A Study on the Game Strategy of Chip Price Behavior at the Background of the US-China Trade War

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Abstract. The US-China trade war has had a profound impact on the game strategy and price behavior of chips in the semiconductor industry. This study aims to analyze the influencing factors, strategic shifts, and game theory dynamics of chip prices in the context of the trade war. The asymmetrical relationship between the United States and China in chip supply and demand, coupled with the imposition of tariffs and restrictions, has disrupted the supply chain, which leads to fluctuations in chip prices. The study highlights the artificial inflation of demand and oversupply of certain chip types because of stockpiling and entity list disruptions. It also examines the impact of tariffs on the cost structure of semiconductor manufacturing and the subsequent adjustments in pricing strategies. Furthermore, the study explores the localization strategies and shifts in global semiconductor production that have been prompted by the trade war and their implications on chip prices. Lastly, the study analyzes the repeated game perspective and its influence on the strategic choices and behaviors of the parties involved in the trade war. Overall, this study provides insights into the game strategy and price behavior of chips in the background of the US-China trade war, contributing to a better understanding of the dynamics and implications for the semiconductor industry.

1.Introduction

The research by Zhang and Zhu suggests that there are significant opportunities for further development and expansion of international trade relations in various segments of the chip industry chain between countries [1]. However, in an era marked by the rise of techno-nationalism, the process of technological decoupling is intensifying, leading to intricate implications where technological capabilities become closely intertwined with a country's national security and geopolitical influence [2]. For instance, the US-China trade war had a profound impact on the semiconductor industry, specifically in terms of the behavior and price of chips. As two global economic powerhouses, the United States and China have engaged in a trade conflict that has resulted in tariffs, restrictions, and supply chain disruptions in the semiconductor trade. The semiconductor trade between the two countries has always been characterized by an asymmetrical relationship, with China heavily relying on the United States as its main supplier of chips.

The imposition of tariffs and restrictions on semiconductor imports and exports has caused significant disruptions in the supply chain, leading to increased costs for manufacturers. Additionally, political tensions and economic uncertainties have resulted in fluctuations in both supply and demand for chips. These factors have contributed to the volatility in chip prices, creating challenges for companies operating in the semiconductor industry.

The objective of this study is to analyze the game strategy behind the price behavior of chips in the context of the US-China trade war. The study aims to identify the key influencing factors that have led to fluctuations in chip prices, including the supply and demand dynamics, tariffs, and strategic shifts in semiconductor production localization.

Additionally, the study will examine the implications of the trade war on the semiconductor industry, both in the short term and the long term. It will analyze the impact on leading US semiconductor companies, as well as the challenges faced by China's high-tech sector. The research will explore the effects on equipment and material procurement costs, international collaboration, talent acquisition, and other business risks. Furthermore, the study will investigate the potential benefits and risks of domestic semiconductor chip production and other high-tech products resulting from localization policy incentives.

Moreover, the study will examine the role of intellectual property (IP) rights and licensing in the semiconductor industry and how they have been affected by the trade war. It will analyze the enhanced scrutiny of IP and trade secret protections, as well as the increased legal and administrative costs for safeguarding technologies. The study will also explore China's response to these protections, emphasizing the development of independent IP and its potential impact on licensing costs and the global pricing ecosystem for semiconductors.

Furthermore, the study will consider the perspective of a repeated game to understand the strategic choices and

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behaviors of the parties involved in the US-China trade war. It will analyze the tit-for-tat and trigger strategies commonly observed in this trade game and their implications for cooperation and non-cooperation between the two countries. The study will examine the long-term benefits of maintaining cooperation and the conditions under which participants may choose non-cooperation.

In summary, this study aims to provide a comprehensive analysis of the game strategy behind the price behavior of chips in the context of the US-China trade war. By examining the influencing factors, strategic shifts, implications, and game theory dynamics, the research seeks to shed light on the underlying drivers of chip prices and their influence on the semiconductor industry.

2.Game strategy of chip price behavior at the background of the US-China trade war

2.1 Influencing Factors of Chip Prices

Firstly, from a supply and demand perspective, the semiconductor trade between the United States and China reflects an asymmetrical relationship. China heavily relies on the United States as its main supplier of chips, with over one-third of total US chip sales being exported to China annually. Additionally, due to its technological leadership in high-tech production, the United States has consistently maintained dominance in the US-China semiconductor trade [3].

