The Impact of Government Subsidies on Sino-U.S. Semiconductor Trade Frictions

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Abstract. As a cornerstone of the high-tech sector, semiconductors play an indispensable role in critical processes such as chip manufacturing and wafer production. They are essential for China to achieve its strategic goal of becoming a high-tech power. This article examines the trade policy of the United States, which imposes tariffs on China's semiconductors, by constructing a profit matrix model that incorporates the primary stakeholders from both China and the United States, utilizing game theory analysis methods. It systematically analyzes the variations in China's export revenue and U.S. income under two scenarios: with and without tariffs. Furthermore, the article introduces government subsidy variables to explore their impact on China's export income and U.S. consumer surplus. The research results show that in bilateral semiconductor trade, adopting a free trade strategy can achieve the balance of dominant strategies between the two sides, thereby maximizing trade interests; in the case of the United States implementing tariff barriers, the Chinese government can effectively alleviate the decline in the income of export companies and maintain industrial competitiveness through subsidy policies. Based on the above conclusions, this article suggests that the Chinese government should strengthen its financial support for the semiconductor industry, respond to the negative impact of trade frictions through targeted subsidy policies, and at the same time actively promote bilateral trade consultations to promote the healthy development of international cooperation in the semiconductor industry.

Keywords: Semiconductors, Tariffs, Sino-U.S. Trade, Game Theory, Government Subsidies.

1. Introduction

Since Donald Trump took office as President, trade tensions between the United States and China have escalated significantly. On March 8, 2018, the United States imposed comprehensive tariffs on Chinese aluminum and steel, citing national security concerns. Later that year, on March 23, the U.S. announced tariffs on $60 billion worth of Chinese goods, and on April 6, it considered imposing additional tariffs on $100 billion of Chinese products. In 2020, the U.S. government implemented a ban requiring any product produced using American technology to obtain a U.S. license before being exported to Huawei. This action marked a substantial escalation in Sino-U.S. trade tensions and a significant increase in technological and trade barriers imposed by the U.S. on China. Throughout the recent trade disputes, the tariff measures enacted by the U.S. have encompassed the entire semiconductor supply chain, adversely affecting China's semiconductor device exports to varying degrees. Currently, Sino-U.S. trade frictions continue to intensify, entering a critical phase. On September 13, 2024, the United States announced a substantial increase in tariff rates, with import tariffs on solar cells and semiconductor products rising by as much as 50%. This new tax rate is set to take effect in January 2025.

As the core area of national scientific and technological competitiveness, the semiconductor industry has always been a strategic industry that China focuses on developing. To promote independent innovation in the semiconductor industry, China invested nearly US$140 billion through the National Integrated Circuit Industry Investment Fund in 2019, significantly alleviating the financing pressure of related companies [1]. This policy support is in line with the semiconductor development goals proposed by China in "Made in China 2025", that is, to achieve global technology leadership and balanced development of the industrial chain by 2030 and to occupy an important position in international trade. However, to achieve this goal, the key is to increase the intensity of

R&D investment in semiconductor companies because R&D investment is significantly positively correlated with technological innovation capabilities.

Compared with the international leading level, there is still a big gap in China's R&D investment in the semiconductor industry. In 2019, US semiconductor companies' R&D expenditures accounted for 16.4% of sales, ranking first in the world, while China only reached 8.3%, about half of that in the United States [2]. This gap not only reflects China's dependence on US semiconductor technology but also becomes a key shortcoming in China's trade frictions. To reduce technology dependence and enhance trade competitiveness, China urgently needs to explore effective policy tools, such as government subsidies, to encourage enterprises to increase R&D investment, promote technological autonomy, and enhance the voice of international trade.

Based on this, the article begins from the perspective of game theory and develops a bivariate income matrix model to analyze the impact of government subsidies on Sino-U.S. semiconductor trade. The study identifies China and the United States as the two primary entities in the game and examines the two strategies employed by the US: imposing tariffs and refraining from imposing tariffs. Meanwhile, China makes decisions based on various scenarios, including whether to import or not and the presence of government subsidies. Through this framework, the article aims to explore how subsidy policies influence trade outcomes and provide policy recommendations for China to navigate semiconductor trade frictions.

2. Review of Domestic and Foreign Literature

2.1. Causes and Impacts of Sino-U.S. Trade Frictions

Many scholars at home and abroad have analyzed the causes and effects of trade frictions. The reason for the Sino-U.S. trade friction is that the US side wants to reduce China's exports to reduce the trade surplus between the goods [3]. This is not only in terms of the economy, but the deeper reason is the US's monopoly on technological hegemony in the political field, as well as its fear and anxiety about China's rise. Therefore, the reason for the Sino-U.S. trade war is not only because of the excessive trade deficit between the U.S. and China but the US's containment and suppression of China's high-tech technology field [4]. The US suppression policy it includes creating "tariff barriers". China is negatively affected by the US tariff increase. The US has used anti-dumping measures to limit the quantity and quality of items imported by enterprises to weaken the quality of Chinese exports [5]. Although the US tariff policy may achieve its goal of curbing the development of China's semiconductor industry in the short term, this trade confrontation cannot make the US "allow it". Research shows that the continued escalation of Sino-U.S. trade frictions will cause long-term damage to both sides' economies [6]. By modeling the impact of tariffs on both countries, the results show that both China and the United States have declined, with China’s economic losses of about 4.1% compared to 0.9% in the United States [7].

