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The international cooperative relationship model based on social network analysis and game theory

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ABSTRACT

This article regards international cooperative trade as a typical organisational cooperation paradigm and behavioural process. The correlation characteristics between multinational enterprises were studied using dynamic game theory. The focus was on resource dependence and collaborative relationships between different types of enterprises. Cooperation and mutual confrontation are game strategies of international industry collaboration organisations. The expected returns, resource dependence, and realistic collaboration costs determine the final consequences of strategic evolution. Resource dependence affects the rate at which the behavioural decisions adopted by participants tend to reach equilibrium strategies. The diversity of collaborations between firms makes strategic evolution more complex. Finally, this article provides relevant suggestions on international cooperative relations based on social network analysis and game theory.

KEYWORDS International cooperative trade; cooperation diversification; game theory; resource dependence; social network analysis
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1. Introduction

The Swedish National Research Institute awarded Robert Mundel, who is an outstanding economist from Columbia University in the United States, the 1999 Nobel Prize in Economics. Mundel is the only person to win the Nobel Prize in Economics since the 20th century. Mundel's achievements include balance of payments equilibrium, capital flow, and stability issues under floating exchange rate systems. He also researched monetary and financial policies and optimal currency areas under various exchange rate systems. Mundel had already established a comparative theory on trade and investment in 1957 (Saleh, 2021). Mundell made assumptions about this: (1) Country X has relatively high financial resources, while Country Y has relatively high human resources; (2) Both countries have their comparative advantages. Among them, country X mainly produces capital-intensive commodity A, while country Y mainly manufactures labour-intensive commodity B; and (3) The output functions of the two countries are the same. In the case of free trade, different factors of production can flow freely between the two countries - Country X exports commodity A, and Country Y exports commodity B. When the international balance of payments equilibrium is reached, the factor rates of return on capital and labour in the two countries are equal, so there is no cross-border flow of international capital. But if the two countries have barriers, such as tariff barriers and industrial barriers, the situation changes. Assume that country Y imposes high tariffs on product A imported from country X, which will inevitably increase the price of product A in country X, thereby promoting the growth of the production scale of product A in country Y. As the domestic demand for the capital factors required to manufacture product A increases, this causes the price of the capital factors in country Y to increase (Bhargava et al., 2021). This increases the capital factor rate of return in country Y. Attracted by the high-yield capital factor, funds from country X will inevitably flow to country Y in various forms. Whether through direct or indirect investment, the output of product A in country Y will be significantly improved. Generally speaking, the total production of country If country Y's demand for category A products does not change, then domestic Y's imports of category A products from country X will also decrease accordingly. This means that international capital flows ultimately replace international trade as a result.

The first person to challenge Professor Mundell's trade and investment substitution model was Professor Kiyoshi Kojima of Hitotsubashi University in Japan. From the late 1970s to the mid-1980s, Kiyoshi Kojima published a large number of articles on international direct investment and international trade. Kiyoshi Kojima emphasised the important role of the principle of the international division of labour, and believed that the international division of labour can explain both international trade and international direct investment. Therefore, international direct investment and international trade can be unified on the basis of the principle of the international division of labour. Unlike Mundell, Kiyoshi Kojima replaced the labour and capital factors in the traditional model with labour and business resources. Therefore, international direct investment is no longer a simple capital flow, but a comprehensive transfer of capital, technology, business management, and human capital.

2. Method

This article first sets the relevant parameters of the network evolution game model. The income and stable cooperation strategy of transnational cooperative organisations based on the income function are derived. Parameter simulations use network evolution strategies to reveal the effects of resource dependence, cooperation diversification, and other factors on the steady-state policy formulation and convergence of my country's transnational cooperation organisations, theoretically revealing the internal mechanisms and laws of evolving collaborative relationships between multinational enterprises. The network evolution game theory model architecture is shown in Figure 1.

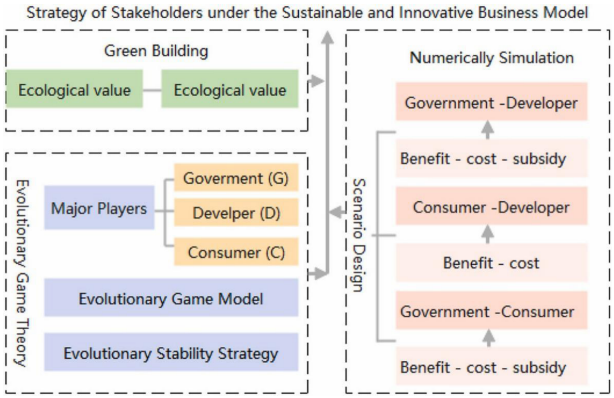

Figure 1. Network evolution game theory model architecture.

