A Game Theory-based Analysis of Trade And Policy Between China and Brazil In Electrical And Mechanical Products

Hongyu Yan*

Macao University of Science And Technology, Macao 99078, China

* Corresponding author:1909853lb011004@student.must.edu.mo

Abstract. China and Brazil are the two largest developing countries in the world in terms of land area with rapid economic development and huge economic potential advantage. Since the resumption of trade between China and Brazil in 1972, the economic and trade relations between the two countries have grown considerably through the joint efforts of both sides . This paper analyses the current situation of trade between China and Brazil by analysing the relevant trade data and applying the game theory approach to analyse the trade competition and cooperation between the two countries under the epidemic. This paper will focus on the trade situation of electrical and mechanical products and make relevant suggestions to address the current problems.

Keywords: China; Brazil; evolutionary game; cooperation and competition; trade.

1. Introduction

1.1 Research Background

At present, Brazil has already been China's largest trading partner in Latin America, and China is Brazil's largest export market in Asia as well. Electrical and mechanical products refer to all types of agricultural machinery, electrical and electronic performance production equipment and household appliances that are produced using mechanical, electrical and electronic equipment. The main commodities imported by Brazil from China are electrical and mechanical products, chemical products and transport equipment. In recent years, the total import and export trade of China has been increasing. The epidemic broke out in China in 2019 and Brazil is also attacked by various epidemics every year, in fact, Brazil could not stay out of it. The epidemic also had an impact on electrical and mechanical products, which are the most exported products from China to Brazil.

1.2 Literature Review

Wei Ling and Wang Wen (2010) found that the dependence of Brazil's export trade on China was far exceeded China's dependence on Brazil's exports, China's development of the Brazilian market was lacking and there was still more possibility for trade with Brazil. The concentration of China's exports to Brazil in recent years was lower than that of imports and China's exports to Brazil were more diversified [1]. Wang Fei and Wu Jinjia (2015) proposed in the International Forum that in the continuing global economic recession, the strategic dialogue between China and Brazil as representatives of emerging economies under the framework of BRICS and G20 is important for global economic recovery and Pan-Pacific economic and political cooperation. At the same time, the development of China-Brazil relations also has an exemplary role for China to expand its influence in Latin America. However, there are still potential risks and competition in the trade policy and investment environment [2]. Li Xuewei (2021) finds that China's trade in electrical and mechanical products with other BRICS countries is of the potential type and the potential development type, and that the trade potential has not yet been fully released and there is still much room for development [3].

1.3 Research Significance

China's post-financial crisis economy particular in the area of international trade has taken on a new dimension that is facing a game of opportunities and challenges and the game of international trade policy is a long and repetitive process. In an increasing globalize economy, the only way to

maximize the well-being of national trade is to combine liberal policies with the current situation [4]. China has always been Brazil's largest trading partner and Brazil is the largest destination for Chinese investment in Latin America [5]. At the same time, providing effective trade policy recommendations for both countries on hs84 products would help to better promote trade relations between China and Brazil.

2. Current Situation Of Bilateral Trade In Electrical And Mechanical Products Between China And Brazil

Since China's accession to the World Trade Organization, China's electrical and mechanical industry has accelerated its integration into the value chain of the global industrial chain and the scale of trade has expanded rapidly [6]. While Brazil, one of China's most dynamic trading partners, has seen a higher growth rate in China-Brazil merchandise trade than China has with any other trading partner. However, from Tables 1 and 2, it can be found that China may have shifted some trade from Brazil to other countries during this period, and Brazil may also seek more other trading partners for hs84 products, speculating that trade relations between China and Brazil are now less close than before for hs84 products.