2.2. Research on the Semiconductor Industry

Regarding the development of China's semiconductor industry, many scholars have conducted multi-angle analyses of related issues. As a technology-intensive high-end manufacturing industry, the semiconductor industry has the characteristics of large R&D investment, high technical threshold, and long industrial chain. It is generally believed in the academic community that its development requires long-term and continuous technical accumulation and financial support. China's semiconductor industry faces challenges such as core technologies being subject to people and key equipment relying on imports [8]. Secondly, in-depth analysis of the development and evolution of China's semiconductor innovation network in terms of semiconductor structure and market attribute research have found that the semiconductor innovation network structure has evolved from loose to concentrated, and the semiconductor market is strategic and market duality [9, 10]. From the development of the semiconductor industry, it was found that semiconductors had the following technical and economic characteristics: the industrial chain was very long, the distribution was uneven, the technical barriers were extremely high, and the upstream and downstream were closely related. In the process of industrial chain development, a high dependence on cross-border collaboration, technology locking, and link monopoly emerges, resulting in the development of the semiconductor industry being on the "blade". The key to solving the problem should focus on the "industrial chain" of semiconductors [11]. Therefore, in the Sino-U.S. trade friction, China's industrial chain has the above characteristics and is highly dependent on foreign technical support, which has led to the shift of China's semiconductor industry chain from the outward movement [12].

Many scholars also focus on analyzing the development decisions of China's semiconductors. The source of decision-making is to learn from foreign successful ideas to apply it to its semiconductor development. Through research on the semiconductor industries of the United States, Japan, and South Korea, the decision to promote the effective development of semiconductors is to attract corporate investment to build R&D consortiums and conduct corporate mergers and acquisitions [13]. Regarding the study of foreign industrial policy, need to consider the strategies of export response challenges. The following scholars have proposed their methods. Enterprises face the problem of information asymmetry when entering the export market. The sunken costs consumed by these assessments of foreign companies can only be afforded by efficient companies, and government subsidies can make up for this cost, allowing inefficient companies to enter the export market and mobilize export enthusiasm [14]. At the same time, the impact of export subsidy policies for specific Colombian enterprises on export products under the conditions of heterogeneous enterprises was studied in a focused manner. The results show that the government's implementation of direct fiscal appropriations can effectively increase the export volume of enterprises, but there is a diminishing relationship between subsidy amount and export volume [15]. There are also focused research on China. It is found that the industrial structure of developing countries has been found that developing countries have performed weakly in the field of high-tech, but in the long-term development, incentives for high-tech export industries can promote the growth and strength of enterprises and is the only way to improve product structure [16].

3. Game Development

3.1. Basic Assumptions

In the context of Sino-U.S. semiconductor trade frictions, this study observes that the United States typically employs a tariff suppression strategy as a first mover, while China responds with subsequent tariff countermeasures. Consequently, this research adopts a dynamic game analysis framework. To determine the Nash equilibrium of this game, a theoretical model is constructed based on the assumption of complete information, ensuring that both parties fully understand each other's strategic options and profit functions when making decisions.

Assuming there are only two trading entities in the international semiconductor market—China and the United States—let us designate China as Country C and the United States as Country A. If China possesses a comparative advantage in producing semiconductor products while the United States has a demand for these products, can analyze the current trade dynamics. Recent trends indicate that trade frictions between China and the United States have primarily been initiated by the U.S. side. Therefore, this article posits that the United States will take the first action, which may include imposing tariffs or refraining from doing so. In response, China will implement further measures to address the actions taken by the U.S., which may involve decisions regarding exports and non-exports, as well as considerations of government subsidies. To evaluate the income implications for both parties, will utilize a bivariate income matrix.

3.2. Revenue Matrix

3.2.1 Scenario 1: China does not implement a government subsidy policy

If Country C does not adopt a government subsidy policy and Country C imports and Country A does not impose tariffs, then Country C's income is R1. Country A imports semiconductor products from Country C to generate benefits in its own country and obtains CS1's consumer surplus. If Country C imports, Country A levies tariffs, and the tax revenue is r. Some enterprises in Country C exit from the market because they cannot afford the sank cost of tariffs, resulting in a reduction in Country C's income to R2-r (R2<R1). Country C must pay Country A's tariff r, and the consumer surplus in Country A drops to CS2 (CS2<CS1). Because there are only two trading entities, if Country C refuses to export, Country C's income is 0, and the remaining consumer in Country A is 0. The income matrix of A and C is shown in Table 1.

