

Cooperative Game Analysis based on Country Size and Market Position

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Abstract

This paper studies the cooperative game theory, and analyzes the cooperative game with international scale and market position. From the perspective of evolutionary game theory, this paper discusses the preconditions for big and small countries to participate in regional economic cooperation and the stability conditions of economic cooperation. This paper combines cooperative game theory with regional economic integration, and the economic and political alliance among countries can be regarded as a cooperative game. In order to analyze the cooperation of member countries, the countries are divided into small countries and big countries according to their size and market position, and the replication dynamic equation is calculated, then the basic conditions of the strategy of big countries and small countries participating in regional economic alliance are obtained, and the strategy selection probability of participants under the conditions of equilibrium strategy and non-equilibrium strategy is analyzed. In addition, using evolutionary game theory and Jacobian matrix to analyze the stability of local equilibrium point, a reciprocal game model of regional economic cooperation between big and small countries is established. Through the research, it is found that the necessary condition for the formation of regional economic integration is the economic complementarity among the cooperative parties, and the sufficient condition is that the cooperative parties can coordinate the distribution of interests among themselves through effective consultation and finally reach a binding agreement on the distribution of interests, thus restricting each other's economic behavior.

Keywords

Cooperative Game; Regional Economic; Comparative Advantage; Economic Integration.

1. Introduction

Since the 1950s, the regional economic cooperation represented by the European Community has swept across the world. Since the establishment of the WTO, regional economic cooperation has been greatly accelerated. According to WTO statistics, up to January 2004, among the 293 regional economic cooperation arrangements notified to WTO, 58% were notified after the establishment of WTO; Of the 197 regional economic cooperation arrangements in operation, a quarter have been established after the establishment of WTO. Before the establishment of WTO, about three or four regional economic cooperation organizations were established every year in the world, while after the establishment of WTO, 15 regional economic cooperation organizations were established every year on average.

All the hustle and bustle of the world are for profit; all the hustle and bustle of the world are for profit. In the process of globalization, every country and citizen is bounded rationality. In the face of the sluggish international trade, the decline in international investment and the social inequality caused by the unfair distribution of world interests after 2008, the political balance formed in the past is also shifting, and trade protectionism and anti-globalization forces are on the rise. Take the European Union, the world's largest political and economic community, for

example. The narrow victory in the Brexit referendum in 2016 can be regarded as the first wave of anti-globalization. In addition, the United States has directly announced its withdrawal from the global multilateral mechanism. Nowadays, trade protectionism is on the rise. It is of great significance to study the stability of regional cooperation between big countries and small countries in the alliance for exploring the establishment of global regional partnership.

2. Stability Analysis of Member States by Country Size

The trend of globalization is unstoppable, but the construction of cooperation mechanism among countries is not in one step, but in the process of game, strategy adjustment is carried out continuously until a stable equilibrium structure is formed. Regional integration is the only way to achieve globalization, and European integration is the deepest and most extensive form of regional integration. In order to promote peace, pursue a prosperous life for its citizens, realize sustainable social and economic development, ensure basic values and strengthen international cooperation, the EU was originally developed from the European Community. Now it has 27 member states and has become a large-scale international organization for regional economic cooperation in Europe. The EU has not developed a stable partnership of member states so far.

2.1. Analysis of Representatives of Small Countries Within the EU

On January 1, 1981, Greece formally joined the European Community and became the tenth member state of the European Community. Free trade means that goods and services can compete in any part of the market, and that factors of production can be moved to where they can be used more efficiently-not just within countries, but between countries. The ultimate goal of the original advocates of European cooperation was some form of political union. Western Europe speaking with a single voice can add weight to its dealings with other major powers. In addition, defense capabilities and strategic integration would provide greater security for member states, benefits that more than compensate for any loss of sovereignty. The EU also uses a single currency. For its member states, the EU also provides loans to them, which can provide financial help to some small countries within the EU.

2.2. Analysis of Representatives of Major Powers within the EU

Take Britain--former member of the European Union--as an example. Brexit is mainly affected by the immigration problem. As an old developed capitalist country, Britain provides high welfare for its residents. However, there is a big gap in the strength of the member states within the EU. In addition, the EU also stipulates that citizens of the member states can work and live in the member states, which will lead to too many British immigrants, thus affecting the employment of local residents. According to the data, 333,000 people emigrated to Britain in 2017 alone, accounting for 0.5% of the total population of 60 million. As far as Britain is concerned, from the perspective of interests, Britain is a developed economy within the EU, and the EU stipulates that developed economies should pay a large sum of membership fees to the EU every year. Obviously, joining the EU will bring greater welfare burden to themselves, affecting the employment of their own country, and may be affected by more refugees in the future. Brexit has obviously become the choice of the British people.

