

Article

Complex Network Game Model Simulation of Arctic Sustainable Fishery Trade Cooperation under COVID-19

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Abstract: Under the background of COVID-19, the conditions and environment of international cooperation in Arctic sustainable fisheries have changed. Accurately predicting the impact of environmental changes on the evolution of Arctic fishery cooperation, identifying its key influencing elements, and formulating appropriate corresponding measures have practical value for the sustainable development of Arctic fisheries. Based on the collection of fisheries trade data in Arctic sustainable fisheries trade cooperation countries, this paper builds a trade cooperation network, identifies key influencing factors, establishes a network game model, and uses simulation methods to verify the variables. The results show that the reward value given by neighboring countries has a positive effect on such cooperation. The higher the reward value is, the more countries choose to cooperate. The cooperation cost has the opposite effect, the lower the cost, the more countries choose to cooperate. The impact of cost on cooperation is greater than the incentives. The game structure also affects the outcome of cooperation, and the number of countries participating in cooperation based on the Stag Hunt Model is the largest. The change of network structure will have an impact on cooperation, and the COVID-19 pandemic has influenced cooperation on Arctic sustainable fisheries trade cooperation in the short term.

Keywords: arctic; complex network; game theory; trade cooperation; sustainable fisheries



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1. Introduction

Marine fisheries are an important part of the exploitation of Marine resources. The global fish and seafood market is one of the largest and most integrated in the world, with a long supply chain and thousands of participants. The market has reached 159 billion dollars in 2020 and is expected to reach 194 billion dollars by 2026 with a sustained growth rate of 3.4% [1]. Relevant data show that marine fisheries provide about two-fifths of the protein for human beings, which plays a pivotal role in the improvement of human health and living standard. With the further improvement of the exploitation and utilization of marine fisheries resources in the future, the impact of marine fisheries on the marine economy of various countries will become increasingly prominent. However, the exploitation and utilization of the oceans are accompanied by some negative consequences. In particular, the excessive and the predatory exploitation of marine resources by some countries has damaged the marine ecosystem and marine fishery resources, which has posed a serious threat to the sustainable development of marine fisheries. To maintain a healthy and balanced marine ecosystem, resolve the global ecological crisis, and achieve the sustainable development of global fisheries requires, all members of the international community to abandon narrow national interests and cry out for joint and effective international cooperation.

The Arctic has rich fishing resources and is a hotspot for disputes over maritime rights around the world. According to the analysis of statistics from the Food and Agriculture Organization of the United Nations (FAO), the average annual catch in the Arctic (zones 18, 21, 27, 61 and 67) from 2011 to 2017 was 34.38 million tons, accounting for 38 percent of the

global average annual catch, which has a significant impact on the security of global food supply and marine economic development. In recent years, the international community has paid more and more attention to Arctic fishery resources. The fishery resources move northward day by day, which can easily lead to a new round of competition for the fishery resources in the Arctic region. The sustainable development of the fisheries in the sustainable fishery trade cooperation among Arctic countries is threatened.

The sudden emergence of COVID-19 has hit all industries hard. The persistence of COVID-19 has also provided new thinking for the sustainable development of Arctic fisheries. As of 31 March 2021, there were more than 129 million cumulative confirmed cases and more than 2.8 million cumulative deaths worldwide. The health and security problems brought about by COVID-19 have caused a huge impact on the global economy and finance. During the epidemic period, there have been many cases of large-scale transmission of COVID-19 caused by cold chain logistics, which had a great impact on fishery trades. The World Trade Organization (WTO) released a forecast in October 2020 that the global commodity trade in 2020 will decline by 9.2% compared to that in 2019 [2]. International trade plays an important role in the development of the world economy. It can promote the circulation of goods at home and abroad and closely link the domestic and foreign markets. Through international trade, sustainable behaviors can be spread among countries. In order to better deal with the sustainable development of fishery under the COVID-19, it is imperative for Arctic shipping countries to carry out extensive cooperation. Most Arctic sustainable fishery trade cooperation countries are close to the Arctic, which can trigger reflection on Arctic fisheries. Therefore, this paper chooses to study trade cooperation in the context of COVID-19.

Sustainable fishery trade cooperation is an important, realistic and international issue under the background of COVID-19. Marine fisheries are an important part of the marine economy and a vital part of human life, providing 40% of the protein of two-thirds of the world's population. Every country and industry around the world has been affected by COVID-19 to different degrees, such as agriculture, manufacturing, imports and exports, tourism, and services. Along with the increasingly severe global outbreak, a lack of food may become a real challenge, which makes sustainable fisheries (The definition is shown in Table A1 of the Appendix A) even more important. In view of the above situation, we raise two research questions:

- Q1: What are the influencing factors of trade cooperation under the epidemic situation?
- Q2: Will the four factors selected in this paper have a positive or a negative relationship with fishery trade cooperation?
- Q3: What research suggestions can we propose for the future cooperation?

In order to answer the above questions, this paper introduces the mechanism of the impact of the epidemic on the development of fishery trade. On the basis of other scholars' models, the game matrix and revenue function are modified in combination with the background of COVID-19 and the characteristics of the Arctic sustainable fishery trade, so as to build the model and simulate it. The rest of this paper is organized as follows: in the next section, we reviewed the literature. In section three, we used UCINET to calculate and map fishery trade networks before and after the outbreak. In section four, we built and simulated the model. Finally, the conclusions and discussions are presented in Section 5.

2. Literature Review

The sudden outbreak of COVID-19 has had a huge impact on the world economy and international relations. The virus spreads internationally with the flow of people and materials, which seriously affects the normal flow of international trade. In the face of the impact of COVID-19, many countries have implemented restrictive trade measures [3]. The global free trade system has been damaged under these restrictive trade measures and the embargo policy of the transportation industry, and global trade protectionism has been amplified, severely impacting both supply and demand. Many countries have strengthened quarantine inspection procedures for imported cold-chain products, which

has increased the difficulty of trade between countries to a certain extent. After the outbreak of COVID-19, trade interconnectedness, connectivity and density among countries has significantly decreased, and trade network structure has undergone significant changes [4]. In addition, COVID-19 will also aggravate the trade frictions between governments and enterprises [5], which will hinder the cooperation in many fields around the world. As a transportation route that runs through many important countries throughout the world, the Arctic shipping route plays an important role in epidemic prevention, control, and cooperation [6]. There are many world-famous fishing grounds (such as the North Sea fisheries and Newfoundland fisheries) near the Arctic waters, and the coastal countries along the Arctic shipping routes are rich in fishery resources. Most of the coastal countries are also important fishery countries in the world (such as Norway, Sweden, Finland, Denmark, and Iceland). How to deal with the current situation of sustainable fishery development under COVID-19 through trade cooperation is a topic worth thinking about.

