

Research on Complex Network Evolutionary Game Model and Simulation of Economic and Trade Cooperation of “the Belt and Road”

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Abstract—The exploration of the influence of the network neighbor's reward, the social pressure of the network, the profit loss rate of the betrayal, the pressure of the opponent's public opinion, the type of the game on the network cooperative behavior of "the Belt and Road" through the network game model is of great significance. The method of simulation examined the game model of the network cooperation of "the Belt and Road", obtained the conclusion that reward of the network neighbor, the social pressure of the network, the betting loss rate has a positive effect on the cooperative behavior of the country of “the Belt and Road”, and the opponent's public opinion pressure has a negative impact on cooperation. Finally, the relationship between the game type and the cooperative behavior of the node was discussed.

Keywords—the Belt and Road; network game; simulation

INTRODUCTION

In the three years since the “the Belt and Road” initiative was put forward, China has signed cooperation agreements with more than 40 countries and international organizations, and has formed a cooperation network system gradually that base on the principle of achieving shared growth through discussion and collaboration. However, its construction and perfection still face many risks and problems. The political and economic game of great powers, religious and cultural conflicts, geopolitics and other factors still threaten the economic and trade cooperation of “The Belt and Road”. Therefore, to identify the influencing factors of “The Belt and Road” economic and trade cooperation and analysis the mechanism of formation of cooperation network to facilitate its construction has realistic significance.

Domestic and foreign scholars have widely interpreted the concept of “The Belt and Road”. There are foreign scholars interpret it as China's "Marshall plan"[1], which is regarded as a game strategy against the United States [2]. Another view is that “The Belt and Road” can promote regional economic integration [3], promote the integration of Asian regions and the world [4], and promote maritime connectivity [5]. It is a diplomatic philosophy strategy of mutual benefit and security. Chinese scholars argued that "the Belt and Road" strategy provides a connecting hub for the political body of geo-space [6], which can inject vitality into global governance and help reduce the geographical

competition between China and the United States [7]. In the content of the study, the results have been concentrated on the mutually beneficial cooperation in economy and trade[8], the regional industrial upgrading[9], the sino-algerian partnership, religious and cultural exchanges, the development of regional economic integration[10], the coordinated development of ethnic minorities, the Chinese companies outbound strategy, RMB internationalization, economic growth in China based on economic corridors, construction of economic belt, strategic layout of maritime powerhouses, and Sino-Indian co-opetitive relations. In the research methods, the qualitative analysis, trade gravity model, panel data analysis, econometric methods and ERGM are main methods. The network game method is relatively rare in the research results of "the Belt and Road".

RESEARCH SCOPE

The main object of this paper is 63 countries along the "the Belt and Road", and divided these countries according to their geographical locations, as shown in the following table:

TABLE I. COUNTRIES LIST OF “THE BELT AND ROAD”

Regions and organizations	countries
West Asia	Iran, Iraq, Turkey, Syria, Jordan, Lebanon, Israel, Saudi Arabia, yemen, Oman, united Arab emirates, Qatar, Kuwait, bahrain, Greece, Cyprus
South Asia	India, Pakistan, Bangladesh, Afghanistan, Sri Lanka, Maldives, Nepal, Bhutan
Central Asia	Kazakhstan, Uzbekistan, Turkmenistan, Tajikistan, Kyrgyzstan
Central and Eastern Europe	Poland, Lithuania, Estonia, Latvia, Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Serbia, Albania, Romania, Bulgaria, Macedonia, Russia, Ukraine, Belarus, Georgia, Azerbaijan, Armenia
East Asia	Singapore, Malaysia, Indonesia, Myanmar, Thailand, Laos, Cambodia, Vietnam, Brunei, Philippines, China, Mongolia

MODELS AND METHODS

To sum up, the following assumptions can be made on the network game model of economic and trade cooperation along “the Belt and Road”:

(1) Assuming that each node country is homogeneous, the impact of economic and trade cooperation on each country is

consistent and brings the same benefits to each country. Cooperation also requires costs. Assuming that the cost of cooperation among different countries is the same, and the value is d . $S_i = \{0, 1\}$ represents the strategy set of node i . There are two strategies for node i that are optional in the game, 1 for cooperation and 0 for betrayal. Betrayal can lead to failure of cooperation and loss of return, assuming that the rate of loss is f . Assuming that each node can get a profit of b from cooperation in a single game. Combined with assumptions 1, the income payment matrix can be obtained as shown in table II.