Germany is a developed manufacturing industry, a big country in foreign trade, and also a big country in capital export in the world. The quality and quality of commodities and manufactured goods are well-known in the world. Because the EU pursues the policy of low tariff and unified currency, it has made a lot of profits. The EU has brought a market with a population of 340 million to it. In addition, although the European Union has 27 member states in name, France and Germany are the two countries with the largest voice in the EU. Rather than leaving the EU, Germany would clearly benefit more from remaining in the EU as a

dominant voice, controlling the spending of other member states, and supplying them with highly competitive products from their home countries.

3. Cooperative Game Framework

The reasons for regional economic cooperation in previous literature can be summarized as follows: (1) The cooperation comes from the historical basis of multilateral or bilateral agreements; (2) From the common culture and social system, such as the cooperation among Commonwealth countries; (3) the impact of economic integration caused by geographical proximity, such as the free trade agreement between the Americas and Mexico; (4) The interaction of ideological or other non-economic factors. For example, Cuba is geographically far away from Eastern European countries, but because of the same ideology, it has also joined the economic union organization. This paper combines cooperative game theory with regional economic integration, and the economic and political alliance among countries can be regarded as a cooperative game. Competition and cooperation coexist, competition is a means, cooperation is an end, countries in the pursuit of maximum interests at the same time also produced conflicts of interest, and the economic complementarity and mutual benefit between countries promote the deepening of economic and trade ties between them.

Evolutionary game theory originated from the game analysis of conflict and cooperation between animals and plants by genetic ecologists such as Fisher and Hamilton. They found that the evolutionary results of animals and plants can be explained by game theory in most cases without relying on any rational assumptions. However, it was not until Smith and Price (1973) put forward the concept of evolutionary stable strategy in their creative paper that the theory of evolutionary game was formally born. The ecologists Taylor and Jonker (1978) first put forward the basic dynamic concept of evolutionary game theory—replicator dynamic when investigating the phenomenon of ecological evolution, which is another breakthrough development of evolutionary game theory. The imitator dynamics and evolutionarily stable strategy (RD&ESS) are the core concepts of evolutionary game theory. They represent the stable state and the dynamic convergence process of evolutionary game respectively. The expansion and dynamics of ESS are the main contents of evolutionary game theory. Evolutionary game theory is different from traditional game theory. It is based on incomplete rationality and from the perspective of dynamic evolutionary process, it believes that individuals with limited rationality in groups will imitate the most favorable strategy adopted by their peers and eventually reach evolutionarily stable strategies. It means that when most members of the population adopt a certain strategy, there is no strategy with mutation characteristics that can affect the stability of the population under the action of natural selection.

3.1. Basic Assumptions

In the alliance between big countries and small countries, it is assumed that the basic benefits of big countries are B_0 ; the costs brought by active cooperation B_1 , including but not limited to actively assuming the responsibilities of big countries and providing support and supervision for cooperative organizations. The benefits brought by active cooperation B_2 , the basic benefits refer to the benefits of economic and trade cooperation obtained from participating in cooperation; In the alliance, if small countries also participate in the alliance, big countries can gain benefits from small countries B_3 . Small countries have no pricing power in the face of international commodities, and only the commodities exported following the status of big countries lose part of their price advantage.

Assume that the basic benefits of small countries are S_0 ; the costs of active cooperation S_1 , including but not limited to actively following the big countries and providing support for cooperative organizations and regulatory measures; The economic and trade cooperation

benefits obtained by participating in the cooperation S_2 ; if the big countries also participate in the alliance, the small countries have no pricing right in the face of international commodities, and some of the benefits will be S_3 seized by the big countries. Therefore, in summary, the payment matrix of both parties is shown in Table 1:

Table 1. Payment Matrix

		Small country	
		Participation in coalitions	Not participating in the alliance
Great power	Participation in coalitions	$(B_0 - B_1 + B_2 + B_3, S_0 - S_1 + S_2 - S_3)$	$(B_0 - B_1 + B_2, S_0)$
	Not participating in the alliance	$(B_0, S_0 - S_1 + S_2)$	(B_0, S_0)