At present, there are some international conventions, multilateral agreements and relevant organizations devoted to the sustainable development of fisheries in the Arctic shipping routes. At the global level, there are global conventions such as the *United Nations Convention on the Law of the Sea* adopted in 1982 and the *United Nations Agreement on Fish Stocks* issued in 1995 [7]. There are also bilateral or multilateral fishery cooperation agreements including the *Treaty on the Conservation and Management of Salmon in the Pacific Ocean* signed by the United States and Canada in 1985, the *Agreement on Common Fishery Relations* signed by the United States and the Soviet Union in 1988, and the *Agreement on Common Fishery Relations* signed by Denmark, Norway, and Russia in 1992 [8]. The fishery operation areas around the Arctic include the Northeast Atlantic Ocean, Northwest Atlantic Ocean, Northeast Pacific Ocean, and Northwest Pacific Ocean, in which some Arctic shipping countries are covered. Different types of fisheries management organizations and fisheries management committees have been established for each operational area, such as the Northwest Atlantic Fisheries Organization, the North Atlantic Salmon Conservation Organization, the Atlantic Tuna Fish Management Committee, the Western and Central Pacific Fisheries Commission, and many others. It can be seen that countries have long been aware of the interaction between fishery ecosystems and economic systems and have thereby achieved a series of achievements in fishery ecological management. Regrettably, cooperation in fishery management among related countries in the Arctic is fragmented. Current international fishery management rules are limited to specific regions and specific fish populations, and there is no management mechanism specifically applicable to the cooperation of countries involved in the Arctic's sustainable fisheries trade [9].

Sustainable fisheries consist of three aspects: environmental, social, and economic sustainability [10,11]. The academic scholars generally use the quality of marine fishery resources and the degree of exploitation and utilization to reflect the sustainable utilization of fishery resources and the environment. Using the input and output of resources and the environment, that is, the amount of fish caught, to measure the sustainable use of economic aspects, sustainable utilization in society is measured by the coordination of sustainable utilization development, labor evaluation index, and the degree to which fishery resources meet the living needs of human beings [12]. The behavior of overfishing will damage the water environment and will thereby have an impact on the fishery ecosystem [13]. Therefore, it is necessary to vigorously promote sustainable development. Since each country is an independent interest body and there is no supranational regulatory body at present, the theoretical community agrees that cooperation is one of the most effective ways to solve regional environmental problems [14]. However, since the nature of environmental cooperation is a kind of public goods cooperation, its international cooperation is bound to undergo the test of "free rider" behavior, which challenges the traditional solutions to environmental externalities. Scholars often use game theory to study international environmental cooperation [15]. Hauer and Runge (1999) [16], for the first time, linked trade and environment in the study of cross-border environmental pollution. The study of Limao (2005) [17] has broadened the horizon for the academic community, proving that

to increase the trade benefits of each country, to some extent, it can be considered to link trade with the environment, so as to achieve the purpose of stimulating environmental cooperation. Some scholars used the models of evolutionary games and cooperative games to analyze the strategy selection of related topics and the stability of equilibrium in the process of fishery cooperation and resource development [18,19]. These studies provide methodological references for the formulation of international cooperation models for sustainable fisheries. In the actual process of international cooperation in fisheries, countries are affected by their economic ties, the regional international organizations they have joined together, and the differences in culture and values, making countries that have good economic cooperation relations more inclined to continue cooperation. Therefore, sustainable fishery cooperation with countries as the main body is obviously affected by the geo-economic network. The relationship network is incorporated into the game model, and the cooperative behavior of the cooperating countries in the Arctic sustainable fishery trade can be analyzed from the perspective of behavioral game. The perspective can provide a more realistic theoretical explanation.

Based on the above literature, it can be seen that in the existing related literature, the research content mainly focuses on the impact of the epidemic at the macro-level and the solutions, and less attention is paid to a micro-area under the background of the epidemic, such as the issue of international trade cooperation in the fishery field. There is very little literature discussing the impact of COVID-19 on certain regions, such as the Arctic route. With a deeper understanding of COVID-19, the micro-level of the research object of the enterprise industry will become the focus of international trade cooperation research.

3. Methodology

As the expected opening of the Arctic shipping route is approaching, the strategic significance of the Arctic region in terms of energy resources, geographical location, transportation value, geopolitics, and military status is becoming increasingly prominent. Once the Arctic region realizes commercial navigation, it will certainly have an important impact on the global transportation system, such as the change and interconnection of cargo transportation modes, the re-selection of transportation routes, and the global change of cargo volume. In order to further study the countries and regions affected by the full opening of the Arctic shipping routes, systematically solve the problems related to the Arctic and the Arctic shipping routes, and steadily establish relevant international coordination mechanisms, the scope of Arctic countries should be expanded. However, the scope of the Great Arctic is too broad, including 53 countries and regions in Asia, Europe and North America [20]. The complicated political, economic, and cultural situations involved make it difficult to carry out overall research. Therefore, the scope of the Great Arctic is further divided. On the basis of learning from scholars who also study Arctic environmental governance [21,22], countries around the Arctic Circle, countries on the extension line of the Arctic, traditional major countries with global influence and countries affected by the Arctic shipping route are selected. The main body of the Arctic sustainable fishery trade cooperation countries is determined as follows: Canada, Finland, Denmark, Norway, Sweden, Iceland, Russia, and The United States (around the Arctic Circle); China, South Korea, Japan, India, and Singapore in Asia; Germany, the United Kingdom, France, Spain, The Netherlands, Poland, and Italy; A total of 20. Table 1.

Table 1. List of Arctic Sustainable Fishery Trade Cooperation Countries.