It is assumed that China and foreign countries have formed collaborations in multiple industries and obtained sufficient heterogeneous benefits through cross-border collaborations. It is also assumed that members in the initial collaboration contract cannot freely determine the end of the collaboration relationship, nor can they change the collaboration goals (Sengar, 2021). Members decide whether to adopt a collaborative or hostile strategy based on the size of their interests in the collaboration. The so-called "joint strategy" means that during the cooperation process, the two companies can maintain relatively harmonious cooperation, and both take action to obtain more benefits, thus bringing the cooperation between the two companies into a relatively stable stage. Countermeasures refer to the fact that one party will reduce its investment when distrust and conflict arise between two people because the income expectations are not met or the other party's behaviour is believed to have harmed one's interests. Such relationships can become unstable. Secondly, it is assumed that behaviour is entirely measurable and that one's strategies and efforts will change in response to the other party's behaviour. It is recommended to use the initial possibility of cooperative intervention to characterise the degree of dependence of an enterprise on its partners before the willingness of both parties to cooperate is formed (Bentley et al., 2021). A high possibility of initiating involvement means that one party finds itself more dependent on the other party's resources and thus becomes more actively involved in the collaboration. This article can assume that the action strategy ratio of the two participants is as follows: the possibility of Organisation 1 adopting a collaborative strategy is α, and the possibility of adopting countermeasures is 1-α; however, the possibility of Organisation 2 adopting a cooperative strategy is β, and the possibility of countermeasures, Sex, is 1-β and has $0 \leq \alpha$, $\beta \leq 1$. The distribution of interests among enterprises under various circumstances is shown in Table 1 below.

Table 1. Benefit matrix of international cooperative trade organisations.

Organisation 1	Organisation 2	
	confrontation	cooperation
confrontation	$S_1+\gamma_1(W_{21}A_{21}-W_{22}A_{22})$ $S_2+\gamma_2(E_{21}B_{21}-E_{22}B_{22})$	$S_1+\gamma_1(W_{21}A_{21}-W_{22}A_{22})$ $S_2+\gamma_2(E_{21}B_{21}-E_{22}B_{22})-H_2$
cooperation	$S_1+\gamma_1(W_{21}A_{21}-W_{22}A_{22})-H_1$ $S_2+\gamma_2(E_{21}B_{21}-E_{22}B_{22})$	$S_1+\Delta S_1+\gamma_1(W_{11}A_{11}-W_{12}A_{12})-H_1$ $S_2+\Delta S_2+\gamma_2(E_{11}B_{11}-E_{12}B_{12})-H_2$

S_1 represents the essential return based on Organisation 1's collaborative strategy. S_2 represents Organisation 2's essential revenue from the collaborative strategy (Rohde et al., 2021). Among them, H_1, H_2 is the price that Organisation 1 and Organisation 2 need to pay under the cooperation strategy. Among them, γ_1, γ_2 is the discount coefficient of the future income of Organisation 1 and Organisation 2. ΔS_1 represents that both Organisation 1 and Organisation 2 adopt a cooperative strategy in the game in a particular area. Then, Organisation 1 receives more income because it adopts a collaborative strategy. If Organisation 2 adopts a hostile strategy, then Organisation 1 cannot obtain more profits. ΔS_{21} represents that Organisations 1 and 2 adopted a collaborative strategy in a particular regional game, and then Organisation 2 obtained excess income and satisfied the uniqueness of additional income. W_{11} is the likelihood of positive network effects of Organisation 1's collaborative strategy (Aichner et al., 2021). W_{12} is the possibility of a negative impact on Organisation 1's collaboration strategy. W_{21} is the possibility of positive network effects of Organisation 1's countermeasures. Among them, W_{22} is the possibility of the negative impact of Organisation 1's countermeasures. E_{11} is the possibility of positive network effects of Organisation 2's collaborative strategy. E_{12} represents the possibility of Organisation 2's collaboration strategy harming the network. E_{21} is the possibility of positive network effects of Organisation 2's countermeasures. E_{22} is the possibility of a negative impact of Organisation 2's countermeasures (Coe et al., 2022).