Table 1. China's exports and China's exports of hs84 products to Brazil and the world [7]

	Total export value ($)	Total value of hs84 from China export to Brazil ($)	Total value of hs84 for China export to world ($)
2010	2590000000000.00	4929104265	310000000000.00
2011	2500000000000.00	5957905816	354000000000.00
2012	2490000000000.00	6451046964	376000000000.00
2013	2260000000000.00	6528986039	383000000000.00
2014	2100000000000.00	5870493289	401000000000.00
2015	2270000000000.00	4035506731	364000000000.00
2016	2340000000000.00	2982234271	344000000000.00
2017	2210000000000.00	3789751767	383000000000.00
2018	2050000000000.00	4166488116	430000000000.00
2019	1900000000000.00	4820147521	417000000000.00
2020	1580000000000.00	5240648087	440000000000.00

Table 2. Brazil's imports and exports and total imports of hs84 from China

years	Brazil total import value ($)	Brazil total hs84 import value ($)	Brazil total import value of hs84 from China ($)
2010	193000000000.00	6099965823	5240648087
2011	239000000000.00	7291924936	4820147521
2012	235000000000.00	8407430766	4166488116
2013	252000000000.00	8640166127	3789751767
2014	241000000000.00	7605746667	2982234271
2015	180000000000.00	5459862611	4035507731
2016	145000000000.00	4201578411	5870493289
2017	166000000000.00	4551344266	6528986039
2018	193000000000.00	5122920986	6451046964
2019	193000000000.00	5531506387	5957905816
2020	166000000000.00	5726795434	4929104265

From Table 1 and Table 2 we can see that although China has a dominant position in world exports, the total final exports are experiencing a downward trend over time. Total value of China's exports is also on a downward trend. Because it shows a first increase then decrease trend and finally increase in the last 10 years, but it can also be seen that the current value of China's hs84 exports to Brazil is lower than the previous level. In the total value of China's exports of hs84 products to the world, these values have an overall increasing trend and at a higher level than before for now, comparing the data on the total value of China's hs84 exports to Brazil, the figure is lower than the previous level.

3. Game Theory Model

3.1 Dynamic Game With Incomplete Information

The game model used in this paper is an incomplete information dynamic game because of the binding cooperative and competitive relationship between China and Brazil, and this relationship affects the final outcome of the game. Incomplete information dynamic games are one of the types of non-cooperative games. The actions of the participants are sequential and the latecomers are able to observe the actions chosen by the first mover; each participant does not have accurate knowledge of the characteristics, strategy space and payoff functions of all other participants. At the beginning of a dynamic game with incomplete information, a participant builds its initial judgement based on the different types of other participants and the probability distribution of the types to which they belong [8]. Once the game has started, the participant can revise his initial judgement based on what he observes what the other participants actually doing. Based on this evolving judgement, the participants can choose his own strategy.

3.2 Parameter Assumptions

At beginning, assuming that China proposes a strategy, it is assumed that if the benefits of the export strategy are higher or equal to Brazil's expectations, it is a cooperative strategy for China and a competitive strategy if it is lower than Brazil's expectations, while if it is lower than Brazil's expectations, Brazil's expectations are relatively higher and Brazil should apply a cooperative strategy. When the revenue of that accepts China's strategy is higher than its own expectations, it is a cooperative strategy for both China and Brazil, as Brazil's own bargaining power increases relative to China's, it will not accept the revenue that is higher than its own expectations and will seek higher revenue. If China accepts the strategy, China will cooperate and Brazil will compete. If China does not accept the strategy, China's strategy will change from one of cooperation to one of competition, and both sides will compete. Assuming that the trade gains of China and Brazil before China's strategy is G1 and G2, the additional gains for both sides are $\triangle$G1 and $\triangle$G2 based on the strategy of cooperation, while in China's choice of cooperation and Brazil's choice of competition, Brazil will have an additional gain of R1 and China will have an additional loss of L1, in Brazil's choice of cooperation and China's choice of competition, Brazil will have an additional loss of L2 and China will have an additional gain of R2,the respective tariffs of China and Brazil are denoted as E1,E2,the probability of China choosing cooperation is α,the probability of competition is $1 - \alpha$,the probability of Brazil choosing cooperation is β,the probability of competition is $1 - \beta$. Assuming that the gains from trade between China and Brazil before China proposes its strategy are G1, G2.

