Discover Global Society

Perspective

Strategic implications of the US-China semiconductor rivalry

Manal Hamdani[1] **· Ismail Belfencha**[1]

Received: 15 May 2024 / Accepted: 13 August 2024
Published online: 02 October 2024

Abstract
The ongoing trade war between China and the United States has had a far-reaching impact on a global scale. This rivalry has been most obvious in the semiconductor industry. The two nations have found themselves in a tense geopolitical situation where any economic attack by either side would affect all parties involved. This paper aims to explore the origins of this conflict and highlight the key actions taken by each country, as well as the consequences of those actions. Additionally, it highlights the areas of interdependence between China and the US (i.e., American high-tech chips and Chinese rare earth materials). The study utilizes the theory of weaponizing independence and game theory's Prisoner's Dilemma to conclude that while both China and the US have suffered negative consequences due to this conflict, China's latest technological advancements in the 7nm chip and their supply of rare earth materials have given them a stronger hand in the game.

Abbreviations

AI	Artificial intelligence
AMD	Advanced micro devices
ASML	Advanced semiconductor materials lithography
DUV	Deep ultraviolet lithography
EU	European Union
EUV	Extreme ultraviolet lithography
FABs	Fabrication plants
SMIC	Semiconductor Manufacturing International Corporation
TSMC	Taiwan semiconductor manufacturing company
US	United States
WTO	World Trade Organization

1 Introduction

The ongoing rivalry between the United States and China has taken multiple forms. From military and economic to cultural and ideological. Nonetheless, one of the main points of competition between the two countries has been what is known as the 'chip war'. The Chip War, which is the name that has been attributed by some authors to the technological rivalry between the United States and China in the field of Semiconductor manufacturing [1–3], constitutes a significant chapter in the global competition for technology dominance. The conflict at its core relates to the struggle

✉ Manal Hamdani, manallhamdani@gmail.com; Ismail Belfencha, ismailbelfencha@gmail.com | [1]International Studies and Diplomacy, Al Akhawayn University, Ifrane, Morocco.

for supremacy in the semiconductor industry, a sector that plays a vital role in the development and security of modern technology. Semiconductors, also known as "chips," are essential components in various devices, including smartphones and advanced military systems, making their production and control a matter of national interest and security. On one hand, the United States has a long-standing reputation as a leader in semiconductor technology and has been taking various strategic measures to keep its competitive edge. Such measures include investing in domestic chip manufacturing, implementing policies to protect intellectual property, and limiting the export of advanced semiconductor technology to China. The driving force behind these actions is based on concerns over national security, economic competitiveness, and technological leadership.

On the other hand, China has been making significant efforts to decrease its reliance on foreign semiconductor technology. The country has been investing heavily in research and development to strengthen its domestic chip industry. China's ultimate goal is to increase self-sufficiency and self-reliance in technological industries and "build an all-Chinese supply chain" when it comes to semiconductor production as part of its wider strategy to attain technological supremacy [4]. Furthermore, the "chip war" between the United States and China is not a simple bilateral conflict, but a highly complex issue with far-reaching implications for the global technology landscape. In the sense that both countries are in a race to achieve technological supremacy in this crucial field, leading other nations, and multinational corporations to navigate a complicated web of alliances, supply chain dependencies, and geopolitical tensions. The outcome of this struggle will have significant consequences, reshaping the global balance of technological power, and impacting everything from consumer electronics to national security.

In this technological conflict, the United States has managed to hold a leading position in R&D and designing high-end semiconductors. This is primarily thanks to Intel and Apple which design some of the most advanced chips in the world in Silicon Valley. Nonetheless, the US semiconductor industry is deeply reliant on other countries. First, 75% of the production process of these semiconductors designed in the US takes place in Taiwan and China [5]. Secondly, the rare earth materials needed for the production of these semiconductors are imported from various countries the main of which is China. Finally, China, since 2017, has been working on expanding its 'legacy chips" (chips that are 28 nm or larger) [6] production accounting for 31% of the global market in 2023. [7] Thus, although the US might be enjoying supremacy with regard to advanced semiconductors, the raw materials, the assembly, and the labor force needed to create the final product are reliant on a larger supply chain.

The seeds of the conflict were planted in 1997 after the joint statement issued by both the US and China which focused on exploring areas of cooperation between the two countries and "strengthening bilateral exchanges and cooperation in economic development, trade, law, environmental protection, energy, science, and technology" [8]. This statement was followed by China's accession to the WTO. These set of actions can be viewed by liberal scholars as a prominent step towards economically induced peace. Their agreement aimed at getting rid of all tariffs on technological products by 200 and paved the way for China's entrance to the World Trade Organization (WTO) in 2001 [8, 9] [10, 11]. However, China's growing economic and military power has unsettled the US, leading to a series of protectionist policies designed to isolate China and bring semiconductor fabrication plants back to the United States. Thus, President Trump's assault on Chinese companies and President Biden's signing of the Chips and Science Act in 2022 exemplifies this approach.

Therefore, this paper aims to explore the complex dynamics of the technological and military competition between the United States and China, and the other actors involved in this war. I argue that the interdependent system that has been constructed by the US and its allies since the end of the Cold War has made protectionist policies adopted by one country harmful to all the others. Not only this, but I even argue that in the long term, it has been and is going to be more harmful to the US than to China.

2 Theoretical framework "Weaponizing interdependence in a Prisoner's Dilemma"

It is important to mention Henry Farrell and Abraham Newman's concept of weaponized interdependence, which they define as "a condition under which an actor can exploit its position in an embedded network to gain a bargaining advantage over others in a contained system" [12]. This concept is extensively explored in their book, 'The Uses and Abuses of Weaponized Interdependence,' where they delve into the strategic use of global economic networks for statecraft and coercion. The authors argue that the interconnected nature of globalization, commonly perceived as mutually beneficial, can be strategically manipulated by powerful states to exert influence and pressure.

The book focuses on how states, particularly powerful ones, leverage their positions within global networks—financial, technological, or trade—to achieve geopolitical objectives. This is illustrated through examples like the United States' use of secondary sanctions against Iran, the NSA's surveillance activities exposed by Edward Snowden, and the use of the SWIFT system to monitor or exclude adversaries [12]. These cases highlight the critical role of technical infrastructures, such as dollar-clearing systems, fiber-optic cables, and communication networks, in geopolitical influence and coercion.

This can be used to understand how both the US and China are able to use the fact that they are important to the international economic system to reap benefits. This situation resembles the state of the world during the Cold War, but, instead of nuclear deterrence, economic interdependence is the main weapon. To support their claim, the authors cited the example of how the US managed to utilize its position in the international economic system to isolate Iran and North Korea which were regarded as "rogue regimes"[12]. Farrell and Newman also discuss the potential risks and drawbacks of weaponized interdependence. For instance, they analyze China's 2010 restriction on rare-earth exports to Japan, noting how short-term strategic gains can be offset by long-term losses in coercive power. This points to the complex dynamics and unintended consequences that can arise from the use of economic interdependencies for strategic purposes. Similarly, we can look at the Oil crisis of the 1970s as another example where interdependence was weaponized leading to harmful consequences for both Middle Eastern countries, who were harmed due to the political threats made by the US as well as the movement of the Western countries towards energy alternatives [13], and the allies of Israel, who lost access to cheap oil imported from the Middle East [14]. This is the approach that is going to be followed in this paper. The purpose behind this is to look at how the attempts of the United States to restrict the interdependent economic system, that it has been striving to build since the Cold War, has led to unwanted results for both the states targeted by those restrictions (China in this case) as well as the state implementing those restrictions (the United States in this case.) This kind of collective consequence to both actors involved is similar to the analysis provided by game theory's prisoner's dilemma.