Region	Country
Within the Arctic Circle	Canada, Finland, Denmark, Norway, Sweden, Iceland, Russia, USA
Asia	China, Rep. of Korea, Japan, India and Singapore
Europe	Germany, United Kingdom, France, Spain, The Netherlands, Poland, Italy

The 20 countries will be the nodes of the network. The amount of fishery trade between two countries determines the weight of the relationship between member states in the network, and the degree of economic and trade links between countries varies with the amount of trade. The larger the trade volume is, the closer the network connection is and the stronger the trade connection. On the contrary, the connection is smaller or there is no cooperative relationship. By referring to the UN Comtrade database, a 20×20 network matrix was constructed by selecting the fishery trade data of 20 countries. We set the total import and export volume of the country to the node country is more than 100,000 dollars as the standard for the existence of economic and trade cooperation between the two countries. There are trade ties between countries, and the corresponding item of the adjacency matrix is assigned a value of 1, otherwise it is assigned a value of 0. UCINET software was used to draw a fishery economic and trade cooperation network diagram of countries in the year before the epidemic (see Figure 1). The 20 countries are arranged by their English first letter, the degree of each node country is (15,12,15,12,17,14,15,8,11,14,10,15,18,13,9,2,17,11,18,15), and the average degree is 13.05. UCINET software is used to map the Arctic fishery economic and trade cooperation network. In 2020, the cooperation network diagram of the countries related to the route is shown as in Figure 2, the degree of each node country can be obtained as (17,9,16,12,0,15,16,7,11,11,0,15, 18, 12, 10, 0, 17, 12, 18, 15), and the average degree is 11.55.

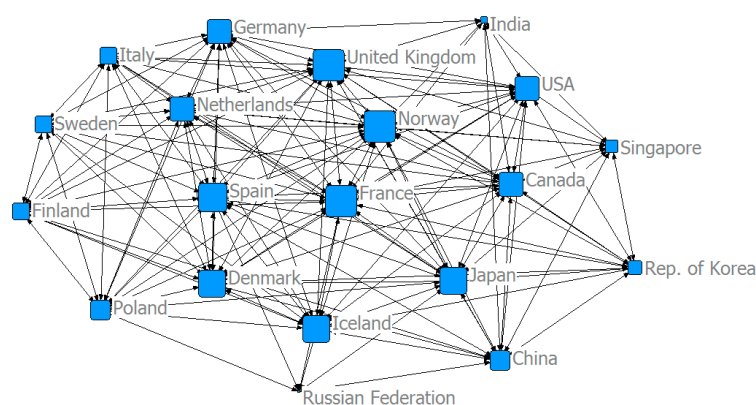


Figure 1. Trade network before COVID-19.

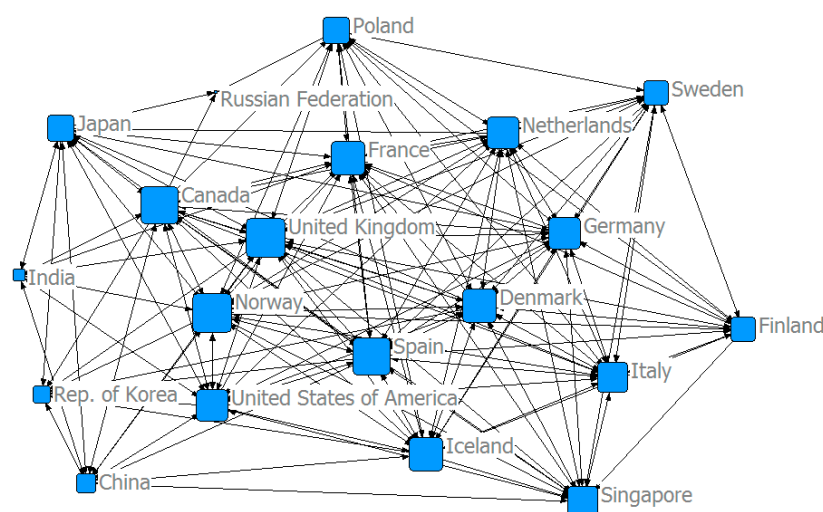


Figure 2. Trade network in 2020.

4. Design of the Network Game Model

4.1. Model Assumptions

Based on the summary and conclusion of the transmission impact of COVID-19 on fishery trade [23,24], this paper summarized the influencing factors of Arctic sustainable fishery trade cooperation into the factors of cooperation cost, incentive policy, cooperation mode, and COVID-19. The specific composition and reasons are as follows.

4.1.1. Cost Factors of Cooperation

A sustainable fishery includes three aspects: the environment, society, and the economy. COVID-19 is likely to affect these three aspects, thus increasing the cost of cooperation and ultimately affecting the sustainable use of fishery resources. In order to prevent further expansion of the epidemic, the state will take measures to restrict the large-scale movement of personnel, which will result in the shutdown of these industries in a short period of time, thus impeding their development. On the one hand, the hindered development process of the industry will increase the fixed cost burden of the enterprises in the industry, resulting in the marginal revenue cannot compensate the fixed cost, which may further cause the rupture of the capital chain of enterprises, business difficulties, and even bankruptcy. If the epidemic breaks out on a global scale, the impact of the foreign epidemic on the development of domestic industries will mainly come from the fact that the affected countries may cancel their habitual orders for some domestic export products, which will further affect the resumption of work and production in the domestic export processing industry and the production and operation difficulties of enterprises. After the outbreak of the epidemic, the cross-border logistics industry of the affected countries will be severely impacted, which will further damage the quality of fresh aquatic products. The massive spread of the epidemic has made people pay more attention to all links of the supply chain of aquatic product trade. The delayed costs caused by labor costs, raw material costs, delayed reworks, cost management of epidemic prevention, and control and social panic have seriously affected the cooperation in the Arctic sustainable fishery trade [25], and fishery trade among countries has been interrupted for a time. Therefore, this paper takes the cost of countries' sustainable fishery trade cooperation as one of the simulation variables. The profit rate of costs and expenses reflects the ability to benefit from all costs and expenses. Therefore, this research uses the cost and expense ratio (with a value range of 0 to 1) to measure the impact of costs on trade cooperation [26].