3.2. Evolutionary Stable Strategy Analysis

3.2.1. Analysis on the Evolution Stability of Great Powers

Suppose that the proportion of the major powers in the alliance at the initial time is x , the proportion of non-participation strategy is $1-x$, the proportion of small countries participating in the alliance at the beginning is y , and the proportion of non-participation in the alliance is $1-y$, from which we can see that the benefits of alliance and non-alliance are respectively U_{b1} and U_{b2} with an average expected return of U_b . They are:

$$U_{b1} = y(B_0 - B_1 + B_2 + B_3) + (1-y)(B_0 - B_1 + B_2) \quad (1)$$

$$U_{b2} = yB_0 + (1-y)B_0 \quad (2)$$

$$U_b = yU_{b1} + (1-y)U_{b2} \quad (3)$$

Therefore, the replication dynamic equation of great power strategy is:

$$F(x) = dx/dt = x(U_{b1} - U_b) = x(1-x)(yB_3 + B_2 - B_1) \quad (4)$$

$$F'(x) = (1-2x)(yB_3 + B_2 - B_1) \quad (5)$$

Let $F(x) = 0$, we obtain the steady-state points of the great-power strategy replication dynamics equation as: $x^* = 0$ and $x^* = 1$.

(1) When $y = y^* = \frac{B_1 - B_2}{B_3}$, $F(x)$ it is always 0, which means that all x levels are the stable state

of the big countries. It can be seen that when the small countries $y = y^* = \frac{B_1 - B_2}{B_3}$ choose to cooperate at the level of, the benefits of the big countries choosing to participate in the alliance or not to participate in the alliance are no different.

(2) When $y \neq y^* = \frac{B_1 - B_2}{B_3}$, $x^* = 0$ or $x^* = 1$ are two stable states. When $yB_3 + B_2 - B_1 > 0$, that is $y > \frac{B_1 - B_2}{B_3}$, because $F'(1) < 0$, it $x^* = 1$ is evolutionarily stable. It can be seen that when y certain conditions are met, big countries will change from not participating in regional economic union to participating in regional economic union. When $yB_3 + B_2 - B_1 < 0$, that is $y < \frac{B_1 - B_2}{B_3}$, because

$F'(0) < 0$, it $x'=0$ is evolutionarily stable. It can be seen that when y certain conditions are met, the big countries will change their strategy from participating in regional economic union to participating in regional economic union.

3.2.2. Analysis of the Evolutionary Stability of Small States

The benefits of small countries in alliance and non-alliance are respectively U_{s1} and U_{s2} with an average expected return of U_s . They are:

$$U_{s1} = x(S_0 - S_1 + S_2 - S_3) + (1-x)(S_0 - S_1 + S_2) \quad (6)$$

$$U_{s2} = xS_0 + (1-x)S_0 \quad (7)$$

$$U_s = yU_{s1} + (1-y)U_{s2} \quad (8)$$

So the replication dynamics of the small state strategy are:

$$F(y) = dy/dt = y(U_{s1} - U_s) = y(1-y)(-xS_3 + S_2 - S_1) \quad (9)$$

$$F'(y) = (1-2y)(-xS_3 + S_2 - S_1) \quad (10)$$

Let $F(y) = 0$, we obtain the steady-state points of the great-power strategy replication dynamics equation as: $y^* = 0$ and $y^* = 1$.

(1) $x = x^* = \frac{S_2 - S_1}{S_3}$ When established, it $F(y)$ is always 0, which means that all y levels are stable

for small countries. It can be seen that when large countries choose to $x = x^* = \frac{S_2 - S_1}{S_3}$ cooperate at the level of, the benefits of small countries choosing to participate in the alliance or not to participate in the alliance are no different.

(2) When $x \neq x^* = \frac{S_2 - S_1}{S_3}$, $y'=0$ or $y'=1$ are two stable states. When $-xS_3 + S_2 - S_1 > 0$, that is

$x < \frac{S_2 - S_1}{S_3}$, because $F'(1) < 0$, it $y'=1$ is evolutionarily stable. It can be seen that when x certain

conditions are met, the small countries will not participate in the regional economic union to participate in the regional economic union strategy. When $-xS_3 + S_2 - S_1 < 0$, that is $x > \frac{S_2 - S_1}{S_3}$,

because $F'(0) < 0$, it $y'=0$ is evolutionarily stable. it can be seen that when x certain condition are met, small countries will turn from participate in regional economic union to refusing to participate in regional economic union.

