authors of the framework deemed their addition a task for future analysis (Farell and Newman 2021). The findings of the thesis where inter-firm collaboration between SMIC and Huawei representing different subnetworks motivated further restrictions by the US government in 2023 validate the authors' speculation of the interactive effects of subnetworks. This contribution of the thesis to the original framework could not have been possible without including firm level data in the analysis.

At the same time, it is important to acknowledge that the findings of this case are specific to the weaponization of trade in technology, which might be less generalizable to other kinds of weaponization involving for example energy or financial networks. However, as the findings of this thesis depict, the inclusion of non-state actors increases the potential of the original framework and therefore must be explored for other cases of weaponization as well.

6 Conclusion

The case of US export controls against Chinese state and firms classifies under the framework of Weaponized Interdependence by Farell and Newman. Since 2019, US has effectively used its influence over the hub nodes of chip design software and cutting-edge manufacturing equipment to enact chokepoints against Chinese firms, cutting them off from the global network of advanced semiconductor production. While US restrictions have directly affected Chinese firms, the official language of export control measures as well as senior bureaucrats in the US government made it evident that the final target of these measures was the Chinese state and its ability to compete on dual use technology.

This thesis sought to contribute to the evolving literature on Weaponized Interdependence by incorporating the target state's response against weaponization measures, which had been left undeveloped in the original framework. The initial framework was also limited by its omission of non-state actors in the process of weaponization. Analyzing China's response to the US's initiation of the tech war against its firms served as fertile grounds for improving these shortcomings in the original concept. Since Chinese semiconductor firms were at the forefront of the US-China rivalry, the thesis set out to analyze the Chinese state's response by incorporating the actions of both the Chinese government and the corporate sector.

Process tracing of the events during case analysis revealed how the Chinese government and corporate sector had responded to US's restrictive measures. Between 2018 and 2024, the Chinese government has increased its policy and financial support for indigenous innovation, generating a top-down push for public-private collaboration. At the same time, domestic chip firms have increased inter-firm partnerships and efforts at innovative solutions to get around the chokepoints imposed on them. There is also a tendency to replace American and other foreign equipment wherever possible. Thus, a nationwide system envisaged during the 14th FYP to foster indigenous innovation is beginning to take shape in China.

Chinese government and semiconductor industry's actions suggest attempts at isolation from the supply chain while subverting it in the long run. The push for indigenization and acknowledgement by the commercial sector is helping China to move towards an inward-looking semiconductor supply chain. A nationwide effort for innovation on the other hand is enabling Chinese firms to move up the value chain, upending the established hierarchies and creating potential for future weaponization by China. From this view, the strategy of weaponization appears to be limited by the pace at which China isolates or subverts the supply chains for semiconductor production. In the longer run, it also appears to be counterproductive by driving up efforts to build local capabilities in the target state.

Despite the progress, Chinese efforts remain limited due to certain constraints. Internally, Chinese Industrial Policy and funding mechanisms have been called out for inefficient resource allocation espousing widespread corruption and political interference (Fuller 2019). At the level of industry, Chinese firms lag other foreign firms at the technology frontier in almost all segments of the value chain, severely restricting their ability to replace foreign equipment in the short to medium term. China's vulnerability towards future use of chokepoints as well as the effectiveness of weaponization as a strategy by the US is contingent upon these constraints which could only be covered briefly due to the limited scope of this thesis.

Further, direct and indirect effects in highly networked domains such as semiconductor supply chains are not bilaterally determined but contingent on multilateral decision making (Warren and Bartley 2023). This thesis was limited in its scope by interpreting the target state's mitigation strategy against weaponization of interdependence by the dominant state. Incorporating other actors in the value chain and their interaction with the target and weaponizing actor would make the analysis more dynamic, an aspect which can be explored in future work.

Important insights generated by the findings benefitted from the inclusion of firms in the Weaponized Interdependence framework. Besides being active agents in leading and developing China's response to the export control measures, the interaction between firms representing different subnetworks of semiconductor production also prompted change in the strategy of the weaponizing actor US. Such findings from the thesis highlight the important role played by firms in understanding the broader weaponization phenomena while improving the potential of the original framework.

Finally, it must be ceded that since the US-China conflict in chip trade is an ongoing phenomenon, the conclusions provided by this thesis are tentative, which can benefit from future research as the dynamic of response-counterresponse to export controls becomes clearer with time. Suggestions for improvements in the original framework made in this thesis can then be made more generalizable to other cases of weaponization such as in the energy or financial networks.

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