4.1.2. Incentive Policy Factors

The use of Marine fishery resources is not exclusive, which determines that the "tragedy of the Commons" is easy to happen in the field of marine fishery resources. If there is no strong government control and perfect management system, the characteristics of maximizing human interests will be fully displayed on the "common land" of marine fishery resources. At this time, the intergovernmental incentive control mechanism is very important [27]. The development of fisheries under the epidemic will be affected by the import and export trade barriers and the potential size of foreign markets. Consumers in importing countries will have a distrust of the products of exporting countries and fear that the exported products will be contaminated by bacteria, viruses, and other harmful microorganisms, thus refusing to buy and consume the products from the affected countries. In response to the food problem, countries are likely to step up their pursuit of high-seas resources, such as the Arctic, at a time when trade is so difficult to import and export. Therefore, under the epidemic situation, it is very necessary to strengthen policy incentives. Therefore, this paper takes the incentive policy factor as one of the simulation variables. This paper uses the degree of national attention to measure the incentive policy factors. National emphasis is a value between 0 and 1, reflecting the extent to which a country has incorporated the concept of sustainable fisheries into its national strategy. The more a country emphasizes sustainable fisheries in the form of major legislation, the greater the weight of this indicator

4.1.3. Game Mode Factor

The Arctic sustainable fishery trade cooperation countries are of different sizes, political systems, cultures, and decision-making capabilities. Therefore, the decision-making process of trade cooperation between countries is not the decision-making process of a rational economic being normally assumed by economics, but is due to incomplete information, an irrational choice in the real situation with differences in cognitive structure. The specific ways that countries cooperate have a direct impact on trade cooperation. In the context of COVID-19, the cooperation and exchanges between countries in the field of economy and trade are based on their own interests. If there are reservations in the face of the epidemic or no united vision to build a community with a shared future for mankind, the final cooperation results are different. This paper takes the type of game model as one of the simulation variables, discusses the most favorable game mode for trade cooperation, and puts forward relevant policy recommendations based on the simulation results and reality. The “Prisoner’s Dilemma” is a classic model of a non-zero-sum game, which reflects that the best choice of individuals is sometimes not the best strategy of the collective [28]. The “Chicken game” shows that two chickens should choose an offensive or retreat strategy in a chicken arena. They must repeatedly test the strength of each other. The two chickens must first collect information and find out the details of each other before choosing the best strategy [29]. It is not a strategy of deciding whether to attack or retreat from the beginning. The “Stag Hunt Model” tells us to “cooperate to achieve a win-win situation”. Cooperation requires both parties in the game to learn to focus on a win-win scenario with their opponents and fully take care of the interests of their partners [30]. This paper assigns values to the matrix based on the characteristics of the three games to verify the degree of influence on the outcome of the cooperation.

4.1.4. The Influence of Trade Network Structure Factors

COVID-19 has had a great impact on world trade. We used data from 2016 to 2020 to analyze the network of the reported countries and the corresponding network centrality parameters (see Table 2).

Table 2. Overall Trade Density from 2016 to 2020.

Years	2016	2017	2018	2019	2020
Overall trade density	0.6421	0.6789	0.6763	0.6868	0.6079

It can be seen that the overall network density decreased in 2020 compared with 2016 to 2019. In particular, the overall network density decreased by 11.5 percent compared with 2019. This shows that countries are less interconnected and trade connectivity is declining. Therefore, it can be seen that COVID-19 has had a huge impact on the structure of the trade network. Based on the zero–one matrix obtained from the binarization of trade data in 2020, the simulation program was changed to verify the degree of influence on the results of the cooperation.

Based on the actual situation of economic and trade cooperation between Arctic sustainable fishery trade cooperation countries, the following assumptions are made for its network game model:

Hypothesis 1. *Each node country has two strategy choices: cooperation and non-cooperation. $s_i = \{0,1\}$ represents the strategy set of node i , 1 represents cooperation, and 0 represents betrayal.*

Hypothesis 2. *There are three game methods that countries can adopt: The Prisoner’s Dilemma game, the Chicken game, and the Stag Hunt Model (The definition is shown in Table A1 of the Appendix A). First, the Prisoner’s Dilemma game is taken as an example to construct the game model.*

Hypothesis 3. Assuming that there is a cost to cooperation, the cost of the node country on the cooperation is assumed to be d , and its value range is $(0 < d < b)$; the benefit of cooperation is b , and the value range is $b > 0$.

Hypothesis 4. Supposing that when two neighboring node countries both choose a betrayal strategy, their respective benefits are e and $e > 0$.

Hypothesis 5. According to hypotheses 1, 2, 3, and 4, the single income payment matrix in Table 3 below is obtained.

Table 3. Single-Game Payment Matrix.

Single Game of i,j Nodes		Node j's Strategy	
		Cooperation	Betray
Node i's strategy	Cooperation	$b-d; b-d$	$-d; b$
	betrayal	$b; -d$	$e; e$

Hypothesis 6. v_i represents the external costs imposed by other countries on country i .

Hypothesis 7. The social network incentive is r_{ij} .

When node i is in the game t times, the total return obtained is:

$$U_{it} = \sum_{j \in N} \sum_{br(i)} \pi_i(s_i, s_j) P(s_{jt}) - v_i \left(\sum_{j \neq i} x_j \right) + \sum_{j \in N} r_{ji}(x_j) \quad (1)$$

The standard Marshall Demand function derivation process starts from the utility function, which is calculated by the Lagrange multiplier method or Rolle identities and assumes that the utility function is strictly concave or quasi-concave. Environmental and resource economists are widely used in applications of Single equation demand function models such as multivariate linear, quadratic, semi-logarithmic, logarithmic linear, and linear logarithmic functions. Some scholars use counting models to discuss resource demand functions, such as the Poisson and negative binomial probability distribution models to evaluate. Thus, we can obtain the following:

$$P(s_{jt}) = \frac{\exp(-\lambda) \lambda^Q}{Q!} \quad (2)$$

where Q represents the demand, which conforms to the Poisson distribution, and λ is the mean value of the random variable.