(2) Each node country is affected by its neighbor nodes. The neighboring nodes have close trade relations with it, and they will influence the game gain of the node through the reward and penalty. Suppose the reward of the cooperative action given by each neighbor node is r_{ij} , and the total reward that node i gets from its neighbors is $\sum_{j \in NBR} r_{ij}$.

TABLE II. SINGLE GAME PAYMENT MATRIX

Single Game of Node I,J		Strategy of Node J	
		Cooperation	Betrayal
Strategy of Node I	Cooperation	$b-d$	$-d; b(1-f)$
	Betrayal	$b(1-f)$	$e; e$

(3) "the Belt and Road" initiative has been widely recognized by the countries along the route. This recognition will generate some social pressure to urge the countries along the route to choose to cooperate. Suppose the value of this pressure is v_i . The node country is constrained by its opponents, assuming that the value of this pressure is c_i .

(4) It can be concluded from the assumptions that the total gains obtained by node I in the t -wheel game are as follows:

$$U_{it} = \sum_{j \in \Omega_i} \pi(s_{it}, s_{jt}) + \sum_{j \in NBR, s_i=1} r_{ij} - v_{it} \sum_{i \neq j, s_i=0} X_j - c_{it} \sum_{j \in NBR, s_j=0} P_{ij}, \quad (1)$$

Using N to represent the total number of nodes, and N_c to represent the number of collaborators. According to the Income matrix of table one and related assumptions, the benefits of node I can be derived as follows:

$$U_{it} = \begin{cases} N_{it}^c b - Nd + \sum_{j \in NBR, s_i=1} r_{ij} - c_{it} \sum_{j \in NBR, s_j=0} P_{ij}, & i: \text{cooperator} \\ N_{it}^c b(1-f) + (N - N_{it}^c) e_i - v_{it} \sum_{i \neq j} X_j, & i: \text{defector} \end{cases}, \quad (2)$$

$P_{ij} = 1$ when the strategy of i is consistent with j , otherwise $P_{ij}=0$. The equilibrium condition that node i chooses cooperative strategy is the return of cooperation \geq betrayal, as shown in formula (3).

$$N_{it}^c b - Nd + \sum_{j \in NBR, s_i=1} r_{ij} - c_{it} \sum_{j \in NBR, s_j=0} P_{ij} \geq N_{it}^c b(1-f) + (N - N_{it}^c) e_i - v_{it} \sum_{i \neq j} X_j, \quad (3)$$

$$\sum_{j \in NBR, s_i=1} r_{ij} + N_{it}^c b f - N(d + e) + N_{it}^c e_i + v_{it} \sum_{i \neq j} X_j - c_{it} \sum_{j \in NBR, s_i=1} P_{ij} \geq 0, \quad (4)$$

SIMULATION OF NETWORK GAME

Transforming "the Belt and Road" complex network into a 63×63 relational matrix. In this matrix, if there is a trade volume between countries that exceeds the set trade volume, there is a closer economic and trade relationship between the two countries with a network connection between the nodes. The value of the intersection of countries in the adjacency matrix is 1, otherwise 0. The total number of 1 in a row in the matrix is the number of neighbors for that line's representative country. The adjacency matrix for the Belt and Road countries is shown in annex 1. The degree of the node country measures the number of neighbors of the node country, that is to say, the degree is the total number of neighbors, which is set as Ω_i . The degree of the nodes $K=[18 \ 20 \ 21 \ 34 \ 29 \ 43 \ 41 \ 3 \ 20 \ 8 \ 45 \ 17 \ 61 \ 38 \ 28 \ 52 \ 47 \ 32 \ 32 \ 49 \ 47 \ 61 \ 52 \ 48 \ 35 \ 35 \ 37 \ 39 \ 33 \ 16 \ 12 \ 34 \ 36 \ 39 \ 57 \ 11 \ 12 \ 18 \ 21 \ 14 \ 3 \ 44 \ 33 \ 55 \ 32 \ 50 \ 58 \ 47 \ 38 \ 54 \ 48 \ 49 \ 34 \ 25 \ 14 \ 51 \ 57 \ 27 \ 52 \ 56 \ 26 \ 51 \ 24]$.

