

Network Game Simulation Research on “South China Sea” Economic and Trade Cooperation Based on Reciprocal Model

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Abstract. According to the economic and trade cooperation network of the stakeholders of the South China Sea, the paper built a reciprocal network game analysis model based on the reciprocal model. And the influence of national type (the degree of altruism or egoism), the belief in the goodwill of other countries, the correlation between the types of countries and their payments, the social pressure to betrayal given by network neighbors and spillover benefits generated by regional cooperation on the regional economic and trade cooperation in the South China Sea was discussed in depth, and tested with simulation method. The results show that all other factors have positive effects on cooperation, except that the influence of the correlation between the type of country and its payment has two sides. The conclusions of the study provide a reference for the formulation of China’s “South China Sea Issue” response strategy.

Introduction

Maintaining stability and prosperity of the South China Sea region has become a consensus between China and ASEAN countries. Facing the situation, how to continuously promote economic and trade cooperation and establish a regional cooperation mechanism for sustainable development have become one of the urgent problems to be solved in the “South China Sea issue”.

On the South China Sea issue, the existing research results mainly focus on the origins, evolution process, influencing factors and countermeasures. The root causes are sovereignty and territorial disputes [1], unclear legal definition [2], national interest drivers of stakeholders [3], historical legacies [4]; the evolutionary process was studied from the game of great powers [5,6], political negotiation [7], simulation and deduction of military power comparison [8] and other aspects; countermeasures mainly include the use of law to protect China’s sovereignty [9], the gradual resolution of the South China Sea issue from a strategic perspective in a separate and systematic way, and the comprehensive use of economic, legal and military means [10,11].

In terms of research methods, qualitative reasoning analysis is the main method, and quantitative methods are rarely used. From the perspective of research, there are many achievements in international politics, international law, military affairs, resources and other perspectives, but few achievements in discussing the south China sea issue from the perspective of network game.

Therefore, in view of the economic and trade cooperation network of the stakeholders on the South China Sea issue, based on the reciprocal model, a reciprocal network game analysis model was constructed to deeply explore the influence of national type (the degree of altruism or egoism), the belief in the goodwill of other countries, the correlation between the types of countries and their payments, the social pressure to betrayal given by network neighbors and spillover benefits generated by regional cooperation on the regional economic and trade cooperation in the South China Sea, and tested by simulation method, providing reference for the formulation of China’s response strategy.

Research Scope

Based on the previous research *Analysis of Complex Network Evolution Process about South China Sea Issue Response* [6], 12 countries were identified. At the same time, ASEAN is an economic and political community, which often adopts a relatively unified diplomatic strategy to deal with the international environment. These countries have a substantial impact on the dispute resolution of the South China Sea issue. Therefore, the South China Sea issue stakeholders can be defined as 17 countries as shown in Table 1:

Table 1 List of stakeholders in the South China Sea issue

Form of participation	Counties
Intra-domain dispute	China, Philippines, Vietnam, Malaysia, Brunei, Indonesia
Intra-domain participation	Cambodia, Laos, Myanmar, Singapore, Thailand
Extraterritorial interference	Japan, USA, India, UK, Australia, Russia

Take the countries shown in Table 1 as nodes to build economic and trade networks. Using UCINET software, the economic and trade cooperation network of stakeholders in the South China Sea issue was drawn, as shown in Figure 1:

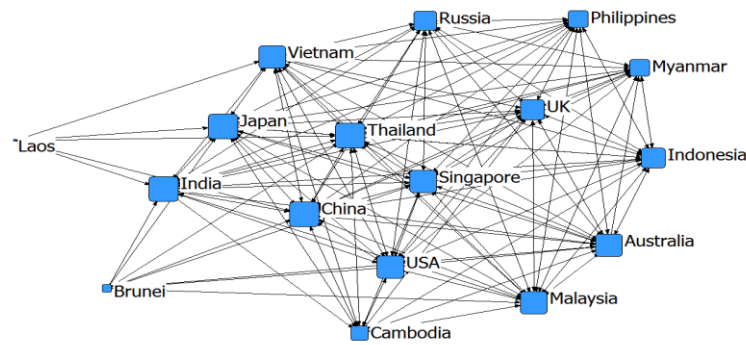


Fig. 1 Economic and trade cooperation network map of stakeholders of the South China Sea