3.2.3. Stability Conditions of Evolutionary Model of Related Agent's Policy

The five equilibrium points of the equation are A (0, 0), B (1, 0), C (0, 1), D (1, 1) and E (x^* , y^*)

$x^* = \frac{S_2 - S_1}{S_3}$ $y^* = \frac{B_1 - B_2}{B_3}$. The Jacobian matrix of the replicating dynamic equations for the large

and small country strategies is:

$$J = \begin{bmatrix} \frac{\partial F(x)}{\partial x} & \frac{\partial F(x)}{\partial y} \\ \frac{\partial F(y)}{\partial x} & \frac{\partial F(y)}{\partial y} \end{bmatrix} = \begin{bmatrix} (1-2x)(yB_3 + B_2 - B_1) & x(1-x)B_3 \\ -y(1-y)S_3 & (1-2y)(-xS_3 + S_2 - S_1) \end{bmatrix} \quad (11)$$

The stability analysis of local equilibrium point of Jacobian matrix of the system is conducted, and the results are shown in Table 2.

Table 2. Stability Analysis of Local Equilibrium Points

equilibrium point	$\det.J$	$\text{tr}.J$
A(0,0)	$(B_2 - B_1)(S_2 - S_1)$	$B_2 - B_1 + S_2 - S_1$
B(1,0)	$(B_1 - B_2)(-S_1 + S_2 - S_3)$	$B_1 - B_2 - S_1 + S_2 - S_3$
C(0,1)	$(-B_1 + B_2 + B_3)(S_1 - S_2)$	$-B_1 + B_2 + B_3 + S_1 - S_2$
D(1,1)	$(B_1 - B_2 - B_3)(S_1 - S_2 + S_3)$	$B_1 - B_2 - B_3 + S_1 - S_2 + S_3$
$E(x^*, y^*)$	0	0

For D(1,1) to be stable, we need to satisfy the condition $\det.J > 0$ and $\text{tr}.J < 0$.

When $B_1 - B_2 - B_3 > 0$, then $S_1 - S_2 + S_3 > 0$, due to $\text{tr}.D > 0$. In order to make D(1,1) a stable strategy, we must make $B_1 - B_2 - B_3 < 0$, and $S_1 - S_2 + S_3 < 0$. In this case, to determine whether point D is the only stable point, we need to observe the stability of point ABC. J and $\text{tr}.J$ of ABC are determined by mathematical derivation $B_1 - B_2$ and $S_1 - S_2$. The positive and negative. There are four cases as follows:

① $B_1 - B_2 > 0$, and $S_1 - S_2 > 0$ the stability analysis results are shown in Table 3.

Table 3. Results of sub-conditional stability analysis

equilibrium point	$\det.J$	$\text{tr}.J$	stability
A(0,0)	+	−	ESS
B(1,0)	+	+	unstable
C(0,1)	+	+	unstable
D(1,1)	+	−	ESS
$E(x^*, y^*)$	0	0	unstable

② $B_1 - B_2 > 0$, and $S_1 - S_2 < 0$ the stability analysis is shown in Table 4.

Table 4. Results of conditional stability analysis

equilibrium point	$\det.J$	$\text{tr}.J$	stability
A(0,0)	−	$\pm$	unstable
B(1,0)	+	+	unstable
C(0,1)	−	$\pm$	unstable
D(1,1)	+	−	ESS
$E(x^*, y^*)$	0	0	unstable

③ $B_1 - B_2 < 0$, and $S_1 - S_2 > 0$ the stability analysis is shown in Table 5.

Table 5. Stability analysis results of sub-condition

equilibrium point	$\det.J$	$\text{tr}.J$	stability
A(0,0)	−	$\pm$	unstable
B(1,0)	−	$\pm$	unstable
C(0,1)	+	+	unstable
D(1,1)	+	−	ESS
$E(x^*, y^*)$	0	0	unstable

④ $B_1 - B_2 < 0$, and $S_1 - S_2 < 0$ the stability analysis is shown in Table 6.

Table 6. Results of conditional stability analysis

equilibrium point	det. J	tr. J	stability
A(0,0)	+	+	unstable
B(1,0)	–	$\pm$	unstable
C(0,1)	–	$\pm$	unstable
D(1,1)	+	–	ESS
E(x^*, y^*)	0	0	unstable

As shown in the table above, there are two stable points A and D in case 1, which indicate that at $B_1 - B_2 > 0$, and $S_1 - S_2 > 0$, both big and small countries do not participate in cooperation and participate in cooperation may become stable points. But in case 2、3 and 4, there is only one stable point in point D, which indicates that there is only one stable deduction point between big country and small country D, that is, regional economic cooperation.

Thus, in order for D to be the only ESS point, the following conditions must be satisfied simultaneously:

$B_1 - B_2 \leq 0$ or $S_1 - S_2 \leq 0$ That is to say, for big countries and small countries, at least one party's basic benefits from participating in regional economic cooperation should be greater than the costs brought by participating in cooperation, so as to constitute the possibility of transnational economic and trade cooperation willingness, emerge an advocate of regional economic cooperation, and reach consistency in economic and political policies.