4.2. Model Analysis

According to the above hypothesis, the equilibrium condition of the node country i in the t -round game is:

$$U_{it} = \begin{cases} N_{it}^c(b-d)P(s_{jt}) - (N - N_{it}^c)(-d)(1 - P(s_{jt})) + \sum_{j \in N} r_{ji}(x_j), \text{Cooperation} \\ N_{it}^c b P(s_{jt}) + (N - N_{it}^c)e(1 - P(s_{jt})) - v_i \left(\sum_{j \neq i} x_j \right), \text{betray} \end{cases} \quad (3)$$

where N represents the total number of countries, N_i^c represents the number of countries participating in fishery trade cooperation in the t round, and the equilibrium condition for node i to choose a cooperation strategy is to meet cooperation benefit $\geq$ non-cooperation benefit:

$$N_{it}^c(b-d)P(s_{jt}) - (N - N_{it}^c)(-d)(1 - P(s_{jt})) + \sum_{j \in N} r_{ji}(x_j) \geq N_{it}^c b P(s_{jt}) + (N - N_{it}^c)e(1 - P(s_{jt})) - v_i \left(\sum_{j \neq i} x_j \right) \quad (4)$$

Thus:

$$\sum_{j \in N_{br(i)}} r_{ji}(x_j) - N_{it}^c dP(s_{jt}) - (N - N_{it}^c)(e + d)(1 - P(s_{jt})) - v_i \left(\sum_{j \neq i} x_j \right) \geq 0 \quad (5)$$

From Equation (5), it can be seen that the choice of a certain round of game strategy of each node country in the Arctic sustainable fishery trade network is directly related to the rewards of cooperative behavior given by neighbor nodes, the cost of cooperation input, and the size of the benefits obtained by a node's selection of the betrayal strategy. The greater the reward for cooperation from neighboring countries, the greater the possibility that formula (5) will be established, and the greater the possibility that the node country will choose a cooperation strategy; the greater the cost of cooperation, the less the node will gain from the cooperation and from formula (5), the less likely it is to be established and the more likely it is that the node country will choose to betray. In addition, different game methods have different profit matrices, which make the number of node countries who choose to cooperate also different. In the face of the sudden epidemic, the trade volume has undergone tremendous changes, and the trade network structure has also undergone corresponding changes, which will also have a certain impact on cooperative behavior.

5. Simulation and Results

Based on the above model, we analyzed the influence of various factors on the network through MATLAB simulation. The simulation process is shown in Figure 1. According to the actual situation and data experiment, a unified setting process of variable values is carried out in the simulation. In order to verify the current situation of fishery trade cooperation between Arctic sustainable fishery trade cooperation countries under COVID-19, MATLAB software was used to simulate the network game model. The simulation process is shown in Figure 3. The simulation time is set to $t = 10$.

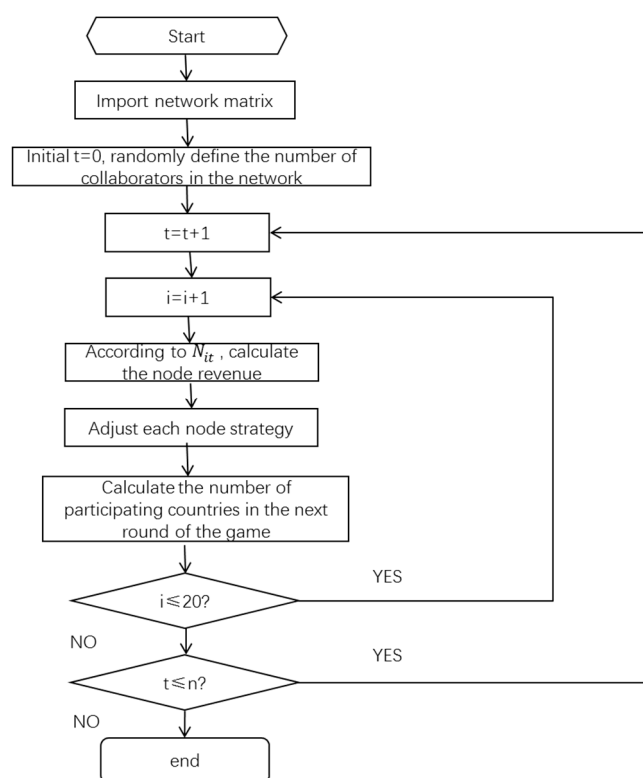


Figure 3. Network game simulation process.

5.1. The Impact of Cost on Cooperation

Assume that the initial game matrix of the trade cooperation node i, j of the Arctic sustainable fishery trade cooperation countries is $(5, -2; 6, 3)$, the game type is the Prisoner's Dilemma game, and the reward of neighbor nodes for cooperative behavior is 0.7. The number of nodes in 2020 is adopted, and the values of cost $c = 0.1, 0.3$, and 0.5 are respectively selected. The simulation results are shown in Figure 4.

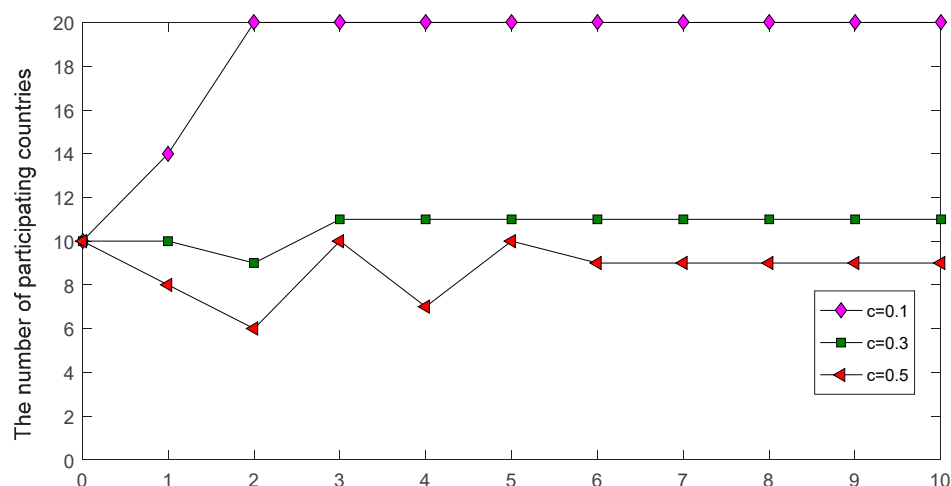


Figure 4. The impact of cost on cooperation.

In Figure 4, the values of other variables remain unchanged. When the value of the cost v is 0.1, after two rounds of games, the number of partners in the trade network of the Arctic sustainable fishery trade cooperation countries stabilizes at 20, that is, all countries will choose cooperation; when it increases to 0.3, after three rounds of games, the number of partners stabilizes at 11; when it increased to 0.5, after six rounds of games, the number of partners in the economic and trade network stabilized at 9. Therefore, costs have a negative impact on cooperation; that is, the lower the cost of sustainable fishery production in the context of COVID-19, the more countries will choose to cooperate and the faster the cooperation can be reached.