Using MATLAB software to simulate the network game model, and the simulation flow charts are shown in Figure 1-7.

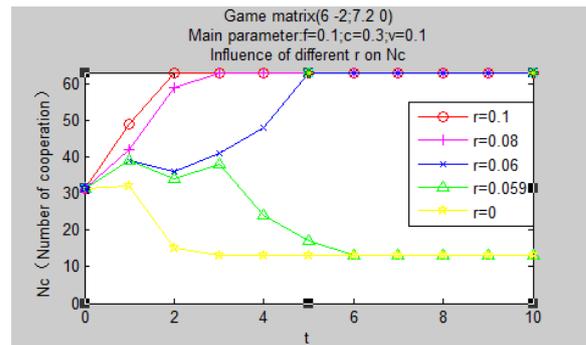


FIGURE I. THE IMPACT OF NEIGHBORHOOD INCENTIVES

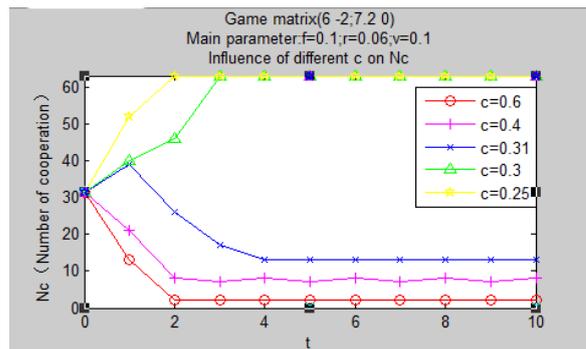


FIGURE II. THE IMPACT OF OPPONENTS' PRESSURE

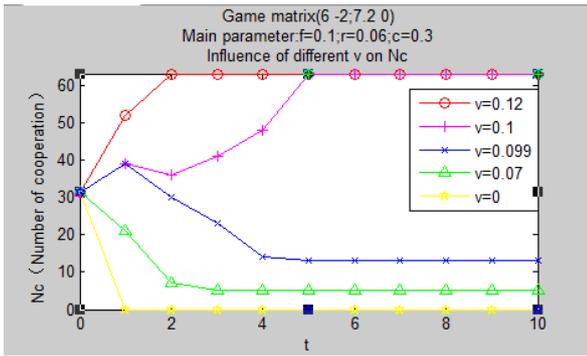


FIGURE III. THE IMPACT OF NETWORK SOCIAL STRESS

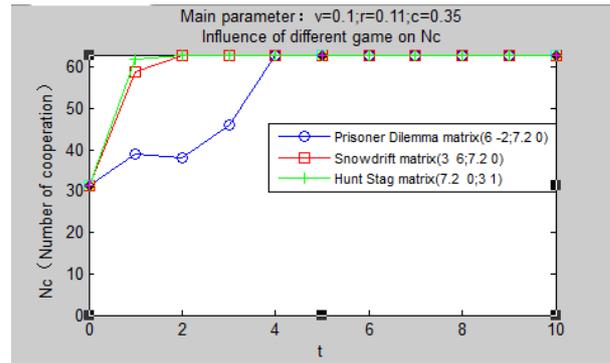


FIGURE VII. R = 0.11, THE THREE DIFFERENT GAME EVOLUTION SIMULATION

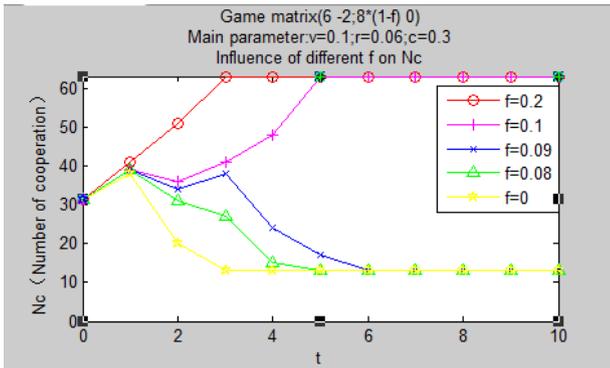


FIGURE IV. THE IMPACT OF THE BETTING PROFIT

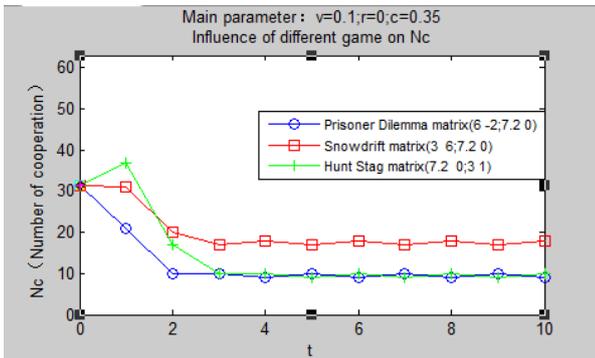


FIGURE V. R = 0, THE THREE DIFFERENT GAME EVOLUTION SIMULATION

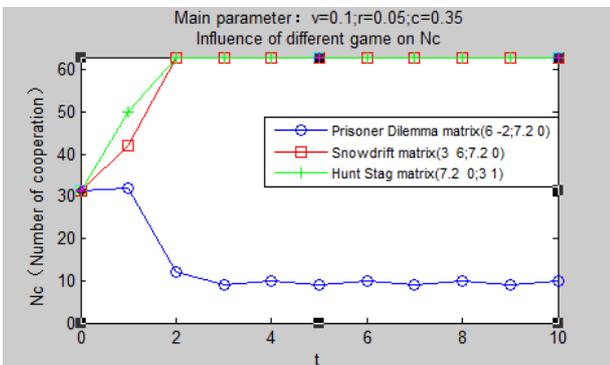


FIGURE VI. R = 0.05, THE THREE DIFFERENT GAME EVOLUTION SIMULATION

Analyzing the figures, we could conclude some results that in the evolutionary game model of "the Belt and Road" economic and trade cooperation, the reward of cooperative behavior by neighboring countries has a significant positive impact on the strategy selection of network node countries. When the proportion of reward reaches a certain height, all Countries regard cooperation as the best strategy. At the same time, the overall social pressure formed by " the Belt and Road" has a positive effect on promoting cooperative behavior. The greater the pressure on the cooperative behavior from the network as a whole, the more the public opinion will cooperate. The more it is possible for all countries in the network to reach a stable Collaboration. The social influence and pressure of opponents in the network have a negative impact on cooperation. The greater the social impact of opponents, the stronger the opposition forces and the less conducive to the emergence of cooperative behavior. The effect of betrayal revenue discount rate on cooperative behavior is positive, the greater the discount rate, the more conducive to node countries choose to cooperate, not betrayal. The structure of the game also has an impact on the cooperative behavior. In contrast, it is more difficult for the prisoner's dilemma to achieve a stable cooperative equilibrium than that of the herd and the avalanche. Only when the neighbors give enough reward can the three games all stabilize in the cooperation strategy Down.

CONCLUSION AND DISCUSSION

A. Conclusion

Countries along "the Belt and Road" have dynamically adjusted their own strategies and behaviors based on their expected political and economic interests, thus constituting a dynamic game process. At the same time, the game process is embedded in the complex network of related countries, whose characteristics and structure have an impact on the expected return of countries along the line, thus affecting their strategy choice and game behavior, changing the structure of the game.

B. Discussion

The research assumes that there is no difference in the node countries, the network structure is stable and the game strategy is changing. The assuming conditions are too strict, there are differences in the actual economic and trade cooperation with the same belt. In order to enhance the explanatory power of the model, In the follow-up study, we will discuss the impact of the

dynamic changes in network structure on the behavior of economic and trade cooperation along the Belt and Road. Bring theory and practice closer together.

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