Table 3. Parameter assumptions of the game model

China	Brazil
Additional benefits from cooperation between the two sides: △G1	Additional benefits from cooperation between the two sides: △G2
Loss to China when Brazil chooses to compete while China choose to cooperate: L1	Brazil's gain when Brazil chooses to compete and China chooses to cooperate: R1
China's gain when China chooses to compete and Brazil chooses to cooperate:R2	China chooses to compete and Brazil chooses to cooperate,Brazil's loss: L2
Tariffs: E1	Tariffs: E2
Probability of choosing to cooperate: α	Probability of choosing cooperation: β
Probability of choosing competition: 1-α	Probability of choosing competition: 1-β

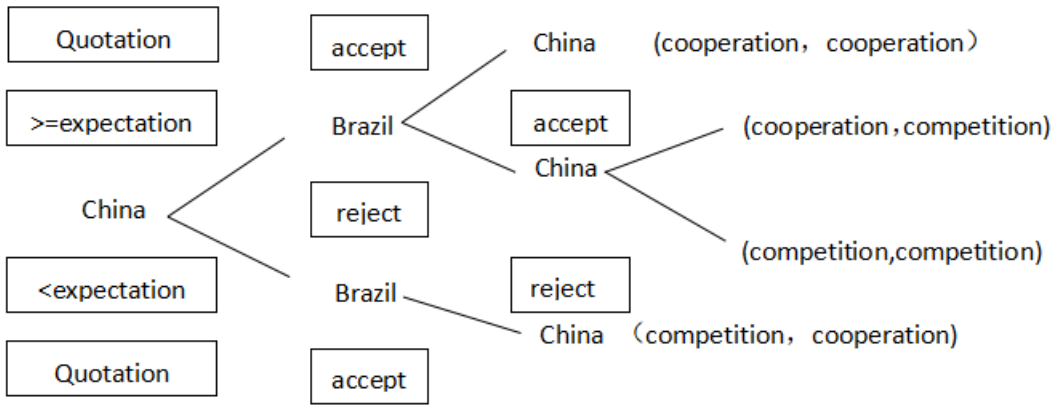

Fig 1. China-Brazil hs84 product competition cooperation game tree

4. Results And Discussion

4.1 Results

Firstly, when Brazil chooses the cooperation strategy, China can choose competition and cooperation, under this condition, the gain of China's cooperation is: G1+△G1-E1, the gain of China's competition is: G1-E1+R2. When China chooses the cooperation , the gain of cooperation is greater than the gain of competition, then G1+△G1-E1>G1-E1+R2, that is: △G1>R2, it means that the additional benefits of cooperation between China and Brazil are greater than the benefits obtained by China if it chooses to compete with Brazil. Secondly, in Brazil's choice of competitive strategy, China can choose to accept or not to accept, in the case of acceptance, China's gain is G1-E1-L1, in the case of non-acceptance, China's gain is G1-E1, so, in Brazil's choice of competitive strategy, China's optimal strategy is to accept that is the cooperative strategy.

From Brazil's point of view, when China chooses the cooperative strategy, the gain of Brazil choosing the cooperative strategy is G2+ΔG2-E2 and the gain of choosing the competitive strategy is G2-E2+R1, when ΔG2>R1, the gain of Brazil choosing the cooperative strategy that is both sides cooperating on hs84 products is greater than the unilateral gain brought by Brazil's competition with China, and when ΔG2<R1, Brazil choosing the competitive strategy it means that the gains from Brazil's unilateral competition are greater than the gains from cooperation between the two sides on hs84 products.

Table 4. China-Brazil revenue matrix on hs84 products

		Brazil	
		Cooperate strategy	Compete strategy
China	Cooperate strategy	(G1+△G1-E1,G2+△G2-E2)	(G1-E1-L1,G2-E2+R1)
	Compete strategy	(G1-E1+R2,G2-E2-L2)	(G1-E1,G2-E2)