Model Design

Introduction of Reciprocal Model

Economists have been trying to incorporate fairness and preference into economic models, which include egoism, altruism, resentment, fairness and reciprocity. Fehr and Schmidt [12] put forward the utility function of inequality aversion, and Rabin [13] put forward the Rabin model. Following Rabin's thought, Samuel Bowles [14] integrated egoism, altruism and reciprocity and proposed a reciprocal model. He believes that the utility of a person depends on the material payment of himself and others. The model is shown in formula (1):

$$U_i = \pi_i + \sum_j \beta_{ij} \pi_j, i \neq j \quad (1)$$

Where β_{ij} denotes the weight of j 's material payment in i 's preference, as shown in formula (2):

$$\beta_{ij} = \frac{\alpha_i + \lambda_i \alpha_j}{1 + \lambda_i} \quad \alpha_i \in [-1, 1], \alpha_j \in [-1, 1], \lambda_i \geq 0 \quad (2)$$

Thereinto, Where α_i denotes the unconditional level of goodwill or malice of i towards others, α_j represents i 's belief in goodwill about j , and λ_i represents the degree to which i thinks others type is related to its payment evaluation.

The reciprocal model has universal explanatory power for generosity and punishment. In this paper, the reciprocal model was introduced to construct the network game analysis model to simulate the decision-making process of the trade network game of stakeholders of the South China Sea issue. It is in line with the current situation of economic and trade cooperation and has unique explanatory power and scientificity.

Hypothesis of Reciprocal Network Game Model

On the basis of simplifying the actual economic and trade cooperation according to the network characteristics, the following model assumptions were put forward:

1) Each node country has two game strategies of cooperation and betrayal. $S_i = \{0, 1\}$ represents the policy set for node i , 1 for cooperation and 0 for betrayal. In the game of each node country, the profit and cost of cooperation are b and c respectively. When the node does not cooperate, the profit of betrayal is e . According to hypothesis (1), the payment matrix of the single game between two neighbor nodes can be obtained, as shown in table 2:

Table 2 Payment matrix of the single game

Single game between i -node and j -node		The strategy of j -node	
		cooperation	betrayal
The strategy of i -node	cooperation	$b-d ; b-d$	$-d ; b$
	betrayal	$b ; -d$	$e ; e$

2) The stakeholders of the South China Sea participating in various economic and trade cooperation agreements and organizations in the region will generate spillover benefits, which are shared by the partners. Assuming the total spillover benefit is σ , the spillover benefit of each partner is $\frac{\sigma}{N_c}$.

3) On the South China Sea issue, China and ASEAN countries have reached a consensus on cooperation, assuming that such consensus has created public pressure on countries that choose betrayal strategies, expressed as v_i .

4) Introducing the reciprocal model, the utility of each node country is related not only to the material gains obtained by the neighbor game, but also to the material payment of the neighbors.

In conclusion, the total utility of node i in the t -th game is:

$$U_{it} = \sum_{j \in NBR} \pi(s_i, s_j) + \sum_{j \in NBR} \beta_{ij} \pi(s_j, s_i) + \frac{\sigma}{N_c} - v_i \cdot \sum_{j \in NBR, s_j=0} s_j \quad (3)$$

N is used to represent the total number of nodes, and the number of cooperators is expressed by N_c . Based on the payment matrix of Table 2 and related assumptions, the revenue of node i in the t -th game is derived as follows:

$$U_{it} = \begin{cases} N_j^c ((b - \beta_{ij} \cdot c_j) + N ((\beta_{ij} \cdot b - c_i)) + \frac{\sigma}{N_c} & i \text{ is the cooperator} \\ N_j^c (b - \beta_{ij} \cdot c_j) + (N - N_j^c)(e_i + \beta_{ij} \cdot e_j) - v_i \cdot \sum_{j \in NBR, s_i=0, s_j=1} s_j & i \text{ is the betrayer} \end{cases} \quad (4)$$