A_{11} represents the positive network effect generated under Organisation 1's collaborative strategy. $-A_{12}$ is the revenue generated by Organisation 1's adverse network effects in the collaborative strategy. Among them, A_{21}

represents the interests of Organisation 1 when generating positive network effects under the competition mechanism (Klerkx, 2021). $-A_{22}$ represents the negative network effect of Organisation 1 in its anti-competitive strategy. B_{11} represents the benefits of positive network effects in Organisation 2's collaborative strategy. $-B_{12}$ represents the benefits of adverse network effects in Organisation 2's collaborative strategy. Among them, B_{21} represents the benefits generated by Organisation 2 under the active network effect. $-B_{22}$ represents the benefit of adverse network effects that arise when Organisation 2 takes countermeasures. Secondly, enterprises' expected income changes under different strategic models were analysed. For Organisation 1, its expected revenue G_α when it adopts the collaborative strategy is:

$$\begin{aligned} G_\alpha &= \beta[S_1 + \Delta S_1 + \gamma_1(W_{11}A_{11} - W_{12}A_{12}) - H_1] \\ &+(1-\beta)[S_1 + \gamma_1(W_{21}A_{21} - W_{22}A_{22}) - H_1] \end{aligned}, \quad (1)$$

where γ_1 represents the discount factor for Organisation 1 on its future income, and γ_2 represents the network discount factor for Organisation 1's future revenue (Yeganeh, 2021). The expected return, $G_{1-\alpha}$, when Organisation 1 adopts the countermeasures is:

$$G_{1-\alpha} = \beta[S_1 + \gamma_1(W_{21}A_{21} - W_{22}A_{22})] + (1-\beta)[S_1 + \gamma_1(W_{21}A_{21} - W_{22}A_{22})]. \quad (2)$$

Organisation 1's expected average return when making strategic choices is:

$$\overline{G_1} = \alpha G_\alpha + (1-\alpha)G_{1-\alpha}. \quad (3)$$

The copy dynamics equation of the possibility of Organisation 1 choosing strategy α is:

$$\begin{aligned} R(\alpha) &= \frac{\Delta\alpha}{\Delta t} = (1-\alpha)(G_{1-\alpha} - \overline{G_1}) = \\ &\alpha(1-\alpha)\{\beta[\gamma_1(W_{11}A_{11} - W_{12}A_{12}) - \gamma_1(W_{21}A_{21} - W_{22}A_{22}) + \Delta S_1] - H_1\} \end{aligned}. \quad (4)$$

When Organisation 2 adopts the "confrontation" strategy, the expected revenue, G_β, is:

$$G_\beta = \alpha[S_2 + \gamma_2(E_{21}B_{21} - E_{22}B_{22})] + (1-\alpha)[S_2 + \gamma_2(E_{21}B_{21} - E_{22}B_{22})]. \quad (5)$$

The expected return, $G_{1-\beta}$, of Organisation 2 under the cooperation strategy is:

$$\begin{aligned} G_{1-\beta} &= \alpha[S_2 + \Delta S_2 + \gamma_2(E_{11}B_{11} - E_{12}B_{12}) - H_2] + \\ &(1-\alpha)[S_2 + \gamma_2(E_{21}B_{21} - E_{22}B_{22}) - H_2] \end{aligned}. \quad (6)$$

In addition, for the possibility, α, of the strategy selected by mechanism 2, its copy dynamic equation is:

$$\begin{aligned} R(\beta) &= \frac{\Delta\beta}{\Delta t} = (1-\beta)(G_{1-\beta} - \overline{G_2}) = \\ &\beta(1-\beta)\{\alpha(E_{11}B_{11} - E_{12}B_{12}) - \gamma_2(E_{21}B_{21} - E_{22}B_{22}) + \Delta S_2] - H_1\} \end{aligned}. \quad (7)$$

This article proposes that the game model does not make strict distinctions between the Chinese and foreign nature of organisations (Ubaedillah et al., 2021). It only identifies differences among cooperating participants based on the differences in resource requirements and cooperation revenue structures. Currently, the cooperation possibilities, α and β, both comply with the symmetry restrictions, so only the decision of a single mechanism will be studied below. The system's stability theory gives the strategy's equilibrium point under various parameter constraints.

$[S_1 + \gamma_1(W_{11}A_{11} - W_{12}A_{12}) - H_1, -\gamma_1(W_{21}A_{21} - W_{22}A_{22})] < 0$. Equation (4) has two equilibrium points $\alpha_1 = 0$ and $\alpha_2 = 1$. Here, $\alpha_1 = 0$ is the stepwise stable point, and $\alpha_2 = 1$ is the saddle point. If the IAC company predicts that the expected revenue discount after executing the countermeasures is 0, the sum of the discount on its additional revenue and network effects after executing the countermeasures is lower than its initial synergy cost. At this point, the organisation's multi-domain collaboration will have adverse network effects (Alvarez-Rodriguez et al., 2021). The organisation's strategy will focus on $\alpha_1 = 0$, and the countermeasures will become a more favourable strategy.