Table 1. When Country C does not adopt the income matrix for government subsidies

CountryA/CountryC	Export	Not Export
Impose tariffs on China	(CS2, R2-r)	(0, 0)
No tariffs are imposed on China	(CS1, R1)	(0, 0)

3.2.2 Scenario 2: China implements a government subsidy policy

If Country C adopts a government subsidy policy, the government expenditure to be consumed is G, and Country C imports, Country A will not impose tariffs. Because Country C adopts government subsidies, it mobilizes the vitality of semiconductor companies, thus improving the quantity and quality of semiconductors in Country C. The income of Country C is R0-G (R0-G>R1), and the consumer surplus in Country A is increased to CS0. If Country C imports, Country A imposes tariffs, and the tax revenue is r. However, the cost of Country C increases, and the quantity and quality of products will decrease. However, due to the effectiveness of government policies, the quantity and quality of products will be better than those of products without increasing tariffs. At this time, Country C's income is R3-r-G(R0>R3>R1>R2), and at the same time (R3-r-G>R2), the consumer surplus in Country A will also decrease. Similarly, the consumer surplus at this time will be more than CS3 (CS0>CS3>CS1) than when there is no government subsidy. The results of Country C's choice not to export are the same as those of scenario one. The income matrix of A and C is shown in Table 2.

Table 2. When Country C adopts government subsidy policy benefits matrix

CountryA/CountryC	Export	Not Export
Impose tariffs on China	(CS3, R3-r-G)	(0, 0)
No tariffs are imposed on China	(CS0, R0-G)	(0, 0)

4. Nash Equilibrium

4.1. China Does Not Adopt the Nash Equilibrium of Government Subsidy Policy

From the chart, it is evident that when Country C does not implement government subsidies and Country A is uncertain about whether to impose tariffs, exporting becomes the dominant strategy for Country C, as R1 > R2 - r > 0. For Country A, since CS1 > CS2, no tariffs are imposed, resulting in a Nash equilibrium characterized by the absence of tariffs and continued exports.

4.2. China Adopts the Nash Equilibrium of Government Subsidy Policy

It can be observed from Figure 2 that when Country C implements a government subsidy policy, it faces two potential benefits regarding whether Country A imposes tariffs. If Country A does not impose tariffs, Country C's income is R0-G, as the income from not exporting is zero. Therefore, exporting becomes the dominant strategy for Country C. The remaining consumer surplus in Country A is represented as CS0. Since CS0 is greater than zero, it also constitutes the dominant strategy for Country A. In the absence of tariff collection, a Nash equilibrium is established (no tariff collection, export). When Country A imposes tariffs, Country C's income is represented as R3 - r - G, provided that R3 > r + G. In this scenario, Country C opts for exporting, as exports become its dominant strategy. Conversely, if R3 < r + G, then non-exporting becomes the dominant strategy for Country C. Consequently, assess its interests to determine the values of "R3" and (r + G) to decide whether to export or not. As a result, there is no pure strategy Nash equilibrium; instead, there exists a unique equilibrium in the form of a hybrid strategy Nash equilibrium. Let the mixed strategy equilibrium for Country C be denoted as N(C) = (p, 1 - p), where $0 \leq p \leq 1$. The results are summarized in Table 3.

Table 3. Nash equilibrium results for the only equilibrium hybrid strategy

CountryA/CountryC	Export (p)
Impose tariffs on China	(CS3, R3-r-G)

EU(C)=p*(R3-r-G)+(1-p)*0=p*(R3-r-G)

If p*(R3-r-G)=0 is satisfied, the result p=0 is obtained

Situation 1: When R3-r-G≠0, the optimal strategy of Country C is not to export, because the return is 0. Because if R3-r-G>0, p=1, then the optimal case is export. If p=0, it is the optimal solution. If R3-r-G<0, P=0, it is also the optimal choice.

Situation 2: When (R3-r-G)=0, then p takes any value between [0, 1], the expected returns of Country C are 0, and a hybrid strategy Nash equilibrium is formed between exports and non-exports.

5. Conclusion

This study is based on the game theory framework and analyzes the dynamic trade game between countries A and Countries C under information asymmetry by constructing a bivariate return matrix model. In the model setting, this article assumes that the US side must take tariff measures and meet the conditions of R3>r+G. Currently, the Nash equilibrium solution is a combination of (tariffs, exports) strategy.

The research results show that from the analysis of the secondary game equilibrium, the adoption of free trade strategies between China and the United States can achieve Pareto optimality and maximize bilateral trade interests; secondly, in the real situation, the United States shows a strong tendency to trade protectionism, even if it needs to bear some welfare losses; finally, when exports are blocked, the benefits of China's implementation of government subsidy policies are significantly better than those without subsidies. Based on empirical analysis, this article suggests that the Chinese government should adopt targeted subsidy policies and establish a dynamic strategy adjustment mechanism in subsequent trade frictions to effectively avoid the risk of corporate profit decline. However, the model assumption conditions are more ideal and fails to fully consider the policy impact of other countries in the multilateral trading system; secondly, the calculation of government subsidy effects is not included in constraints such as fiscal sustainability; finally, the static game framework may not fully capture the dynamic evolution characteristics of trade policies. These limitations provide further expansion directions for future research.

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