The prisoner's dilemma is a famous simulation that has found its way to different fields with the purpose of explaining and predicting the actions of a set of rational actors. In this simulation, we have two prisoners being interrogated separately and cannot communicate. Each prisoner has the option to either cooperate with the other by staying silent or to defect by betraying the other. The outcomes are represented in a payoff matrix: if both prisoners cooperate, they each receive a light sentence of one year; if one defects while the other cooperates, the defector goes free while the cooperator gets three years; if both defect, they each receive a moderate sentence of two years. In the usual one-time play, the best choice would always be to defect. This is to avoid the three-year sentence. Nonetheless, with repeated interaction, the actors would learn to cooperate as that would allow them both to get the lowest sentence [15].

The chip war between the United States and China can be understood through the lens of the Prisoner's Dilemma, where both nations face a strategic decision: cooperate or defect. For the United States, maintaining the status quo, where both countries cooperate, allows China's economic and military growth to continue unimpeded. This situation is perceived as primarily beneficial to China, given its ambitions to become a global technology leader. Consequently, the U.S. has opted to defect by imposing stringent export controls and sanctions aimed at curbing China's access to advanced semiconductor technologies. This strategy is designed to slow China's technological progress and preserve U.S. dominance in critical sectors like AI and quantum computing.

China, on the other hand, sees mutual cooperation as a path to bolster its technological capabilities and economic growth. The Chinese government has invested heavily in its semiconductor industry to reduce dependency on Western technologies and achieve greater self-reliance. However, U.S. defection, manifested through trade restrictions and the CHIPS Act, compels China to intensify its efforts to develop indigenous semiconductor technologies. China has responded by accelerating its domestic production capabilities and finding ways to circumvent U.S. restrictions, such as acquiring high-end processors through resellers. This tit-for-tat escalation reflects the core principles of the Prisoner's Dilemma, where each party's decision to defect leads to a mutually detrimental outcome.

Both countries defecting is mutually harmful, reflecting a zero-sum game where technological advancements and economic benefits are fiercely contested. The U.S. faces pushback from its own tech industry and allies, who may not fully align with U.S. export controls due to the strategic importance of China's semiconductor industry and rare earth materials. Meanwhile, China's accelerated self-reliance efforts face significant technological and infrastructural challenges due to its need for Western machinery and chips. This complex interplay between cooperation and defection highlights the broader implications of the chip war on global technological and economic stability, where both nations must navigate their strategic interests within an interconnected international supply chain.

The other theoretical framework that is going to be used in this paper is Game Theory. It examines how the players involved, China on one side and the US on the other with their respective allies, are trading blows regarding the semiconductor industry. This is going to be done through analyzing the actions taken by different actors and the resulting short- and long-term outcomes. Game Theory posits that repeated interactions in a Prisoner's Dilemma scenario can increase the likelihood of cooperation. The neoliberal belief that economic international interconnectedness promotes peace has dominated the field of game theory and international relations in the past decade. Authors like Correa (2001) and Evans and Newnham (1988) describe a globally interconnected system where economically every state is interdependent [15, 16]. However, the current international political state with regards to the trade war between the US and China challenges this assumption. Both actors are pursuing their economic interests, which may clash with the international system's preference for openness and free trade. This paper aims to analyze whether economic interdependence has made both actors unable to successfully restrict the other actors without harming themselves.

When looking at the actors involved in this game, there is a risk of determining which actors are relevant to this study. Should we define actors as multinational companies or states? The focus here will be on states because major Chinese companies involved in this conflict are state-owned, while US companies like Intel have successfully lobbied the US government to implement favorable policies. Additionally, although initial US sanctions targeted Huawei, later restrictions impacted all companies dealing with US-made technologies. In contrast to the usual game theory alignment where both actors prefer the other's cooperation while maintaining a confrontational posture, each actor in this trade war has distinct interests. The US aims to prevent Chinese companies from dumping products in its market and limit their access to high-tech products, while maintaining access to Chinese rare earth materials. Conversely, China desires access to the US market and products, preferring the pre-sanctions status quo. Thus, the Prisoner's Dilemma framework helps analyze the US-China interaction within the international semiconductor supply chain, assessing whether economic interdependence has promoted cooperation or default.

3 Historical background

"I would say that hardware is the bone of the head, the skull. The semiconductor is the brain within the head. The software is the wisdom and data are the knowledge" [17]. These were the words of Masayoshi Son after he was asked about the different parts that make up his company, Softbank Group. This interview took place in 1992 at the height of the US outsourcing of its semiconductor industry to manufacturers in Taiwan, Japan, and China. Before that, in the 1980S, the US was at the top of the pyramid, holding more than half of the semiconductor market share. However, with the fall of the Soviet Union and the establishment of "the unipolar moment" [18], the US found itself in a position where it had to spread the victorious neoliberal order [19]. This liberal order is based on "economic openness, multilateral institutions, security cooperation, and democratic solidarity" [20].

This process of outsourcing can be seen in Fig. 1. In that figure, we can look at how the US used to be the largest manufacturer of this technology but slowly started to get smaller while other Asian and European countries started to get larger. U.S. factories produced 37% of the world's semiconductor chips in 1990, but this figure dropped to 19% by 2000 and 13% by 2010. [3] This outsourcing was a physical process as these semiconductors require a particular type of factories and labor. These factories are called fabrication plants (FABs), and they need huge sums of money yearly to keep running. For example, the operational expenses of Taiwan Semiconductor Manufacturing Company Limited (TSMC), the largest semiconductor manufacturer in the world, reached 39 billion dollars in 2022. [21, 22] Therefore, the destination to which this industry was going to be outsourced needed to have cheap and skilled labor that would agree to work under harsh working conditions. Additionally, this destination needed to have attractive trade policies that would make relocating worth it. Thus, Taiwan took advantage of that and started offering international "firms attractive terms for setting up a business, as well as a range of taxation benefits and allowances." [23]

4 The chip war

Today, about thirty years later, the US is trying to revive its semiconductor industry due to several economic and geopolitical reasons. First, there is the rise of China as a superpower that is competing with the US. This rise made US decision-makers worried as the Chinese economy became the second largest economy after that of the US. Furthermore, the growth achieved by China was due to currency devaluation and a huge amount of subsidies. These two policies allowed Chinese companies to grow and increase their exports while maintaining comparatively attractive low prices. Therefore, they were regarded as "unfair trade practices" that "hurt a variety of US-headquartered companies" [24]. Second, there is the fear of losing Taiwan. Taiwan has been a hot topic between the US and China. The US relies on Taiwan for high-tech products (Taiwan and South Korea are the only countries capable of manufacturing semiconductors lower than 5nm).