$$E\ (ri)=rf+\beta im\ (E\ (rm)-rf) \tag{1}$$

From the table 4:
The expectation revenue of China choose cooperating

$$Ea=\beta(G1+\triangle G1-E1)+(1-\beta)(G1-E1-L1) \tag{2}$$

The expectation revenue of China choose competing

$$Eb=\beta(G1+R2-E1)+(1-\beta)(G1-E1) \tag{3}$$

Average expectation revenue of China

$$Ec=\alpha Ea+(1-\alpha)Eb \tag{4}$$

The expectation revenue of Brazil choose cooperating

$$Ea1=\alpha(G2+\triangle G2-E2)+(1-\alpha)(G2-E2-L2) \tag{5}$$

The expectation revenue of Brazil choose competing

$$Eb1=\alpha(G2+R1-E2)+(1-\alpha)(G2-E2) \tag{6}$$

Average expectation revenue of Brazil

$$Ec1=\beta Ec+(1-\beta)Ed \tag{7}$$

$$f(\alpha)\ =\ d\alpha/dt \tag{8}$$

The replication dynamic equation in China when adopting a cooperative strategy

$$f(\alpha)\ =\ d\alpha/dt\ =\ \alpha(Ea\ -\ E)\ =\ \alpha(1\ -\ \alpha)(Ea\ -\ Eb)=\ \alpha(1-\alpha)(\Delta\beta G1-\beta R2-L1+\beta L1) \tag{9}$$

Replication dynamics equation when adopting a cooperative strategy in Brazil

$$f(\beta)\ =\ d\beta/dt\ =\ \beta(Ec-Eba)\ =\ \beta(1\ -\ \beta)(Ec-Ed)=\ \beta(1-\beta)(\alpha\triangle G2\ -\ \alpha R1-L2\ +\ \alpha L2) \tag{10}$$

Combining f(α),f(β) yields the system of equations

$$f(\alpha)=\alpha(1-\alpha)(\triangle\beta G1-\beta R2-L1+\beta L1) \tag{11}$$

$$f(\beta)=\beta(1-\beta)(\alpha\triangle G2-\alpha R1-L2+\alpha L2) \tag{12}$$

Let f(α)f(β) equal 0 to get 5 possible five equilibrium point :

$$Q1(0, 0), Q2(0, 1)Q3(1, 0),Q4(1, 1), Q5(\alpha^*, \beta^*)$$

$$\text{where } \alpha^*=L2/(\Delta G2+L2-R1) \text{ and } \beta^*=L1/(G1-R2+L1)$$

4.2 Discussions

Considering that the epidemic is based on the macroeconomic level, the COVID-19 epidemic will significantly impact different economies worldwide, especially in the United States, the European Union, and China. Based on the country level, there is a significant difference in the impact of the epidemic on the value added of trade between China and Brazil [9]. Combined with the data for the two years 2019 and 2020 in Part 2, it can be found that China's exports to hs84 products have gradually decreased because of the impact of the epidemic and are in line with the overall world trend (see Figure 1). While for Brazil, the global imports of hs84 have decreased, Brazil's imports of hs84 products have increased from 2019 to 2020, and imports to China have decreased, and Brazil has shifted the center of trade in hs84 from China to other countries. In this case, Brazil has already reduced its imports of hs84 products from China to gain more. Brazil will continue to choose to reduce imports from China in the next year, which means that Brazil will adopt a competitive strategy to any strategy proposed by China, and China will consider G1-E1-L1 when it has seen the complete data of both sides for the years of 2019 and 2020 with the gain of G1-E1. There is no doubt that the latter being higher, the choice for both China and Brazil would be (competition, competition).

For the revenue perspective, China need to change the trend , because the competition will bring the following hazards to China .Firstly, First of all, for China's local employment, China's hs84 products are labor-intensive products, so at first it will intensify the competition of local industries, and due to the reduction of exports, the relevant hs84 products will produce an oversupply in the local area, which will eventually lead to a rise in local unemployment.

Subsequently, because exports to Brazil are not as good as before, China may expand production to emerging markets in other countries, such as India, Russia, etc. However, because Brazil previously accounted for a very large market share, it may lead to a reduction in the market size of hs84 products in China for a period of time and a decrease in the level of competition.

The last point, hs84 products exported to different countries, China's exports of hs84 products are mainly concentrated in four categories: Class 74 is not otherwise specified general industrial machinery and equipment and its not otherwise specified machine parts, Class 75 is office machines and automatic data processing equipment, Class 76 is telecommunications, recording and playback devices and equipment and Class 77 is not otherwise specified electrical machinery, devices and apparatus and their electrical parts The reduction in exports to Brazil and its electrical parts is likely to lead to a change in the size structure of hs84 exports, and China may need to change its response regarding the structure of its exports.