The equilibrium condition of the i -node selection cooperation strategy is the benefit of cooperation \geq the betrayal benefit, as shown in formula (5):

$$N_j^c (b - \beta_{ij} \cdot c_j) + N (\beta_{ij} \cdot b - c_i) + \frac{\sigma}{N_c} \geq N_j^c (b - \beta_{ij} \cdot c_j) + (N - N_j^c)(e_i + \beta_{ij} \cdot e_j) - v_i \cdot \sum_{j \in NBR, s_i=0, s_j=1} s_j \quad (5)$$

Then the condition that node i changes the cooperation strategy is as shown in formula (6):

$$v_i \cdot \sum_{j \in NBR, s_i=0, s_j=1} s_j + \frac{\sigma}{N^c} + N(\beta_{ij} \cdot b - c_i - e_i) + N_j^c(e_i + \beta_{ij} \cdot e_j) \geq 0 \quad (6)$$

Analysis of Simulation Results

Substituting the different degree values of each country into the reciprocal network game model, which are 12, 7, 9, 16, 14, 14, 15, 5, 15, 10, 11, 13, 15, 15, 12, 15, 15 respectively; and the MATLAB software was used to simulate the payment matrix of Table 2 and formula (3) and (5) on the network in figure 1, the simulation results are shown in figures 2-8:

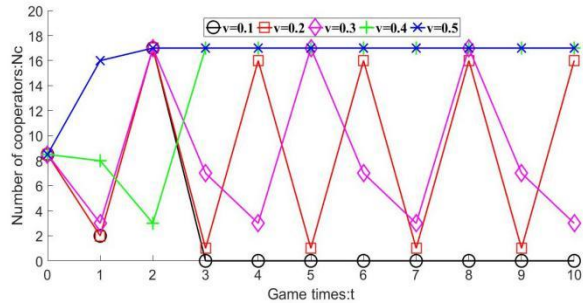


Fig.2 Simulation result of betrayal pressure affecting cooperation

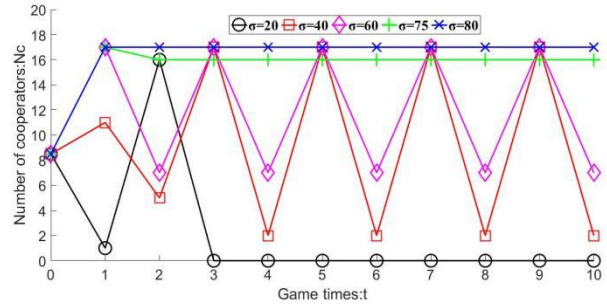


Fig.3 Simulation result of spillover benefits affecting cooperation

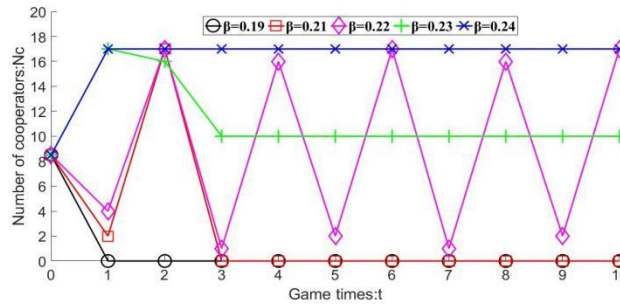


Fig. 4 Simulation result diagram of β_{ij} affecting cooperation

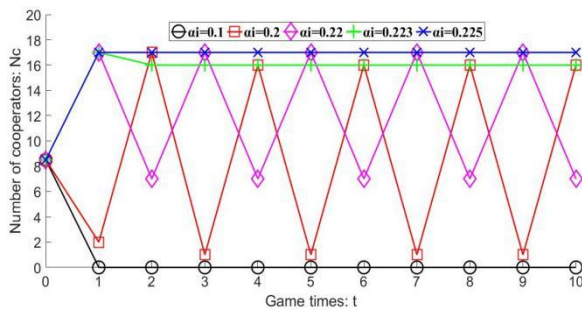


Fig.5 Simulation result diagram of α_i affecting cooperation

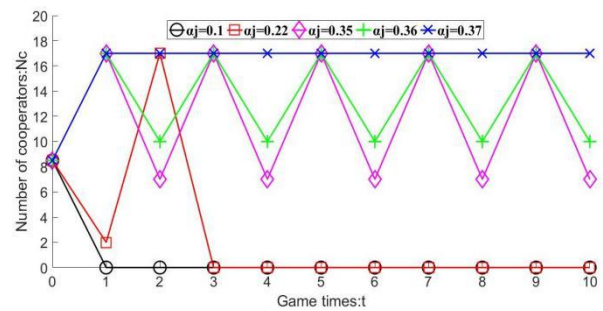


Fig.6 Simulation result diagram of α_j affecting cooperation

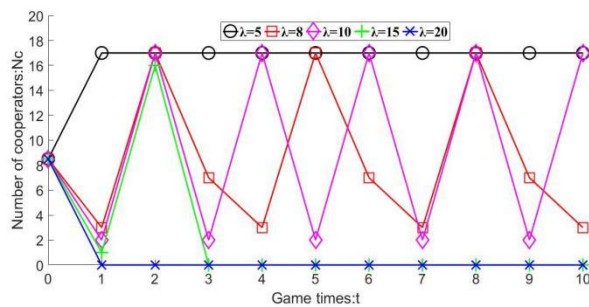


Fig.7 The impact of λ on cooperation when $\alpha_i=0.6, \alpha_j=0.15$

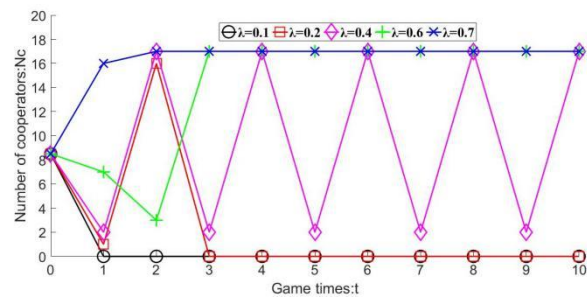


Fig.8 The impact of λ on cooperation when $\alpha_i=0.15, \alpha_j=0.3$

Analyzing the figures, we could conclude some results as follows:

1) Neighbouring countries' pressure on betrayal and spillover benefits of regional cooperation have a significant impact on the economic and trade cooperation of stakeholders in the South China Sea issue: the greater the betrayal pressure and the greater the spillover benefits, the easier the overall cooperation of stakeholder networks in the South China Sea issue will be achieved.

2) The weight of material payment of other nodes in the preference of i has a direct positive impact on the economic and trade cooperation of the stakeholder network in the South China Sea issue. And the degree of goodwill of a country towards other countries and its belief in goodwill of other countries firstly affect weight of material payment of other nodes in the preference of i , and then affect the cooperation: the greater the goodwill degree of stakeholders towards other countries and the higher their belief in goodwill towards other countries, the easier it is to achieve the overall cooperation of the network.

3) The relevance of other participants' types considered by one country and their evaluation of payment has two-side effects on the network economic and trade cooperation of stakeholders in the South China Sea: when a country's goodwill towards other countries is greater than its belief in the goodwill of other countries, the greater the degree of correlation, the more unfavorable to the cooperation of the network of stakeholders in the South China Sea issue; while when its goodwill towards other countries is less than its belief in their goodwill, the greater the correlation, the easier it will be to promote cooperation.

Conclusions

It is easier to promote cooperation by creating a public opinion atmosphere for economic and trade cooperation in the South China Sea and maintaining strong social pressure on the betrayers, which coincides with the reality of the "South China Sea issue". Stakeholders in the South China Sea should create an altruistic image and restrict the excessive egoistic behaviors of "egoistic countries" through reasonable mechanisms. At the same time, through regional economic and trade cooperation, more public goods will be provided to the south China sea to generate greater spillover benefits, thus promoting the prosperity and stability of the South China Sea.

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