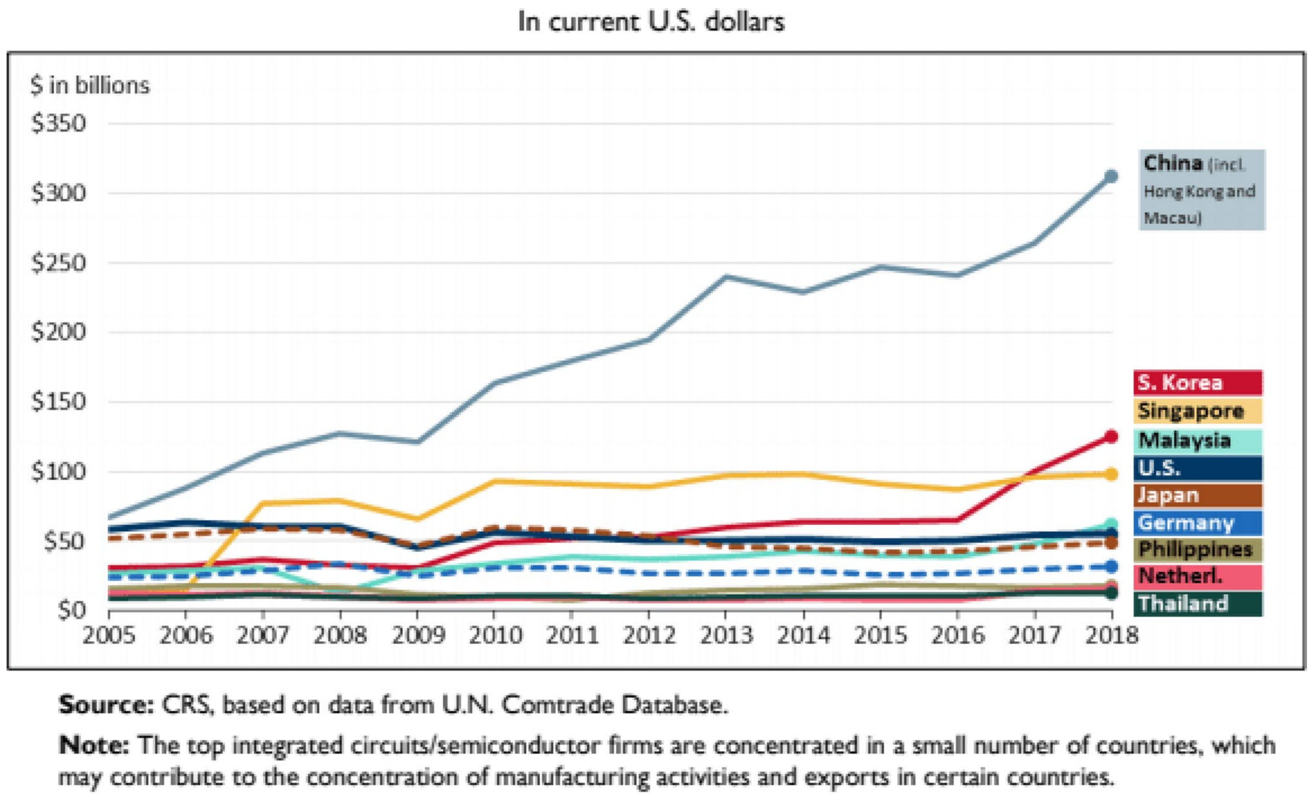

Fig. 1 The outsourcing of the semiconductor industry

Additionally, Taiwan is regarded by several US decision-makers as a symbol of liberalism and democracy. Since the end of the Chinese Civil War and the retreat of the government of the Republic of China into Taiwan, China has retained its claims of sovereignty over the island of Taiwan and called for reunification regardless of whether that reunification was achieved through peaceful measures or otherwise with a preference for peaceful reunification.

"We insist on striving for the prospect of peaceful reunification with the greatest sincerity and best efforts, but we will never promise to give up the use of force and reserve the option to take all necessary measures." Xi Jinping [25].

In addition to the ideational reasons for being regarded as a symbol of liberalism and democracy, there is an economic reason behind the importance of Taiwan. Although the United States used to dominate the semiconductor industry with companies like Intel and Advanced Micro Devices (AMD), Taiwanese companies (especially TSMC) managed to achieve significant growth in the past twenty years (Fig. 2) This rapid development allowed TSMC to be the most advanced semiconductor manufacturer, being responsible for more than 90% of the production of cutting-edge semiconductors (5nm and lower). Therefore, with the political tension between China, the US, and Taiwan, the danger of having an unforeseeable political or military stunt by China can threaten to cut the supply of these chips to the United States.

Finally, there is the economic and political issues that have accompanied the rising unemployment in the United States, especially during the period of COVID-19. All of these elements resulted in the elections of presidents who favored protectionism and moved away from globalization and interdependence. This was made evident by the fact that some of the slogans that Trump's presidential campaigns used were "Make America Great Again" and "Bringing back American jobs" [26]. The protectionist policies that have resulted from this put the US in direct confrontation with China.

Before outsourcing this industry, the main source of technological development and breakthroughs was the US Department of Defense (the DoD). During the Cold War, people like Donald W. Gunter, Westinghouse Semiconductor General Manager, and Jack Kilby, one of the inventors of the inverted circuit, used to work closely with the DoD, receiving funding for the development of technologies that can aid the US in its war against the USSR [27]. This provided the US with the ability to control where these technologies go and in case they fell into "the wrong hands," they would have some countermeasures [28]. However, now, private companies have become the leading bodies when it comes to technological development, creating fertile ground for security dilemmas. One of the possible explanations for this fear is the privatization of the security dilemma. In the sense that private companies have managed to gain control over

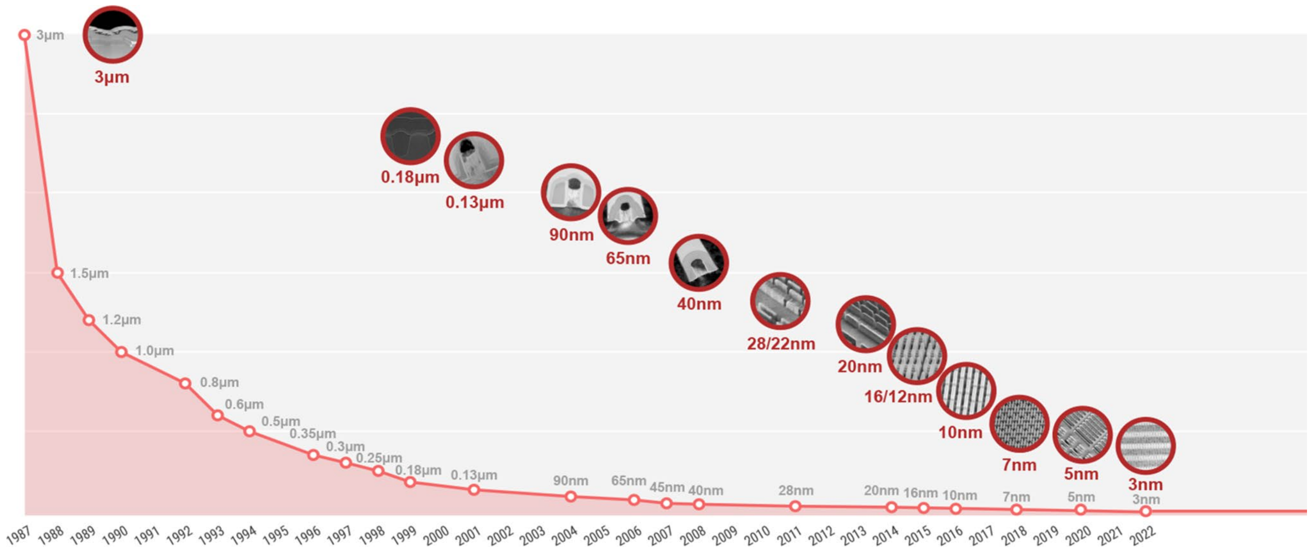

Fig. 2 the development of TSMC chip manufacturing (TSMC, 2022)

some important products such as advanced technologies that can be used in weapons. Additionally, with the rise of AI technologies which are completely reliant on breakthroughs in the semiconductor industry, the fear has increased.

4.1 US restrictions

The US was determined to slowly disarm China's supply chain. The goal behind this is twofold. First, there is the goal of undermining China's control over this industry as that control has been regarded by the Biden administration as "Unfair" [29, 30]. Secondly, there is the aim to restrict China's access to technology that can be used in military and intelligence [31]. This was done through various steps. This started in July 2018 when the United States imposed 25 percent tariffs on semiconductors imported from China and put restrictions on the types of semiconductors China can receive from the US [24]. This did not have a major impact on China's economy and development as it was still able to get its semiconductors from Taiwan and South Korea which have much more advanced chips than those made by the US. In addition to this, the US market is not the main target of China's chips, but it is the Netherlands, Hong Kong, and India.