$B_3 - B_1 - B_2 > 0$ That is to say, for big countries, in order to make the two sides cooperate efficiently to form regional alliances, the sum of the cooperation benefits obtained by big countries and the benefits obtained from small countries should be higher than the cost of actively promoting cooperation, so as to make the alliance stable.

$S_2 - S_1 - S_3 > 0$ that is to say, for small country, in order to make that two side cooperate efficiently to form regional alliance, the benefits obtained by forming alliance between small country and big country should be higher than the cost of active cooperation and the partial loss of benefits grabbed by big countries, so that small countries can join the alliance and have stable regional economic partnership.

Take the European Union as an example. The predecessor of the European Union was the European Community. In September 1946, United Kingdom Prime Minister Winston Churchill proposed the establishment of a "United States of Europe." On 9 May 1950, Robert Schuman (1886 - 1963), then France Foreign Minister, proposed the establishment of a European Coal and Steel Union on behalf of the French government. The initiative was echoed by France, Germany, Italy, the Netherlands, Belgium and Luxembourg, which jointly established the European Community. After 1973, United Kingdom, Denmark, Ireland, Greece, Spain and Portugal joined the European Community successively, and its member countries expanded to 12. It can be seen that the first country to propose the alliance must be the country with relatively developed economy in the organization, meeting the first condition in the conclusion. By 2020, United Kingdom will formally leave the European Union. For Britain, continuing to join the European Union will make Britain not much profit, and the immigration problem and the loss of monetary autonomy make the development speed of Britain 's native economy slow, so Britain at this time is far from reaching the second condition.

It can be said that the first condition is the prerequisite for the emergence of the alliance, while the second and third conditions are related to the stability of the alliance. For countries with close geographical or political distance and close economic ties, if they want to form regional economic cooperation, they should pay more attention to condition 1, while existing alliances

such as European Union and other organizations should pay more attention to conditions 2 and 3. The interests of big countries and small countries should be obtained, and reasonable interest transfer policies should be set up when necessary to ensure that each participant can obtain due interests and jointly maintain the stability of transnational alliances.

4. Conclusion

The necessary condition for the formation of regional economic integration is the economic complementarity among the cooperative parties, and the sufficient condition is that the cooperative parties can coordinate the distribution of interests among themselves through effective consultation and finally reach a binding agreement on the distribution of interests, thus restricting each other's economic behavior. Regional economic cooperation that meets these conditions will certainly bring greater benefits to all members than they can obtain without cooperation. In addition, large and small countries have different positions in transnational cooperation. Since countries with a lower level of economic development generally use high tariffs to protect their industries, they cannot compete with countries with a higher level of development within integration organizations when applying tariff preferences or concessions. For small countries, joining the alliance will make them lose part of their sovereignty, weaken the price advantage of their own products, and make the benefits not as good as those gained by big countries in the alliance. For big countries, if they join the alliance, they can not only gain the basic benefits brought by participating in the cooperative alliance, but also grab some benefits from small countries, such as opening up the internal markets of small countries through tariff reduction and exemption. However, no matter big or small, the condition for the emergence of an alliance must be that there is a profitable situation on either side to promote the emergence of an alliance as much as possible.

The difference of benefits between big and small countries in the alliance comes from the influence of their own economic status, so we can design the benefit compensation mechanism. As far as possible, attract those countries that have greater positive externalities to other countries to participate in regional economic cooperation. Through effective consultation, the cooperative parties can establish an interest balance mechanism, so that the members who benefit less from cooperation can be convinced that temporary gains and losses can be compensated by long-term stable cooperation, while the members who benefit more will voluntarily promise certain concessions for the interests of other members in some aspects. In other words, in the long run, a stable economic cooperation will give all partners a roughly equal share of the benefits.

No country exists in isolation. At the same time, it is impossible for all goods to have a comparative advantage. Economic cooperation means that developed countries need to buy raw materials and sell products in developing countries. Developing countries need to import capital, equipment, advanced production technology and management expertise from developed countries, and buy some products that are difficult to produce at home. Only in this way can countries gradually narrow their differences in various fields and retain their place in the world, so that they will not fall further behind and be carved up. Therefore, international cooperation must be strengthened for their own good. Regional economic cooperation has not come easily. The global economy is weak against the backdrop of the COVID-19 pandemic. As for the regional cooperation organizations that have taken shape, we should strive to maintain their stability. As for the regional cooperation that has yet to take shape, we should seek common ground while shelving differences and aim for global economic stability and development.

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