Study on Game Model of Soybean Price: A Case Study of China-US Trade War

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Abstract. In China's soybean import market, according to the market share of all countries in China's soybean import market over the years, it is judged that China's soybean import market is a typical duopoly market. In this paper, Brazil and the United States are regarded as two monopoly manufacturers in China's soybean imports, and a dynamic decision-making model composed of these two monopoly manufacturers is established. The chaotic characteristics of the system are analyzed by numerical simulation, bifurcation diagram and maximum Lyapunov exponent. The stability of Nash equilibrium point of the system is observed. It provides a theoretical reference for price maintenance of domestic soybean prices which are fluctuated by the China-US trade.

Keywords: Price Change; Price Dynamic Game Model; Nash Equilibrium.

1. Introduction

In recent years, the demand for soybean in China has been increasing year by year. The domestic soybean production in China is far from meeting the huge national production and living needs. Imported soybean has become the main source of soybean in China. According to the US Department of Agriculture, China is the world's largest soybean importer, accounting for 61.2% of total U.S. soybean exports to China. Brazil and the United States account for about 80% of China's soybean imports. In recent years, the total share of Brazil and the United States has shown an upward trend year by year. Figure 1 shows the changes in China's soybean imports from 2006 to 2017.
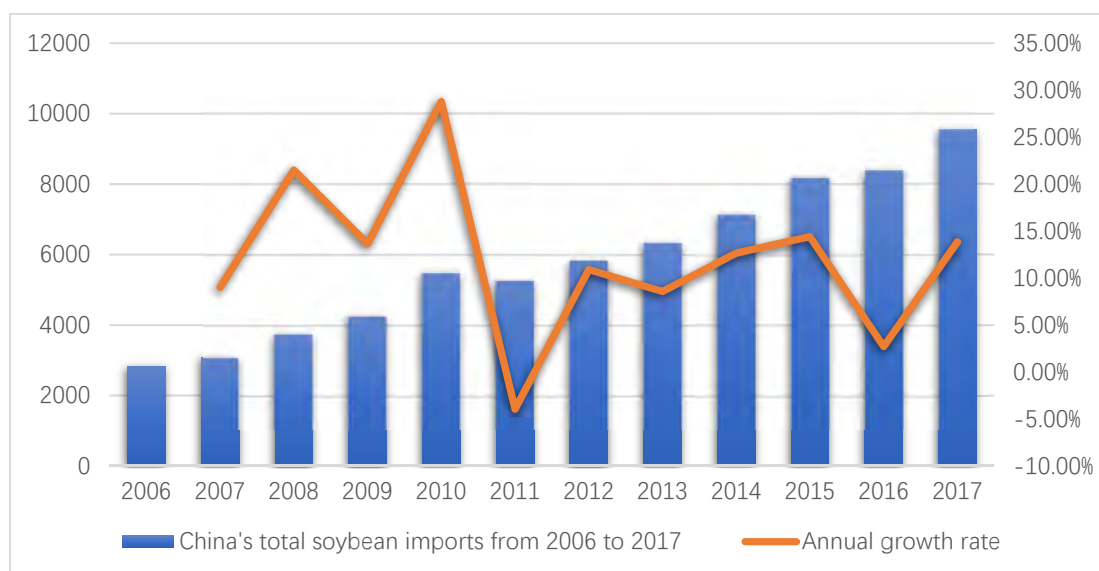

Fig.1 Changes in China's Soybean Imports from 2006 to 2017

In the China-US trade in 2018, China included US soybeans in the proposed tax list. The tariff on imported US soybeans jumped to 25%, and the volume of imported US soybeans fell. Other countries are not optimistic about the form of soybean. Therefore, it is of great practical significance to study and compare the changes in soybean prices before and after the trade war.