Looking at these results, the US moved to what Chris Miller called "an assault on Huawei" [3]. The Trump administration accused Huawei, one of China's largest technology companies, of espionage and posing a national security threat. However, these accusations were not the sole basis for Huawei's placement on the U.S. Entity List in May 2019. The primary legal grounds for this action were indictments by the U.S. Department of Justice earlier that year, alleging Huawei's involvement in financial fraud, violations of sanctions on Iran, theft of trade secrets, and obstruction of justice [32]. While concerns over espionage were part of the narrative, the formal actions taken against Huawei were based on these specific legal allegations and compliance issues under U.S. law. The placement of Huawei in the entity list made it unable to sell its product in the US market and even restricted it from using Google services. Although the company was issued a Temporary General License (TGL) which allowed it to maintain a level of business activity with American companies during which it stockpiled a significant amount of chips, the stockpile only lasted the company two years [33, 34]. Huawei managed to hold 20% of international smartphone share in 2020, surpassing both Apple and Samsung. However, when the sanctions took effect, Huawei's market share reached 8% in the first 2020 only to completely disappear from the charters in 2021 (Fig. 3). This disappearance pushed Huawei to refrain from including its market share in its annual report.

In 2023, the United States, through the CHIPS Act, invested approximately $53 billion in its semiconductor sector [35]. This substantial investment is a strategic effort to reduce reliance on semiconductor imports, especially from Taiwan, in light of potential geopolitical uncertainties. The enactment of the CHIPS Act led to announcements of more than $166 billion in investments in the semiconductor and electronics manufacturing sectors [35]. Key states like Ohio, Arizona, and Texas are seeing significant development of semiconductor facilities. These initiatives are integral to enhancing the U.S.'s competitive edge, strengthening supply chain resilience, and ensuring national security. This

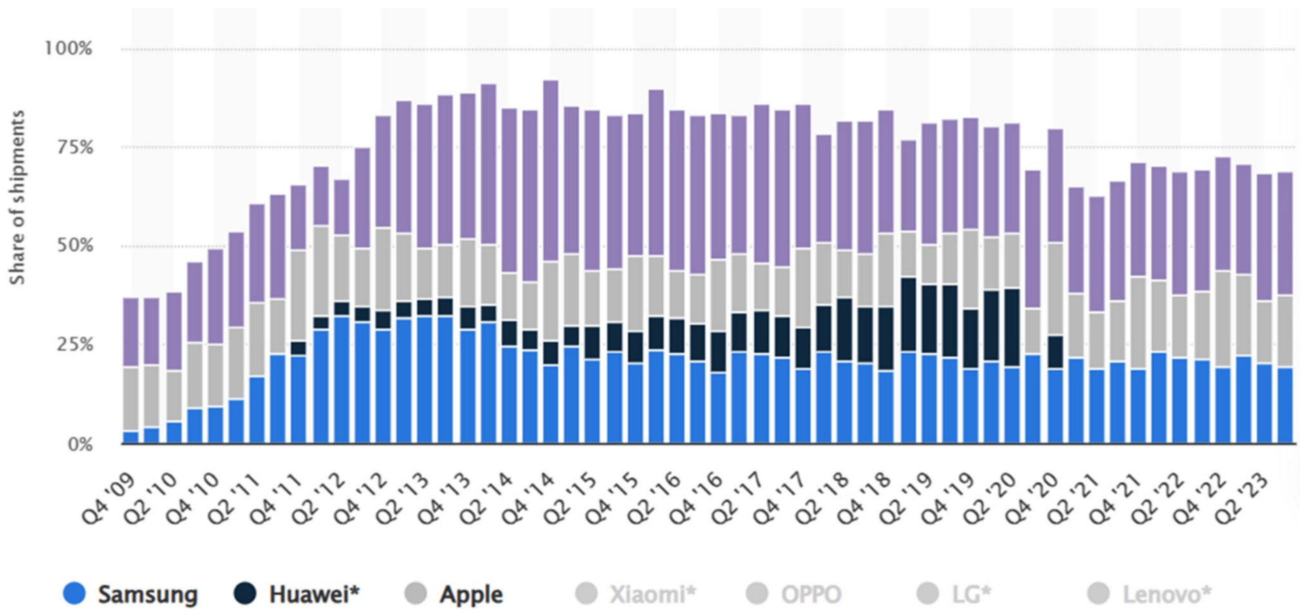

Fig. 3 Smartphone Market Share by Vendors (Smartphone Market Shares by Vendor 2009–2023)

move underscores the U.S.'s commitment to revitalizing and advancing its domestic technological infrastructure, marking a significant shift in its approach to semiconductor production and innovation.

In addition to this, the US managed to secure the help of both Japan and the Netherlands both of which implemented some restrictions on the kind of Chips and machinery that China could get. [36] In January 2023, the United States made an understanding with the Netherlands and Japan to enforce new semiconductor export controls to China. This was a significant diplomatic victory for the United States and part of a broader effort to restrict China's access to advanced semiconductor manufacturing technology. The deal's specifics are not fully public, and the involved countries have remained tight-lipped to minimize the risk of Chinese retaliation. The Dutch and Japanese governments are expected to update their export control regulations in the coming months, and some policy changes may never be publicly disclosed.

The context of this agreement is rooted in the strategic roles that Dutch and Japanese companies play in the global semiconductor value chain. While the U.S. has a strong overall position in the global semiconductor industry, Dutch and Japanese companies possess advanced technological capabilities in highly related disciplines, particularly in the production of lithography equipment. Dutch companies are world leaders in lithography steppers and scanners, which are crucial for chip production. Japanese companies are also major producers of steppers and scanners, with both countries combined holding more than 99% of the worldwide market share in 2019 [36]. Most importantly, the Netherlands exports the most crucial tool which is responsible for extreme ultraviolet lithography (EUV) which is manufactured by the Dutch company ASML (Fig. 4).

The U.S. initiative aimed to prevent Dutch and Japanese companies from filling the categories of semiconductor manufacturing equipment that the U.S. no longer sells to China. Additionally, the agreement aimed to restrict the export of advanced lithography equipment to China, which is crucial for maintaining U.S. technological leadership and hindering China's military technology trajectory. The agreement with the Netherlands and Japan extends some of the export controls that the U.S. adopted in October. This includes restrictions on companies like ASML Holding NV, Nikon Corp, and Tokyo Electron Ltd. These controls are part of a larger effort by the Biden administration to slow China's technological and military advances by limiting its access to U.S. chipmaking technology.

"We have made it very clear to the Dutch: We believe that this kind of sensitive technology does not belong in certain places" [38]. These were the words of Pete Hoekstra the US ambassador to the Netherlands after the US started to pressure the Netherlands to implement restrictions on China. This pressure would eventually pay as both the Netherlands and Japan would announce trade restrictions on semiconductor equipment in March and July respectively after the US did so in April 2022 [39]. This triggered a reaction from China who accused the US of committing "technological terrorism", trying to block China's development, and going against the very free trade system that the US is famous for promoting.