The US-China trade war has led to tariffs and restrictions on semiconductor imports and exports, causing supply chain disruptions and increased costs for manufacturers. Additionally, political tensions and economic uncertainties have impacted investor confidence and demand for chips. These factors have contributed to fluctuations in chip prices.

The first and most immediate effect of the trade war on chip pricing was through the lens of supply and demand. As Chinese companies anticipated the worst, they began to stockpile essential chips, fearing prolonged restrictions or embargoes. This artificial inflation of demand led to a corresponding increase in prices. Conversely, the entity list disrupted the supply chain, leading to an oversupply of some chip types, reducing their market price.

Furthermore, tariffs on Chinese goods affected the cost structure of semiconductor manufacturing. Many elements of the production process involve a complex global network; a chip might be designed in the US, manufactured using equipment from Europe, and assembled and packaged in facilities in Asia. Tariffs imposed inefficiencies on this process, which sometimes resulted in a significant enough disruption to alter pricing strategies as companies sought to mitigate increased manufacturing costs or shifts in demand.

The imposition of tariffs during the US-China trade war disrupted the supply chain of the semiconductor industry, causing both short-term and long-term fluctuations in chip prices. As Chinese companies anticipated potential trade restrictions, they began stockpiling semiconductors, resulting in an artificial increase in demand. This surge led to a corresponding increase in prices. However, as the trade tensions continued, the semiconductor market experienced a correction, with prices returning to normal levels.

2.2 Strategic localization and shifts in global semiconductor production

The trade war prompted a strategic shift in the localization of semiconductor supply chains. The United States sought to reduce reliance on Chinese semiconductor products by incentivizing domestic production and research. The US CHIPS and Science Act passed in 2022 is an example, which is aimed to solidify its leading position in the semiconductor industry [4]. The passing of the Act, combined with the escalating strategic competition between the US and China, underscores the recognition by both superpowers regarding the paramount importance of the technological revolution in an era marked by fragmented globalization [5]. Simultaneously, China implemented the " National Integrated Circuit Industry Investment Fund" initiative as a policy instrument [6] and invested heavily in its domestic chip industry to achieve self-sufficiency and reduce dependency on imported chips.

The impact of such localization strategies and shifts in global semiconductor production on chip pricing can be multifaceted. As companies invest in domestic manufacturing facilities and R&D, it may lead to increased costs that can influence pricing strategies to recover these investments. Additionally, the relocation of production or adoption of alternative supply sources in response to trade barriers could introduce complexities to market competition.

2.3 Impact of the Trade War on the Semiconductor Industry

The US-China trade conflict not only imposes profit losses and marketing obstacles on leading US semiconductor companies but also inflicts a severe impact on China's high-tech sector, which is unavoidable and irreversible in the short term. Chinese firms will encounter increasing equipment and material procurement costs, a flight of international orders, challenges in international collaboration, and talent acquisition, among other business risks. The semiconductor industry, in particular, will bear a more substantial brunt. However, in the short term, domestic semiconductor chip production and other high-tech products can benefit from localization policy incentives, domestic design, and equipment and materials, which are expected to absorb domestic demand orders, providing direct benefits [7].

In the future, the domestic semiconductor industry faces long-term risks such as product blockades, technological monopolies, and heightened international competition. Overseas cooperation and mergers and acquisitions may also be inhibited. However, concurrently, the trade war fosters domestic enterprises' independent research and development, encourages close collaboration within the local industry chain, enhances industrial ecology, and promotes industry growth [7].

The trade war resulted in an acceleration of technological advancements as Chinese firms sought to "leapfrog" to the next level of semiconductor technology. The US restrictions on technology transfers prompted China to invest significantly in research and development to achieve self-reliance in chip production. This aggressive push for indigenous innovation in China's chip industry not only impacts the market competition but can also potentially lower prices as Chinese-made chips become technologically competitive.

2.4 The Role of Intellectual Property and Licensing

Intellectual property (IP) rights play a considerable role in the semiconductor industry, with patents protecting much of the technology that goes into chip design and manufacturing. The trade war led to enhanced scrutiny of IP and trade secret protections. On one end, the fear of loss of IP to Chinese companies under potentially relaxed enforcement conditions led to higher pricing due to increased legal and administrative costs for safeguarding technologies. On the other end, the Chinese response to these protections was to develop independent IP, potentially reducing licensing costs and impacting the global pricing ecosystem for semiconductors.