5.2. The Impact of Social Incentive on Cooperation

Assume that the initial game matrix of the trade cooperation node i, j of the Arctic sustainable fishery trade cooperation countries is $(5, -2; 6, 3)$, the game type is the Prisoner's Dilemma game, and the cost of sustainable fishery production $c = 0.3$. The number of nodes in 2020 is adopted, and the reward $r = 0.3, 0.5, 0.7$, and 0.9 for cooperative behavior given by neighbor nodes are selected, respectively. The simulation results are shown in Figure 5.

In Figure 5, the values of other variables remain unchanged. When the value of the social incentive r is 0.9, after two rounds of games, the number of collaborators in the trade network of Arctic sustainable fishery trade cooperation countries stabilizes at 19. Continue to reduce social incentives; when it is reduced to 0.7, after two rounds of games, the number of partners stabilizes at 18; when it is reduced to 0.5, after two rounds of games, the number of participants stabilized at 15; when it is reduced to 0.3, after two rounds of games, the number of partners in the economic and trade network stabilized at 14. Therefore, social incentives have a positive impact on cooperation, that is, for sustainable fisheries cooperation in the context of COVID-19, the more external incentives that are given, the more countries will choose to cooperate and the faster the cooperation can be reached.

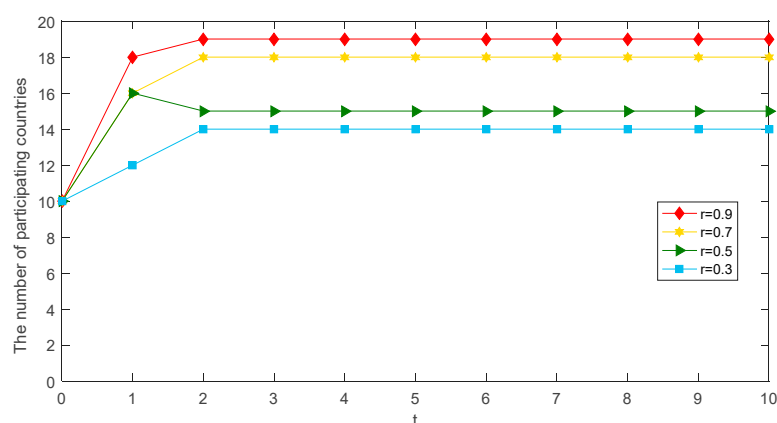


Figure 5. The influence of social incentive on cooperation.

From the analysis of the above two factors, we can see that when the cost increases from 0.1 to 0.5, the number of cooperating countries drops from 20 to 9. When the level of incentives rose from 0.3 to 0.7, the number of countries that cooperated rose from 14 to 18. It can be seen from this that the impact of cost on cooperation is greater than incentives. To achieve cooperation, we should start with reducing costs.

5.3. The Influence of Game Mode on Cooperation

Assume that the cost of sustainable fishery production in Arctic sustainable fishery trade cooperation countries is $c = 0.3$, and the reward for cooperative behavior given by neighboring nodes is $r = 0.7$. The number of nodes in 2020 is adopted, and the Prisoners' Dilemma, the Chicken game, and the Stag Hunt Model are selected, respectively. The game structure is simulated, and the simulation results are shown in Figure 6.

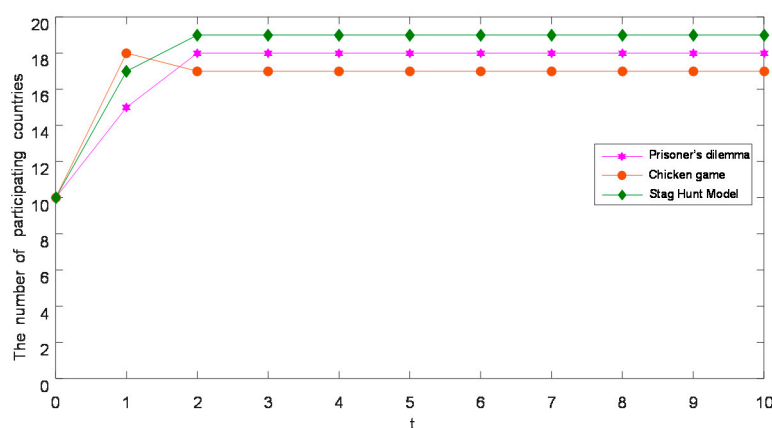


Figure 6. The influence of game structure on cooperation.

In Figure 6, the values of other variables remain unchanged. When the participating countries cooperate based on the Chicken game, after two rounds of the game, the number of partners stabilizes at 17; when the participating countries cooperate based on the Prisoner's Dilemma game during cooperation, after two rounds of games, the number of collaborators in the trade network stabilized at 18. When participating countries cooperate based on the Stag Hunt Model, after two rounds of games, the number of collaborators in the trade network stabilized at 19. Therefore, different game structures have different effects on cooperation. It can be seen that the number of cooperative participating countries based on the Stag Hunt Model is the largest, followed by the Prisoner's Dilemma game, and finally, the Chicken game.

5.4. The Impact of Network Structure Changes on Cooperation

Assuming that the initial game matrix of the trade cooperation nodes i, j of the Arctic sustainable fishery trade cooperation countries is $(5, -2; 6, 3)$, the game type is the Prisoner's Dilemma game, the cost of sustainable fishery production is $v = 0.3$, the neighbor nodes give cooperative behavior Reward $r = 0.7$, and select the number of nodes in 2019 and 2020 and the corresponding binarization matrix for simulation. The simulation results are shown in Figure 7.