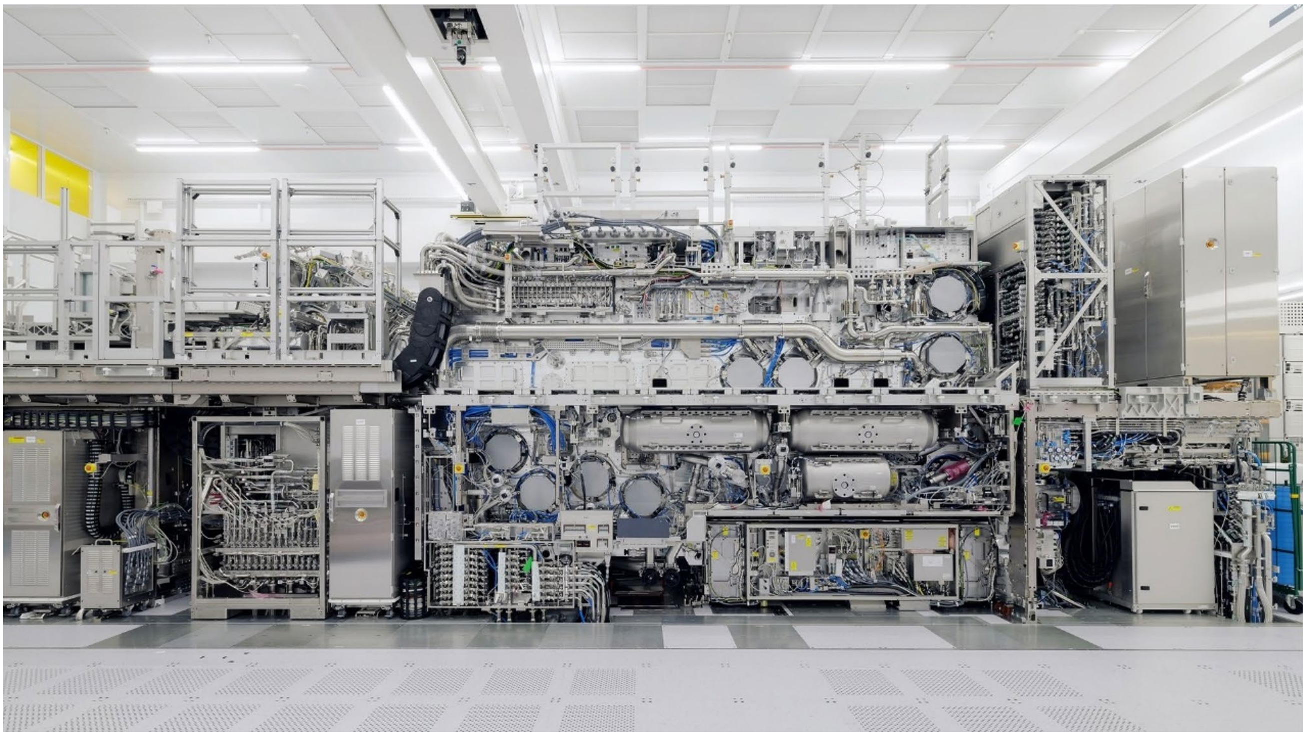

Fig. 4 Extreme Ultraviolet Lithography (EUV) machine from ASML [37]

The final nail in the coffin was adding Semiconductor Manufacturing International Corporation (SMIC), China's largest semiconductor manufacturer, to the US Treasury Department's entity list. This was done due to the alleged involvement of SMIC with the Chinese military [40]. Being put on the entity list means that if US companies would like to export to the said company, they would require a special license. This includes investment and patent deals. As a result, China faced some issues with regard to accessing the US market. This includes both selling in the market and receiving some technological parts that are important for the Chinese economy. The impact of these limitations was felt by both the US and China. The former worsened the semiconductor shortage it had already been experiencing while the latter faced some stumbling blocks to revive one of its biggest technological companies.

Some authors looked at the technological war between China and the United States and argued that a "targeted decoupling" has taken place [41]. In thier article, Ryan and Burman explain the US's attack on Huawei as part of Washington's move away from its post-Cold War "role as the guarantor of the global market" towards favoring domestic economic interests. While this paper provides a detailed analysis of the impact that this decoupling has had on Huawei and how by doing it, the United States risks jeopardizing other cooperation prospects with China, the paper fails to look at the issue in relation to the larger supply chain where China plays an important role thanks to its rare earth materials. Furthermore, the paper only looks at the technology needed and imported by China from the United States, not the other way around. It did not highlight how together with COVID-19, the sanctions imposed on China have caused a shortage in semiconductors causing issues to automotive companies in the US [42]. A similar discussion is highlighted by Adam Segal's chapter "Huawei, 5G, and Weaponized Interdependence". This chapter provides a comprehensive analysis of the U.S.-China competition over 5G technology, focusing on the concept of weaponized interdependence. Segal elucidates how global ICT supply chains have fostered economic interdependence, which both nations leverage for strategic advantages. The chapter thoroughly details the Trump administration's measures to restrict Huawei's market access and disrupt its supply chains through economic statecraft tools [12]. However, similar to the previous paper, this chapter lacks an international perspective by not considering the role of U.S. allies in enforcing these restrictions. Additionally, it overlooks the impact of these restrictions on the U.S. itself.

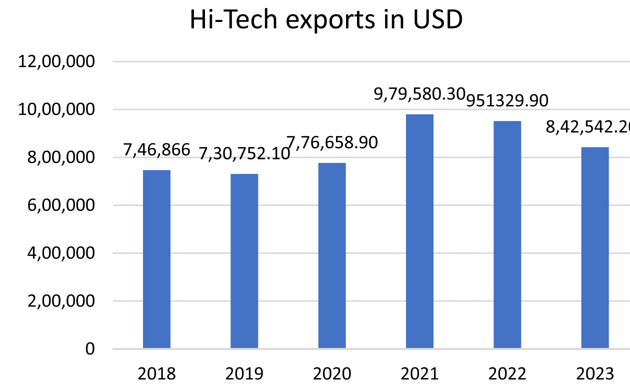

Fig. 5 China's Hi-Tech exports from 2018 to 2023 (data gathered by the author from the annual reports released by the General Administration of Customs of the People's Republic of China)

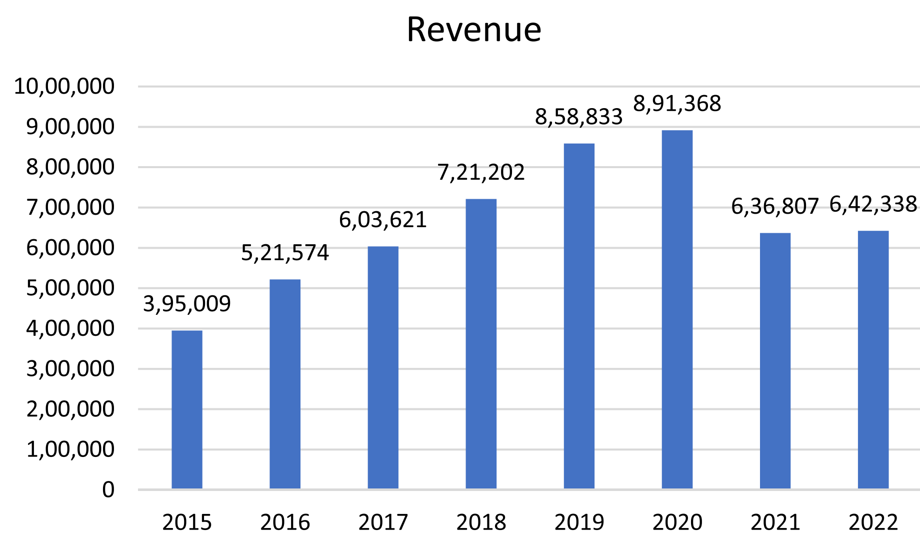

Fig. 6 Huawei yearly revenue from 2015 to 2022

4.2 The outcome of the restrictions

The restrictions the US put against China had a multifaceted impact on China. Huawei was not able to release new technology at the same level of advancement as it used to. This is because it did not have access to either semiconductors or Google's operating system, Android. When it comes to the Chinese economy, it is hard to identify whether the reduction of speed that China's growth was due to Covid-19, or the restrictions put in place by the US and its allies. What we can be sure of is that China's access to chips faced a huge fall when it comes to semiconductor imports in 2022 as it dropped by 12% from the previous year [43]. Thus, lower access to semiconductor technology, machinery, and the latest developments in the field made China unable to reach the goals it set "to increase its domestic production to 70% by 2025" [44]. This goal was part of the plan titled "Made in China 2025" released by the Chinese government in 2018.