The intricacies of intellectual property (IP) rights and their protection—underscored in the World Intellectual Property Organization (WIPO)'s reports on the patent landscape—demonstrate a battleground beyond tariffs and trade restrictions. The semiconductor industry heavily relies on a complex web of IP rights and licensing agreements to operate globally. Moreover, the costs associated with IP litigation and the creation of new IPs as a reaction to the trade war likely resulted in some price adjustments within the industry, reflecting increased operational costs.

The protection of intellectual property and trade secrets has long been a critical aspect of the semiconductor industry. However, the US-China trade war heightened concerns over the loss or misuse of IP, resulting in increased legal and administrative costs for safeguarding technologies. Additionally, to reduce licensing costs, China has also emphasized the development of independent IP. These factors have implications for chip pricing as costs associated with IP protection and licensing influence overall product expenses. According to Liu, China currently occupies the low-end sector of the global trade division [7]. Li also points out that China's high-tech industry is currently lacking strength and is vulnerable [8]. As a result, in the event of sanctions being imposed by both sides, China is likely to experience greater losses. Therefore, Li suggests that China should prioritize the development of high-tech industries and proactively prepare for potential sanctions [8].

For instance, under the condition of strong capital and talent reserves, Huawei offers a strategy for other high-tech enterprises in China to manage the risk of supply chain disruption, which is independent R&D and production. This approach is the optimal choice to mitigate the impact of supply chain disruptions [9].

3.The perspective of the repeated game

3.1 Two model of repeated game

A repeated Game is a dynamic game where the same structure game is repeated multiple times. In daily life, people usually tend to chase short-run payoffs for the following three reasons:

1. Psychologically, People want to enjoy something today rather than in the future

2. The sooner people get the payoff, the more flexibility and options for people to use it

3. Financial payoffs can be reinvested, so money now is worth more than money in the future

Repeated games can lead to cooperation because they can change participants' space of strategic choice. Both reality and theory show that tit-for-tat and trigger strategies are the most used strategies.

As mentioned above, now we have two strategies in the repeated game ——tit-for-tat and trigger strategy.

The former means that each player's action is based on their opponent's previous move.The latter means that if one person cooperates with the other and the other does not break the cooperation, the person will continue to cooperate; but if the other breaks the cooperation, the person will never cooperate with them again. For instance, once the US side behaves in a way that breaks cooperation in China-US trade, China will refuse any further cooperation, leading to the complete collapse of cooperation.

To calculate the long-term benefits, a general prisoner's dilemma game can be described using table 1;

Table 1: Prisoners' Dilemma matrix in the short run

		player B	
player A		cooperate	not cooperate
	cooperate	T , T	S , R
	not cooperate	R , S	P , P

In a one-shot game, if players A and B cooperate, they both get a payoff of T. If both do not cooperate, they both get a payoff of P. Suppose one cooperates and the other does not. In that case, the one who cooperates gets a payoff of S and the one who does not cooperate gets a payoff of R. We can easily conclude that R > T > P > S. At the same time, the total value for both players is greater than the total value of one player cooperating and the other not cooperating, as well as the total value of both players not cooperating, i.e. (T+T) > (S+R), (T+T) > (P+P).

Now suppose that player A and player B play an infinitely repeated prisoner's dilemma game. If they never cooperate, the payoff for each player in each period is P.

Now imagine that both players have cooperated until a certain point in time t. What is the value of continuing to maintain cooperation forever? To calculate this value, the concept of discount factor will be introduced, which represents the value of tomorrow's money compared to today's money. The writer will use $0< \theta <1$ to represent the discount factor, which reflects the patience level of the participants. A larger θ means a greater emphasis on the future. Therefore, the discounted value of maintaining long-term cooperation is:

$$V= T + \theta 1T + \theta 2T + \theta 3T + \theta 4T + ... \quad (1)$$

Mathematically, we know that this value equals T / (1-θ). θ is vital here.

3.2 Model analysis of repeat game

3.2.1 Tit-for-tat

This strategy constitutes a Nash equilibrium. In the trade game between China and the United States, if both sides adhere to the tit-for-tat strategy, an ideal situation is that no one initiates non-cooperation, and both sides will receive a payoff of T in each period, resulting in a total payoff of T/(1-θ) after discounting. A more likely scenario is that the US side initiates non-cooperation at stage t, and then China implements this strategy by choosing not to cooperate with the US in stage t+1 as a punishment for its non-cooperative behaviour. The actions of both sides from stage t+1 onwards will be as follows:

US side's actions: Cooperate, Not cooperate, Cooperate, Not cooperate, ...