In recent years, dynamic game has been a hotspot of international scholars' research. A. A. ELSADANY [1] proposed a bounded rational duopoly game with time delay. The dynamic evolution was analyzed. The existence of game economic equilibrium is derived. Taking the wholesale price of

Chinese cabbage as an example, Su et al. [2] identified the non-linearity, fractal and chaos of the data by means of multivariate test. It is found that there is some confusion in the wholesale price data of agricultural products in China. Ma Junhai et al. [3] used bifurcation theory and numerical simulation tools to study dynamic pricing game in supply chain with incomplete information under the background of two-channel and fluctuating consumer demand.

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2. Game Model

2.1 Model Building

Based on the above analysis of market share, we regard Brazil and the United States as two oligarchy manufacturers of soybean imports from China. The soybean price is the duty paid average import price. Under bounded rationality, the two oligarchs make independent decisions at discrete time periodic points t=0,1,2…in order to maximize their own interests. $p_i(i=1,2)$ represents the import price of oligopoly i. p_1 represents the price of soybeans imported from the United States. p_2 represents the price of soybeans imported from Brazil. The demand function q_i can be expressed as (1).

$$q_1 = a_1 - b_1 p_1 + c_1 p_2,$$
$$q_2 = a_2 - b_2 p_2 + c_2 p_1, \tag{1}$$

In the game of two oligarchs, the two oligarchs constantly adjust their prices in order to maximize their profits. If Nash equilibrium is to be realized, the marginal profits of the two oligarchs must be 0, that is, the first derivative is 0. From this calculation, Cournot Nash equilibrium is shown in (2).

$$p_1 = \frac{a_1 b_2 - a_2 b_1 + 2 b_1 b_2 p_2 + b_2 c_1 p_2}{b_1(2b_2 + c_2)}$$
$$p_2 = \frac{-2 a_2 b_1 - a_1 c_2 + 4 b_1 b_2 p_2 - c_1 c_2 p_2}{b_1(2b_2 + c_2)} \tag{2}$$

The profit function of two soybean manufacturers is expressed as (3).

$$\pi_1 = q_1(p_1 - w) = (a_1 - b_1 p_1 + c_1 p_2)(p_1 - w)$$
$$\pi_2 = q_2(p_2 - w) = (a_2 - b_2 p_2 + c_2 p_1)(p_2 - w) \tag{3}$$

Two oligarchs with bounded rationality constantly adjust their decision-making. The decision-making of t+1 period is based on the adjustment process of marginal income in t period. The price adjustment model of i (i=1,2) in t+1 period is as (4). g_i represents the speed of price adjustment of i. p_i represents the profit of i (i=1,2).

$$p_i(t+1) = p_i(t) + g_i \times p_i(t) \times \frac{\partial \pi_i(t)}{\partial p_i(t)} \quad (g_i \geq 0) \tag{4}$$

2.2 Model Simulation.

According to Jury's condition, it is known that model (3) has a local equilibrium point. Suppose $a_1 = 2.3, a_2 = 2.1\ b_1 = 1.5, b_2 = 1.6, c_1 = 1, c_2 = 1.2, w = 0.2$. After bring the parameters into the model (4), the model as shown in (5) is obtained.

$$p_1(t+1) = p_1(t) + g_1 \times p_1(t) \times (2.6 - 3p_1 + p_2)$$
$$p_2(t+1) = p_2(t) + g_2 \times p_2(t) \times (2.42 - 3.2p_2 + 1.2p_1) \tag{5}$$