Nonetheless, using deep ultraviolet lithography (DUV), which is an older and less advanced version of the EUV exported by the Netherlands, SMIC was able to manufacture its first 7nm chip which US companies like Intel still have not been able to achieve on their own. Some specialists argue that this achievement is not something significant as DUV is not as advanced as EUV, and China does not have the capabilities to develop DUV without access to Dutch machinery. However, one should take into consideration the targeted market of Chinese goods. China and its technological companies (like Huawei) might be reliant on the United States and Taiwan for some of their machinery and parts. Nonetheless, when it comes to market, China is more focused on diversifying its exporting destination in Asia, the Middle East, and Africa.

In terms of the tangible impact on exports, we can see that China's High-tech exports have experienced a relative decrease in 2022 and 2023. Additionally, Huawei's revenue experienced the same dynamics (Figs. 5 and 6). However, looking at this set of data, we should take into consideration that although there was a decrease in the years 2022 and 2023, the exports remained higher than in the years before 2021. Therefore, it is difficult to determine whether the decrease in Huawei's revenue and China's exports is due to the restrictions set by the United States or they are due to the COVID-19 pandemic. This was highlighted in the Annual Report released by Huawei in 2022 and the General Administration of Customs of the People's Republic of China where they stated that challenges have been faced in the past few years due to both geopolitical conflicts and the COVID-19 pandemic. The only direct and visible negative impact that the restrictions put in place have had on China's economy is the access to the US market and technological equipment from Taiwan and some European countries.

This can lead us to the conclusion that US sanctions might have had some short-term impact on China, but in the long-term, they have forced it to develop better technologies and reduce its dependence on Europe and Taiwan, something it was already planning to do since 2017. Paradoxically, an argument can be made that the US would have benefited more if it focused on policing the kind of technologies developed and exported to China rather than completely restricting and cutting China from the semiconductor supply chain. The other alternative would have been allowing the technological development that China has been enjoying and working alongside it to achieve collective development, something that the neoliberal system is built on. Thus, rather than trying to challenge Chinese growth or trying to put a stop to it, the US would have reeked more benefits from using that development for its own gain as well. Nonetheless, choosing to look at the chip war from a zero-sum game perspective, the US, on the one hand, motivated further development in the Chinese semiconductor industry. On the other hand, the US pushed China to react negatively in other fields like rare earth materials exports.

4.3 China's reaction

What Miller did not go in-depth into was how the use of interdependence as a political tool has had a negative impact on the United States itself, leading to some economic difficulties. These difficulties are due to how China managed to gain an important role in the neoliberal interdependent system that was forged after the end of the Cold War. All of these restrictions did hurt China which suffered a significant cut in its primary semiconductor and machinery exporters. This motivated it to start implementing restrictions of its own starting with Critical Earth Minerals exports. These include Silicon, Gallium, and Germanium all of which China is the world's top importer [45]. China has the largest reserve of rare earth materials, and it is the highest exporting country of those materials in the world. The EU and the US are highly dependent on China when it comes to these materials as it is the only stable country with a reserve of that size. The alternatives are the Democratic Republic of Congo and Russia, but the former suffers from domestic political unrest and the latter has been heavily sanctioned by Western countries after its attack on Ukraine.

Furthermore, in addition to the political issues that plague the countries that can work as an alternative to the Gallium and Germanium coming from China, there is also the issue of processing capacity. Thus, although "The Democratic Republic of the Congo (DRC) and People's Republic of China (China) were responsible for some 70% and 60% of global production of cobalt and rare earth materials respectively in 2019", China refines nearly 90% of the rare earth materials. This is not only done domestically but also internationally through state-owned Chinese companies that operate in Myanmar, DRC, and Australia. These companies include China Rare Earth Group Co. Ltd, China Southern Rare Earth Group Co., Ltd, and China Xiamen Tungsten Co., Ltd, the three of which merged in 2022 to give China better control over rare earth material prices [45].

In a congressional report by Brandon Tracy in 2020, the level of Chinese dominance over mining and processes of rare earth materials was highlighted as then China was producing 85% of the world's supply of these elements and the US imported 80% of its yearly requirement from China [46]. Today, in terms of mining, China mines 54% of the world's rare earth materials and refines 77%. The other two countries that are currently leading in these two areas are Myanmar and Australia, both of which have been flooded with Chinese companies. Thus, China has found a vulnerability that it can use as a retaliation against the restrictions imposed on it, and it started using that card in late September of the year 2023. China imposed a license on the exports of both Gallium and Germanium [47].

When it comes to semiconductor manufacturing, China followed suit and invested up to 40 billion dollars in the establishment of the fabs and the purchase of old patents in order to reverse engineer them with the hope of manufacturing high-tech semiconductors, something that China still has not been able to do. Nonetheless, in a surprising move, China released its latest 7nm chip which the US thought would be impossible without the machinery exported from the Netherlands. This technology puts Huawei at the same level of development as Apple products in 2018 and 2019.

Thus, we can argue that there are two games at play here. First, the US and its allies are trying to restrict China's access to semiconductor technology while trying to decrease their dependency on China's rare earth materials. The second game is China trying to improve its domestic semiconductor industry while implementing restrictions on the exports of rare earth materials to the US and its allies. Both parties started to increase their investment in the establishment of domestic FABs. The US, with the Chip Act, invested 53 billion dollars in the establishment of FABs in Arizona, Ohio, and Texas. These fabs are scheduled to start operating in 2024.

This puts forward a crucial idea which is the need to make a distinction between semiconductors. Some semiconductors are low-tech and are used in simple things like kitchen mechanical equipment (90 nm) [48]. These chips are widely manufactured in various countries. However, when it comes to the chips used in cutting-edge technology (from 12 nm below), they are only manufactured by a few companies all of which are either in the US, Taiwan, or the Netherlands [49]. It was only in the second half of 2023 that China managed to produce its first 7nm chips thanks to SMIC.

When it comes to the impact of this Chip War was felt by the US as well. First, the idea of reviving the Rust Belt is still in development and has been facing some difficulties. This is because the FABs that the US wants to construct in Arizona, Ohio, and Texas have been facing some delays due to the lack of skilled and chip labor that would want to work in the harsh conditions of the fabrication plants [50]. In addition to this, the US now has to find an alternative to China's rare earth as without these materials no semiconductors can be produced. The US does have reserves of some of these minerals, but it does not have reserves of all of them, and the other major alternative exporters like Congo and Russia are experiencing political unrest and military conflicts. Furthermore, although China does not produce cutting-edge semiconductor technology, the US still needs semiconductors made by China. China is an integral part of the supply chain of integrated circuits (Fig. 7).

The often overlooked aspect of these restrictions is their impact on US companies. China, the world's largest importer of semiconductors, purchased over $85 billion worth of chips in the first quarter of 2023. This makes the Chinese market crucial for European, Japanese, and American chip manufacturers. The significance of this market was underscored by the ripple effects of the permit obligations imposed by the US. Companies like Intel and Qualcomm have expressed dissatisfaction with these restrictions, as they heavily rely on Chinese markets for their annual revenue. Consequently, Intel had to reevaluate its revenue projections for the coming years. "Without orders from Chinese customers, there will be much less need to go ahead with projects such as Intel's planned factory complex in Ohio"[51]. The company reportedly experienced a 2.6% drop in its stock value after its trade license with China was revoked. Similarly, Nvidia's financial chief has expressed similar concerns stating that US restrictions on China "would result in a permanent loss of opportunities for the U.S. industry" [52].