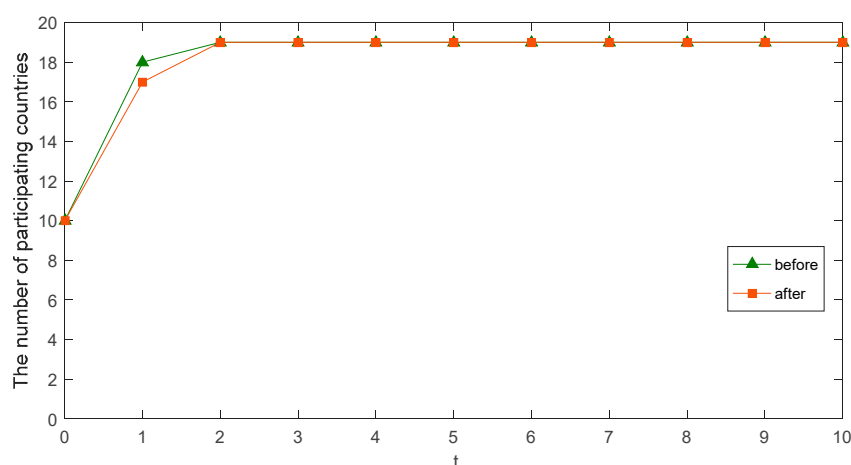


Figure 7. The impact of network structure change on cooperation.

In Figure 7, the values of other variables remain unchanged. It can be seen that the speed of cooperation between countries before and after the epidemic is different. The speed of cooperation before the epidemic is faster than after the epidemic. In the end, after two rounds of games, the number of partners in the trade network stabilized at 19. Therefore, changes in the network structure will have an impact on cooperation, that is, sustainable fisheries cooperation under the background of COVID-19 will slow down the speed of reaching cooperation. However, because the epidemic is a sudden and temporary event, it will only affect cooperation for a short period of time.

6. Discussion

From the simulation results, it can be seen that the sustainable fishery trade cooperation of Arctic sustainable fishery trade cooperation countries is significantly affected by the cooperation cost, incentive policy, game mode, and trade network structure. The greater the social incentive value is the more likely and faster the countries choose to cooperate. The smaller the cooperation cost is, the more likely the countries will choose to cooperate and the faster the cooperation will be achieved. Different game structures have different effects on cooperation. The Stag Hunt Model has the largest number of participating countries, followed by the Prisoner's Dilemma and the Chicken game. COVID-19 will lead to changes in network structure, which will have an impact on cooperation, that is, sustainable fishery cooperation in the context of COVID-19 will slow down the speed of cooperation.

The costs of cooperation will hinder economic and trade cooperation between Arctic sustainable fishery trade cooperation countries. The investment of capital and technical support can provide more guarantees for the Arctic sustainable fishery trade cooperation countries and can encourage these countries to adopt a cooperative attitude, which is conducive to promoting full cooperation. Unpredictable market shocks, such as economic recessions, political instability, trade wars, or natural disasters, are all too common, so it is important to increase financial protection. To promote sustainable fishery cooperation among Arctic sustainable fishery trade cooperation countries, it is necessary to control the cost within a reasonable range and at the same time realize cost recovery and economic recovery by means of economic investment. First, coastal and marine ecosystems should

be rehabilitated, and tourism and recreational fisheries should be strengthened to create jobs. Second, sewage and waste water infrastructure can be expanded to improve water quality related to fisheries production. Third, investing in sustainable, community-led, non-feeding marine culture, such as shellfish, will improve local livelihoods, increase the variety of products that can be produced, and make economies more efficient. Technological innovation also plays an extremely important role in Marine sustainable development. Low carbon transportation is another new technology to realize the sustainable development of the ocean. More than 90% of global cargo is transported by sea, but ships using heavy fuel oil can release coal ash and sulfur into the environment, and reduced carbon dioxide emissions and the decarbonization of transportation can generate 1 trillion dollars to 9 trillion dollars worth of benefits in 30 years, accelerate transition to a low-carbon economy, promote efficiency, and to a certain extent, reduce the shipping department of stranded assets [31]. The Food and Agriculture Organization (FAO) in the latest edition of the world's fisheries and aquaculture status report pointed out that in capture fisheries, by providing more accurate weather forecasts for fishermen and satellite positioning, new products or service innovation can change their activities, making it more safe, more accurate, and more predictable. Moreover, the emerging technologies of the information stored in the collection and security benefit can help to better comply with stricter regulatory and traceability requirements.

Neighbor rewards can promote the evolution of the economic and trade network of Arctic sustainable fishery trade cooperation countries to the direction of cooperation. With COVID-19 becoming the norm, it is difficult for a single country to achieve sustainable development and resolve the current dilemma. International cooperation needs to be strengthened. One of the ways of mutually beneficial cooperation between social organizations and multiple social subjects is the multi-level social participation network. The denser the networks of social participation, the more likely its participants are to cooperate because of their mutual interests. All types of social capital (fishing communities, between groups of fishermen, between fishermen and regulators) are important, and close-knit groups contribute to conflict mitigation and problem resolution [32]. It is impossible to achieve sustainable fisheries only with the strength of Arctic sustainable fishery trade cooperation countries. To ensure the stability of the trade network under the epidemic situation and expand the breadth of the sustainable fishery trade network are the appropriate countermeasures at present. To this end, in the context of COVID-19, countries should support research on the improvement and advocacy of sustainable fisheries; strengthen the position of fisheries both within and outside the field of marine management; provide knowledge exchange on the state of fisheries, with traditional knowledge provided by fishermen and scientific knowledge provided by regulators; and enhance resilience to changes in fisheries and external influences through common management. Countries should further strengthen the improvement of emergency response mechanisms, strengthen the implementation of various preferential policies for enterprises by local governments, make every effort to ensure smooth logistics and customs clearance, build strategic mutual trust, and reduce trade barriers so as to jointly cope with the impact of COVID-19 on fisheries and aquaculture.