5. Suggestion

5.1 Using The Trade Characteristics of Both Countries For Deeper Cooperation

In the context of the growing international trade between China and Brazil, Brazil is optimistic that the benefits of economic and trade interactions between the two countries will beyond the disadvantages for the country [10]. Although there are occasional frictions, the overall situation is favourable for Brazil's own interests. Therefore, combining the comparative advantages of China and the demand situation of Brazil that is the intersection of supply and demand between the two countries, can be exploited to increase the scope of exports, for example by improving China's policy of exporting additional products such as coke, electrical circuits and batteries to increase the additional benefits of China and Brazil cooperation and make it more profitable for Brazil to cooperate with China.

5.2 China Strengthens Infrastructure Development To Facilitate Chinese Exports To Brazil

Compared to labour-intensive electrical and mechanical products, the level of trade facilitation has a more obvious role in promoting the export of capital- and technology-intensive electrical and mechanical products, and infrastructure is an important support for social development. Many shortcomings in terms of service security capacity and other aspects are therefore needed in transportation, ports, railways, airports and other facilities based on continuous improvement and expansion to improve transport capacity [11]. As Brazil's huge infrastructure needs provide a wide space for China's competent enterprises to invest in Brazil. Chinese companies should be fully aware of the relevant Brazilian laws and regulations before participating in the construction of infrastructure facilities, and should build a good corporate image with high quality and efficiency during the construction process.

5.3 China Should Reduce Its Tariffs

First of all, reducing tariffs can deepen trade cooperation between the two countries and expand the areas of cooperation, because the tariffs can play a supportive and protective role for the domestic industry it can selectively introduce foreign products to reduce their impact on the local industry, it will reduce the cost of imports, stimulating the potential of imports, to meet the domestic consumer demand for high-quality products. At the same time it can make the diversity of imported products increase, the consumers are expected to have more choices and the implementation of preferential policies can expand the market for hs84 products, increasing the supply of hs84 products at the same time to improve the level of openness of the two countries to the outside world and have more opportunities in the international trade market.

6. Conclusion

6.1 Key Findings

This paper analyses the current state of trade in electric-mechanical products between China and Brazil, and analyses the different strategies and benefits adopted by the two countries through a dynamic game model with incomplete information. As the trade relationship between China and Brazil is not as close as before, Brazil is seeking new trading partners for hs84 products, and due to the epidemic, China's own import and export level is also affected, while Brazil receives less negative influence from the epidemic than China, resulting in the trade of hs84 products for both China and Brazil is favourable to Brazil and unfavourable to China. Therefore, through the above game model analysis, it is concluded that China needs to change from (competition, competition) to (cooperation, cooperation) if it wants to turn the situation around, and the benefits of both sides change from (G1-E1,G2-E2) to (G1+$\triangle$G1-E1,G2+$\triangle$G2-E2), i.e. increase $\triangle$G2, or decrease E1. The Chinese government can promote China-Brazil relations by using its trade characteristics, strengthening infrastructure development and lowering tariffs, so that China has enough new attraction for Brazil in terms of hs84 products, i.e. changing Brazil's original competitive attitude to cooperation.

6.2 Future Prospects

Above all, the paper show that the continued development of China-Brazil trade in electric-mechanical products and the strengthening of relations between the two countries are not only in line with the current economic interests of China and Brazil, but also with the long-term interests of China's development in Latin American countries. On the basis of developing trade cooperation with Brazil, China can further unblock the channels of economic and trade cooperation between China and other Latin American countries. Therefore, strengthening trade relations between China and Brazil in electric-mechanical products can play a linking role in the expansion of trade relations between China and other developing countries in Latin America, and is benefit to promote the diversification of China's markets in the Latin American region and the sustainable development of markets. As two

influential developing countries in the world, China and Brazil share many commonalities and problems, not only in the trade of electric-mechanical products, but also in international issues. In fact, both countries need to strengthen coordination and cooperation in the context of today's economic globalization and seek to maximize their national interests. Therefore, China and Brazil have broad prospects for hs84 products, which can promote economic and trade relations between China and Brazil and deepen their cooperation in many fields, in line with the common interests of both sides.

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