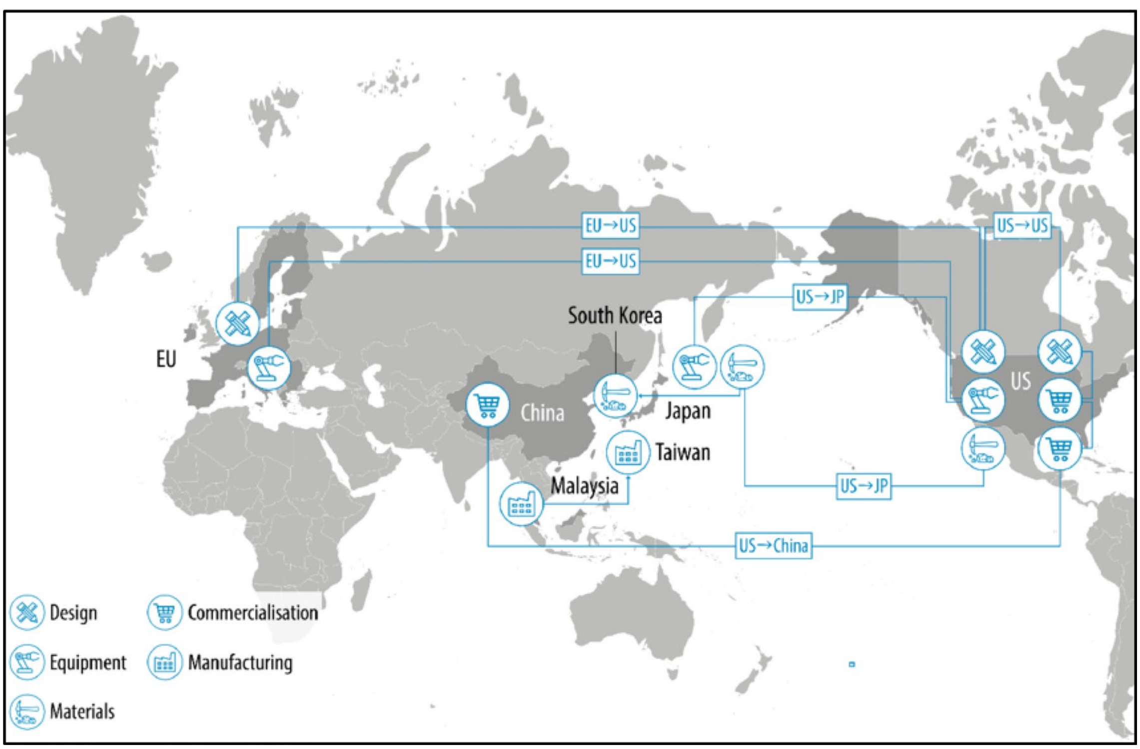

Fig. 7 the semiconductor supply chain (*Global Semiconductor Supply Chain*)

Cutting China out of this chain does not hurt China alone but also the whole system. This was one of the arguments raised by the Dutch government when it was approached by the US to restrict its imports to China. This was highlighted by Liesje Schreinemacher, former minister for Foreign Trade and Development Cooperation of the Netherlands when she stated that "this mutual dependence works to both our [China and the Netherlands] advantages" and that the protests made by China as a reaction to restrictions is "understandable". [53] The advantages that the Netherlands, and even the US, can enjoy by maintaining close ties with China are access to rare earth materials, legacy chips, and skilled labor.

5 Conclusion

In conclusion, the semiconductor conflict between the United States and China epitomizes a critical facet of their geopolitical rivalry, intricately linked to the quest for technological supremacy. This paper has underscored the U.S.'s strategic pivot towards protectionism in reaction to China's rapid technological advancements. Despite these efforts, China's significant progress, particularly with the development of the 7nm chip, indicates its substantial strides in the semiconductor domain. This technological leap not only challenges the U.S.'s dominance in the industry but also signifies a shift in the global balance of technological power.

While the U.S. aims to protect its interests, China's advancements demonstrate its resolve and capability to influence the future of this vital industry. The implications of this rivalry extend beyond the two nations, affecting global technological innovation, supply chains, and even territorial claims. In recent years, China has fully integrated itself into the semiconductor supply chain, complicating the U.S.'s attempts to restrict it. This integration is highlighted by three key elements: China's dominance in mining and refining crucial materials, the critical role of Chinese-manufactured legacy chips in the American automotive industry, and the importance of the Chinese market to U.S. companies. These factors make the U.S. restrictions on China's semiconductor industry mutually harmful.

Initially, the semiconductor shortage was exacerbated by the COVID-19 pandemic, which disrupted global supply chains and significantly impacted the automotive industry. However, the situation worsened due to the U.S. restrictions on semiconductor exports to China. These restrictions not only strained the supply of essential legacy chips but also led to significant revenue losses for U.S. companies heavily reliant on the Chinese market. Moreover, the restrictions have yielded unintended consequences for the U.S. First, they have spurred China to innovate and reduce its dependence on the international supply chain, a feat the U.S. has not yet achieved with its new fabs. Second, the U.S. has lost its semiconductor leverage as China continues to possess the "rare earth materials card," which it is using strategically. This leverage could have been reserved for critical situations, such as a potential conflict over Taiwan. Third, the restrictions have had a symbolic impact, casting doubt on the U.S.'s adherence to the liberal order it once championed.

Author contributions I.B. analyzed the qualitative data M.H. gathered Data and graphs I.B. and M.H. authored the manuscript.

Data availability Data used in the research can be found in the next websites: http://english.customs.gov.cn/statics/report/preliminary2022.html https://www.huawei.com/en/annual-report.

Declarations

Competing interests The authors declare no competing interests.

References

1. Chu MM. The East Asian computer chip war. London: Routledge; 2013.
2. Kim Y, Rho S. The US–China Chip War, economy-security nexus, and Asia. J Chin Polit Sci. 2024. https://doi.org/10.1007/s11366-024-09881-7.