When Brazil imports soybean price adjustment speed $g_1 = 0.1$, with the change of U.S. import soybean price adjustment speed g_2, the trajectories of p_1 and p_2 are shown in Figure 2. Figure 3 is the maximum Lyapunov index with the change of g_2. When the exponent equals 0, the bifurcation occurs. When the index is greater than 0, the system enters chaos.
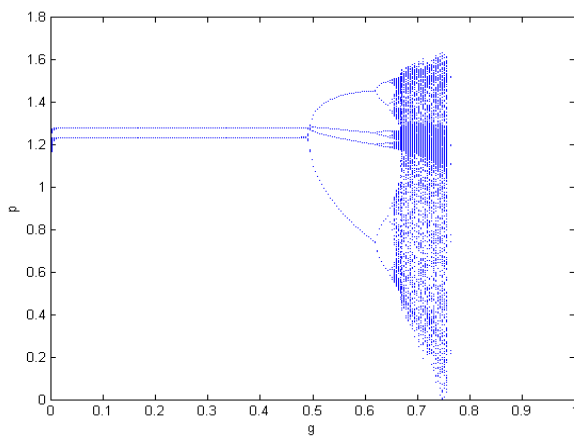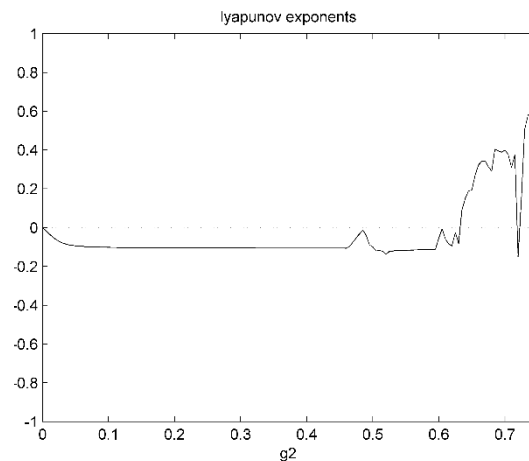

Fig.2 The trajectories of p_1 and p_2 Fig.3 The maximum Lyapunov index with the change of g_2.

3. Conclusion

Based on the classical Cournot model, this paper constructs the bounded rational duopoly game model of the United States and Brazil, and makes a dynamic analysis of the model. It is found that the acceleration of price adjustment will cause a large fluctuation in the price of the changing party, while the price adjustment speed of the unchanged party will cause a very small fluctuation in the price. It can be seen that China imposed a 25% tariff on soybeans from the United States, which caused the import price of soybeans from the United States to rise rapidly in a short period of time. The import price of soybeans from the United States increased substantially, but had little impact on the import price of soybeans from Brazil. If the U.S. imports of soybeans want to maintain the stability of imported soybeans trade, price reduction should be taken to maintain volatile import demand and avoid large losses, otherwise China will shift its demand for soybeans to other countries.

After the trade war, although China quickly shifted its soybean import target to other countries, because of soybean growth cycle and other countries' past soybean planting inertia, other countries could not meet the huge demand of soybean import in a short time. Therefore, in order to maintain domestic supply stability, the United States is still a major oligopolistic Supplier except Brazil in the short term, and the duopoly game model is still applicable to the United States and Brazil in the short term.

4. Suggestion

Soybean is an important agricultural product with dual properties of grain crops and cash crops. It is an important feed material for daily consumer goods and aquaculture industry. China's demand for soybeans has a certain degree of "rigidity".Because of the large demand in China, if the demand for soybeans from the United States is transferred to other countries, the price of soybean imports will also rise. Therefore, in a short period of time, half a year or one year, it is our strategic choice to reduce the import scale of soybean by a large margin. It is necessary to reduce the import scale of soybean by a large margin without affecting the consumption demand of domestic residents and the development of feeding and other industries. Therefore, on the one hand, our government should encourage enterprises in the feeding industry to reduce the use of soybean feed by a large margin. On the other hand, enterprises should be encouraged to increase imports of soybean substitutes and their downstream products. This requires our government to adjust the import policy of the corresponding products, especially to reduce the import tariffs of soybean substitutes and their downstream products.

In the long run, soybean cultivation in China has great potential. We should properly increase subsidies for soybean cultivation, encourage soybean cultivation, increase R&D investment, improve soybean yield and quality, and then reduce the dependence on imported soybeans. At the same time, we should also pay attention to diversification of import sources and avoid over dependence on a particular country. We should optimize foreign trade policies, develop and tap the potential of soybean cultivation in other countries, and increase the enthusiasm of soybean cultivation in other countries. This series of measures will play an important role in maintaining the stability of China's soybean import market.

Acknowledgements

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