The game mode will affect the cooperation between countries, and the Stag Hunt Model is beneficial to the cooperation. The Stag Hunt Model tells us that "cooperation is a win-win situation". Cooperation requires that both parties learn to collaborate with their rivals and fully take into account the interests of their partners. Sustainable fishery cooperation among Arctic sustainable fishery trade cooperation countries is feasible and has a certain practical basis. The first is the existence of a rich, if imperfect, range of rules and regulations, and the frequent meetings of countries to agree on sustainable fisheries management. For example, on 16 July 2015, the five Arctic coastal countries (Canada, the United States, Russia, Norway, and Denmark) signed the Declaration on the Prevention of Irregular High Seas Fishing in the Core Area of the Arctic Ocean. On 1 December 2015, China, Japan, the Republic of Korea, Iceland, and the European Union (EU) held the first round of talks on the establishment of a fisheries management agreement on the high seas of the Arctic Ocean in Washington, DC, USA. At the

2016 meeting, there was a consensus to collaborate on fisheries research, despite disagreements over the timing of exploratory and commercial fishing, decision making, and the legal binding power of fisheries agreements. The above-mentioned countries held another meeting in Iceland from 15–18 March 2017. They reached agreement on most issues and promised to summarize the results of the consultations in the near future. On 3 October 2018, those countries concluded the Agreement in Ilulissat, Greenland [33]. After discussions at several meetings from 2015 to 2018, cooperation on Arctic fisheries management has finally been tentatively reached. Accordingly, it can be seen that fishery cooperation in the Arctic region is feasible and underway, but how to better cooperate still needs to be considered. In addition, each country has a cultural heritage of sustainable development. Taoism, which was born in China, contains ecological thoughts, while European and American countries emphasize ecological criticism. Taoism's main feature are ecological holism, which emphasizes that the overall interests of the ecosystem are of the highest value, and maintaining and protecting the integrity, harmony, stability, balance, and sustainable existence of the ecosystem is the fundamental measure to measure everything [34]. Therefore, countries belonging to the Arctic shipping routes have consensus and basic conditions for the development of sustainable fisheries. Sustainable fishery cooperation requires all countries to continuously uphold the concept of win-win cooperation and establish a large organization including all countries of the Arctic shipping routes to discuss sustainable fisheries management in the Arctic region.

From the actual situation and research conclusions, the change in the network structure will have an impact on cooperation; that is, in the context of COVID-19, the speed of cooperation in sustainable fisheries will be slowed down. However, as the impact of the epidemic on the economy is a shock change, it will only affect the cooperation for a short period of time. The epidemic is a sudden factor for the economy, and in the short term, COVID-19 could have an impact on cooperation. Products related to COVID-19 (such as masks, disinfectants, hand sanitizers, and other pharmaceutical chemicals) may damage aquatic ecosystems, particularly in and around urban areas, and trade disruptions and loss of income may increase the exploitation of more available and less valuable fish. Under COVID-19, countries have taken measures to restrict the movement of people and goods, which has affected the increase of export trade revenue. At the same time, human and material resources have to be spent to deal with health and security issues, which have greatly affected the enthusiasm of countries for cooperation. In the longer term, however, as COVID-19 becomes the norm and countries step up vaccination, the cooperation of countries in the sustainable fisheries trade in the Arctic may return to normal over time. The outbreak of COVID-19 highlights that policy action lags behind the release of data on fisheries and seafood supply, the short-term need to strengthen the monitoring of epidemic information related to fisheries, control and monitoring, and weekly updated public land data, which can provide the production and policy making with scientific and effective information [35]. In addition, countries need to collect data on consumer demand and on the physical fitness of workers in aquatic production on a regular and extensive basis in order to provide important information to policy makers before and during shocks.

7. Conclusions

This article uses a complex network method combined with game theory to discuss the cooperation of Arctic sustainable fishery trade cooperation countries under COVID-19, which is different from previous studies on the Arctic region [36]. The economic and trade cooperation of the Arctic route economic circle is most significantly affected by the cooperation costs of various countries, the incentive policies of each country, the cooperation methods of each country, and the structure of the trade network. The specific conclusions are as follows.

First of all, because the Arctic sustainable fishery trade cooperation countries have certain differences in cultural concepts, economic development levels, and sustainable fishery technology levels, it will be a long-term process for countries to accept and practice the concept of sustainable fishery development. Second, the smaller the cost of cooperation,

the more likely countries are to adopt cooperative strategies. Third, the greater the value of the reward given by neighboring countries, the more countries will adopt cooperative strategies, and the impact of cost on cooperation is greater than the incentives. Fourth, different game structures have different effects on cooperation. The Stag Hunt Model has the largest number of cooperative players, followed by the Prisoner's Dilemma game, and finally the Chicken game. In summary, for sustainable fisheries cooperation in the context of COVID-19, the speed of reaching cooperation will slow down. However, because the epidemic is a short-term, non-traditional security risk, the epidemic will likely only be a sudden factor affecting the trade cooperation status of Arctic sustainable fishery trade cooperation countries in a short period of time. Under the COVID-19 epidemic, countries have taken measures to restrict the movement of people and goods, which has affected the increase of export trade revenue. At the same time, human and material resources have to be spent to deal with health and security issues, which has greatly affected the enthusiasm of countries for cooperation. However, in the longer term, as the COVID-19 becomes normal and countries step up vaccination, cooperation in Arctic sustainable fisheries trade may return to business as usual. This article proposes measures that countries may take to better cooperate in sustainable fisheries development, which will help expand the literature on Arctic fisheries-related cooperation. Future scholars can also explore the mechanisms that make countries better accept sustainable fisheries on the basis of the research in this article. The research scope can be expanded from the Arctic route to other regions. In addition, future scholars can add some baseline scheme to compare the results. For example, compare the data to the year 2000.

This study also has the following limitations: First, although there are many fishing countries along the Arctic route, we only selected those countries with established trade relations. Researchers can try to verify the model by simulation analysis of the whole network in the future; second, there are many factors that affect the cooperation of companies in the trade of Arctic sustainable fishery under COVID-19. Only four of them are discussed in this research, and there may be other factors, such as initiator cooperation ratio and pressure, which are worth exploring in the future.

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Appendix A

Table A1. List of Major Technical Terms.

Term	Explanation
Complex network game	Complex network game is a game based on the definition of network structure, which mainly uses the game rules of complex network to play the game.
Sustainable fisheries	The sustainable development of fisheries refers to the three aspects of the development of ecology, economy, and society in fisheries.
Prisoner's Dilemma game	The prisoner's dilemma is a representative example of non-zero-sum games in game theory, reflecting that the best choice of individuals is not the best choice of groups.
Chicken game	Two chickens have to find out the details of each other through repeated testing of each other's strength, and then they can choose the best strategy, not the strategy of deciding whether to attack or retreat from the beginning.
Stag Hunt Model	The Stag Hunt Model tells us to “cooperate and win-win”, and cooperation requires that both parties in the game learn to win-win with their opponents and fully take care of the interests of the partners.

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