3. C Miller. Chip War: The Fight for the World's most critical technology. New York: Scribner. 2022. https://www.amazon.com/Chip-War-Worlds-Critical-Technology/dp/1982172002.
4. GC Allen. "China's new strategy for waging the microchip tech War." 2023. https://www.csis.org/analysis/chinas-new-strategy-waging-microchip-tech-war.
5. Varas Antonio. "Strengthening the global semiconductor supply chain in an uncertain era—semiconductor industry association." https://www.semiconductors.org/strengthening-the-global-semiconductor-supply-chain-in-an-uncertain-era/. Accessed 08 Jul 2024.
6. S Shivakumar, C Wessner, T Howell. "The strategic importance of legacy chips." 2023. https://www.csis.org/analysis/strategic-importance-legacy-chips.
7. RKJ-PGL Goujon. "Thin Ice: US pathways to regulating china-sourced legacy chips—Rhodium Group." https://rhg.com/research/thin-ice-us-pathways-to-regulating-china-sourced-legacy-chips/. Accessed 08 Jul 2024.
8. U.S. Department of State. "97/10/29 Joint US-China Statement." https://1997-2001.state.gov/regions/eap/971029_usc_jtstmt.html. Accessed 09 Jul 2024.
9. Ministry of Foreign Affairs of the People's Republic of China. "Bilateral Agreement on China's Entry into the WTO Between China and the United States." 1999. https://www.fmprc.gov.cn/mfa_eng/ziliao_665539/3602_665543/3604_665547/200011/t20001117_697866.html. Accessed 09 Jul 2024.
10. Goldstein A. China in 1997: a year of transitions. Asian Surv. 1998;38(1):34–52. https://doi.org/10.2307/2645466.
11. Ianchovichina E, Martin W. Impacts of China's accession to the world trade organization. World Bank Econ Rev. 2004;18(1):3–27.
12. Drezner DW, Farrell H, Newman AL. The uses and abuses of weaponized interdependence. Washington: Brookings Institution Press; 2021.
13. Spiro DE. The hidden hand of american hegemony: petrodollar recycling and international markets. 1st ed. Ithaca: Cornell University Press; 1999.
14. Issawi C. The 1973 oil crisis and after. J Post Keynes Econ. 1978;1(2):3–26. https://doi.org/10.1080/01603477.1978.11489099.
15. Correa H. Game theory as an instrument for the analysis of international relations. Ritsumeikan Ann Rev Int Stud. 2001;14(2):187–208.
16. G Evans, J Newnham. The Penguin dictionary of international relations. Penguin, 1988. https://www.academia.edu/download/32848114/Dictionary_of_IR.pdf.
17. Webber AM. Japanese style entrepreneurship: an interview with SOFTBANK's CEO Masayoshi Son. Harvard Business Rev. 1992;70(1):92–103.
18. Krauthammer C. The unipolar moment. Foreign Aff. 1990;70(1):23.
19. Fukuyama F. The End of History? Natl Interes. 1989;16:3–18.
20. Ikenberry GJ. The end of liberal international order? Int Aff. 2018;94(1):7–23.
21. "Taiwan Semiconductor Manufacturing Operating Expenses 2010–2024 | TSM | MacroTrends." https://www.macrotrends.net/stocks/charts/TSM/taiwan-semiconductor-manufacturing/operating-expenses. Accessed 08 Jul 2024.
22. "TSMC 2022 Annual Report," 2023.
23. Yang C, Hung S-W. Taiwan's dilemma across the strait: lifting the ban on semiconductor investment in China. Asian Surv. 2003;43(4):681–96. https://doi.org/10.1525/as.2003.43.4.681.
24. Bown CP. How the United States Marched the semiconductor industry into its trade war with China. SSRN Electron J. 2020. https://doi.org/10.2139/ssrn.3766574.
25. CM-T. Strategists and undefined 2022. "The CCP 20^(th) National Assembly and PLA live-fire drills around Taiwan: lessons learned," pf.org.twCK MaTaiwan strategists, 2022•pf.org.tw,. https://www.pf.org.tw/wSite/public/Attachment/003/f1670297321499.pdf. Accessed 08 Jul 2024.
26. M O'Brien, "Donald Trump's plan to bring jobs back to America comes with one giant asterisk." Washington Post, 2021. https://www.washingtonpost.com/news/wonk/wp/2017/01/30/donald-trumps-big-plan-to-bring-jobs-back-to-america-has-one-giant-astericks/.
27. History of Semiconductor Engineering. Berlin, Heidelberg: Springer, 2007. https://doi.org/10.1007/978-3-540-34258-8.
28. J Cui, "Study of the export control tendency in the United States and the European Union and the response strategy of S company," 2023. https://repositorio.iscte-iul.pt/handle/10071/29515.
29. "Commerce Department Outlines Proposed National Security Guardrails for CHIPS for America Incentives Program | U.S. Department of Commerce," U.S. Department of Commerce. https://www.commerce.gov/news/press-releases/2023/03/commerce-department-outlines-proposed-national-security-guardrails. Accessed 08 Jul 2024.
30. "FACT SHEET: President Biden Takes Action to Protect American Workers and Businesses from China's Unfair Trade Practices | The White House." https://www.whitehouse.gov/briefing-room/statements-releases/2024/05/14/fact-sheet-president-biden-takes-action-to-protect-american-workers-and-businesses-from-chinas-unfair-trade-practices/. Accessed 08 Jul 2024.
31. N Dalmia, "US is constantly assessing expansion of export controls on chips that could boost China's military," *The Economic Times*, 2024. https://economictimes.indiatimes.com/news/defence/us-is-constantly-assessing-expansion-of-export-controls-on-chips-that-could-boost-chinas-military/articleshow/108427937.cms?from=mdr.
32. E Geller, "Trump signs order setting stage to ban Huawei from U.S—POLITICO," Politico. https://www.politico.com/story/2019/05/15/trump-ban-huawei-us-1042046. Accessed 09 Jul 2024.
33. M Wheatley. "Huawei has finally depleted its stockpile of advanced chips for smartphones—SiliconANGLE," *siliconangle*. 2022. https://siliconangle.com/2022/12/21/huawei-finally-depleted-stockpile-advanced-chips-smartphones/. Accessed 08 Jul 2024.
34. I Hong. "Huawei chip stockpile 'can't meet demand' for new premium phone." https://www.asiafinancial.com/huawei-chip-stockpile-cant-meet-demand-for-new-premium-phone. Accessed 08 Jul 2024.
35. Zhou B. The impact of the US Chip act and the Chip4 alliance, and China how to respond It. Trans Soc Sci Educ Humanities Res. 2023;1:407–10.
36. GC Allen, E Benson, M Putnam, "Japan and the Netherlands Announce Plans for New Export Controls on Semiconductor Equipment." 2023. https://www.csis.org/analysis/japan-and-netherlands-announce-plans-new-export-controls-semiconductor-equipment.
37. "5 things you should know about High NA EUV lithography," ASML. https://www.asml.com/en/news/stories/2024/5-things-high-na-euv. Accessed 11 Jul 2024.
38. J Teer et al., "Winning interdependence: semiconductor and CRM rivalry in a de-globalising world," Hague Centre for Strategic Studies. 2022. https://www.jstor.org/stable/resrep44057.8.

39. GC Allen. "Choking off China's access to the future of AI," 2022. https://www.csis.org/analysis/choking-chinas-access-future-ai.
40. Fuller DB. China's counter-strategy to American export controls in integrated circuits. SSRN Electron J. 2021. https://doi.org/10.2139/ssrn.3798291.
41. Ryan M, Burman S. The United States-China 'tech war': decoupling and the case of Huawei. Glob Policy. 2024;15(2):355–67. https://doi.org/10.1111/1758-5899.13352.
42. A Chakraborty, "Global semiconductor shortage triggering obstructions and production delays." Global journal of Business and Integral Security. 2016. https://www.gbis.ch/index.php/gbis/article/view/276
43. J Horwitz. "China chip imports drop 12.4% year-on-year in September—govt data," Reuters. 2022. https://www.reuters.com/technology/china-chip-imports-drop-124-year-on-year-september-govt-data-2022-10-24/.
44. Wübbeke J, Meissner M, Zenglein MJ, Ives J, Conrad B. "Made in china 2025", Mercator institute for China studies. Papers on China. 2016;2(74):4.
45. Jia H, et al. Evolution of the anthropogenic gallium cycle in China from 2005 to 2020. Front Energy Res. 2022. https://doi.org/10.3389/fenrg.2022.944617.
46. B Tracy, "An overview of rare earth elements and related issues for congress." The congressional research service. 2020. https://crsreports.congress.gov/product/details?prodcode=R46618.
47. Yu Y, Ma D, Wang Y. Economics, and undefined 2024, Structural resilience evolution and vulnerability assessment of semiconductor materials supply network in the global semiconductor industry. Int J Produc Econ. 2024. https://doi.org/10.1016/j.ijpe.2024.109172.
48. Hoefflinger B. Chips 2020: a guide to the future of Nanoelectronics. Berlin, Heidelberg: Springer, Berlin Heidelberg; 2012. https://doi.org/10.1007/978-3-642-23096-7.
49. Lee H-B-R, Kim S. Borderless collaboration in materials chemistry for an industrial ecosystem in the semiconductor industry. Chem Mater. 2023;35(11):4117–9. https://doi.org/10.1021/acs.chemmater.3c01077.
50. SA Clark Don. "Plans to Expand U.S. chip manufacturing are running into obstacles—The New York Times." 2024. https://www.nytimes.com/2024/02/19/technology/semiconductor-chip-factories-delays.html. Accessed 08 Jul 2024.
51. F, M Feifel. "US tech investment curbs slammed," Chinadaily. https://www.chinadailyhk.com/hk/article/345691. Accessed 06 Aug 2024.
52. "Nvidia sees permanent loss of opportunities from China export curbs | Reuters," Reuters. https://www.reuters.com/technology/nvidia-sees-no-material-impact-reported-ai-chip-restrictions-china-cnbc-2023-06-28/. Accessed 06 Jul 2024.
53. P Blenkinsop, "Dutch trade minister: China protest over export rules is 'understandable,'" *Reuters*. 2023. https://www.reuters.com/world/dutch-trade-minister-china-protest-over-export-rules-is-understandable-2023-03-09/.