China's actions: Not cooperate, Cooperate, Not cooperate, Cooperate, ...

China's expected payoff stream will be R, S, R, S, R, S (2)

This pattern continues. But if China chooses to forgive the US, cooperation will resume from stage t+1 onwards, and China's expected payoff stream will be T, T,T,T,T, (3)

Comparing equations (2) and (3), it is clear that the sum of the latter is significantly larger than the former. In theory, given that the US initiates non-cooperation at a certain stage, as long as China believes that the US is implementing the tit-for-tat strategy, China will not have the motivation to implement punishment and will choose to forgive the US and continue to cooperate.

3.2.2 Trigger strategy

The main idea behind the trigger strategy is that once the other one makes a mistake, you will never forgive them.

It is easy to prove that if θ is sufficiently large, the trigger strategy not only constitutes a Nash equilibrium but also a subgame perfect Nash equilibrium. Specifically, assuming that both China and the US choose the trigger strategy, meaning that if the US breaks cooperation in a period of good cooperation, China will never cooperate with the US again. Suppose that both parties cooperate consistently and China can receive a payoff of T in period t and afterward, the discounted value of the payoff stream is $T / (1-\theta)$. But if the US chooses to break cooperation which causes China to suffer a loss in the current period, then from the next period onwards, China will never cooperate with the US again.

In this case, the best outcome the US can achieve is to never cooperate again, and it will only receive a payoff of P in each subsequent period. The total value of the payoff stream is then $R + P [\theta / (1-\theta)]$. If the condition $T / (1-\theta) \geq R + P [\theta / (1-\theta)]$ is satisfied, the US's best choice is to always cooperate rather than initiate non-cooperation midway. In other words, as long as $\theta \geq (R - T) / (R - P)$, both players choosing the trigger strategy (not initiating non-cooperation) is the best choice.

The above condition can be restated as $\theta (T - P) / (1-\theta) \geq R - T$, where the right side of the inequality represents the increase in current income brought by choosing non-cooperation in a certain period, and the left side represents the discounted value of future loss caused by this non-cooperative behavior (where T - P is the loss in each period).

Therefore, whether participants will cooperate or not depends on whether the long-term benefits outweigh the immediate benefits and the level of patience. Specifically, given the level of patience, the greater the temptation of non-cooperation, the greater the immediate benefits brought by non-cooperation compared to the long-term benefits brought by cooperation, and the greater the possibility of participants choosing non-cooperation. In addition, given the temptation of non-cooperation and the long-term benefits of cooperation, the importance of the future, the greater the possibility of cooperation.

In this case, research by Liang also suggests that China will not take action at first because China is more dependent on this bilateral trade than the United States [10].

4.Conclusion

In conclusion, the US-China trade war has had a significant impact on the game strategy and price behavior of chips in the semiconductor industry. The asymmetrical relationship between the two countries in terms of chip supply and demand, along with the introduction of tariffs and restrictions, has disrupted the supply chain and increased costs for manufacturers. This has led to fluctuations in chip prices, with artificial inflation of demand and oversupply of certain chip types.

The trade war has also prompted strategic shifts in the localization of semiconductor production, as both the United States and China have sought to reduce reliance on each other. This has resulted in increased costs associated with domestic manufacturing and research, which can influence pricing strategies in the industry.

Furthermore, the protection of intellectual property (IP) rights and licensing has played a crucial role in the semiconductor industry and has been a battleground in the trade war. The trade war has brought about enhanced scrutiny of IP and trade secret protections, leading to higher pricing due to increased legal and administrative costs. However, it has also spurred China's development of independent IP, potentially reducing licensing costs and impacting global pricing of semiconductors.

In terms of game theory, the repeated game perspective has shed light on the strategic choices and behaviors of the parties involved. Both the tit-for-tat and trigger strategies have been observed in the trade game between China and the United States. The choice of strategy depends on factors such as patience levels, the balance between short-term and long-term benefits, and the need for cooperation or non-cooperation.

As the trade war continues to evolve, it is important for stakeholders in the semiconductor industry to understand the driving forces behind chip price behavior. This study has provided insights into the influencing factors, strategic shifts, and game theory dynamics, which can inform pricing strategies and decision-making in the industry. Moving forward, it will be crucial for industry players to adapt and navigate the changing landscape of the US-China trade war while also considering long-term risks and opportunities in the global semiconductor market.

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