If $[S_1 + \gamma_1(W_{11}A_{11} - W_{12}A_{12}) - H_1, -\gamma_1(W_{21}A_{21} - W_{22}A_{22})] > 0$, there are two equilibrium points, $\alpha_1 = 0$ and $\alpha_2 = 1$, in equation (4), and their stable points are determined by the sign of $\beta - \beta_0$. First, it is assumed that the cooperation starting probability, β_0, among members reflects the difference in resource dependence among the members (Hudders et al., 2021). The degree of interdependence among the members will increase their initial cooperation intention, thereby prompting them to converge on the $\alpha_2 = 1$ cooperation strategy. Its long-term evolution will show a tendency to confront or collaborate, mainly determined by the intention to cooperate among its internal members. The initial resource dependence and resource complementarity between enterprises are the main limiting variables that affect the direction of collaboration between enterprises, while the collaboration mechanism between enterprises is the core element that affects the collaboration between enterprises.

If $\Delta S_1 + \gamma_1(W_{11}A_{11} - W_{12}A_{12}) - H_1 > 0$ and $-\gamma_1(W_{21}A_{21} - W_{22}A_{22}) < 0$ hold, then equation (4) has two equilibrium points, $\alpha_1 = 0$ and $\alpha_2 = 1$, (Nambisan et al., 2021). Here, $\alpha_1 = 0$ is a gradually increasing stable point, while $\alpha_2 = 1$ is not. However, equation (4) at time $\Delta S_1 + \gamma_1(W_{11}A_{11} - W_{12}A_{12}) - H_1 > |-\gamma_1(W_{21}A_{21} - W_{22}A_{22})|$ can have two equilibrium points, $\alpha_1 = 0$ and $\alpha_2 = 1$, or an infinite number of equilibrium points. The sign of $\beta - \beta_0$ is used to determine the stability of the equilibrium point.

3. Results

The cross-regional collaboration among departments depends on the degree of interest spillover between regions. If the degree of correlation within the scope of coordination is high, then the effect of behavioural decisions on each

market will be appropriately amplified, thereby motivating the organisation to implement prudent behaviour (Wu et al., 2022). Assuming that the scope of collaboration between Chinese and foreign enterprises is interrelated, and the correlation coefficient is represented by $\varphi(0<\varphi<1)$, if they adopt a collaboration strategy, the additional income that they can obtain is additional income and network effects.

$$\begin{matrix}\gamma_1(W_{11}A_{11}-W_{12}A_{12})-\gamma_1(W_{21}A_{21}-W_{22}A_{22})+\Delta S_1\\ \gamma_2(E_{11}B_{11}-E_{12}B_{12})-\gamma_2(E_{21}B_{21}-E_{22}B_{22})+\Delta S_2\end{matrix}. \quad (8)$$

φ is used to express excessive returns.

$$\begin{matrix}r_1(\varphi)=\gamma_1(W_{11}A_{11}-W_{12}A_{12})-\gamma_1(W_{21}A_{21}-W_{22}A_{22})+\Delta S_1\\ r_2(\varphi)=\gamma_2(E_{11}B_{11}-E_{12}B_{12})-\gamma_2(E_{21}B_{21}-E_{22}B_{22})+\Delta S_2\end{matrix}. \quad (9)$$

When the degree of regional correlation is high, the correlation coefficient is more significant, and the additional benefits that enterprises can obtain from the collaborative approach within the region will be more significant. The positive indirect network effect is higher, and the negative indirect network effect is more minor. Let $S_1=6, S_1=7, H_1=2, H_2=2$, $\alpha=0.3$ and $\beta=0.6$ be the research objects, and the influence of related factors $r_1(\varphi)=1,2,3,4,5$ and $r_2(\varphi)=1,2,3,4,5$ on the game strategy between enterprises be studied. This problem was numerically simulated using Matlab2020b software. The study found that if the countermeasure system conforms to (1,1), the degree of correlation increases (Valeri et al., 2021). This allows players to join forces more quickly and maintain stability for longer (Figure 2); when this condition does not hold, and the degree of correlation decreases, the additional returns decrease. At this time, the countermeasure system will accelerate the adoption of countermeasures and maintain a more extended period of stability.

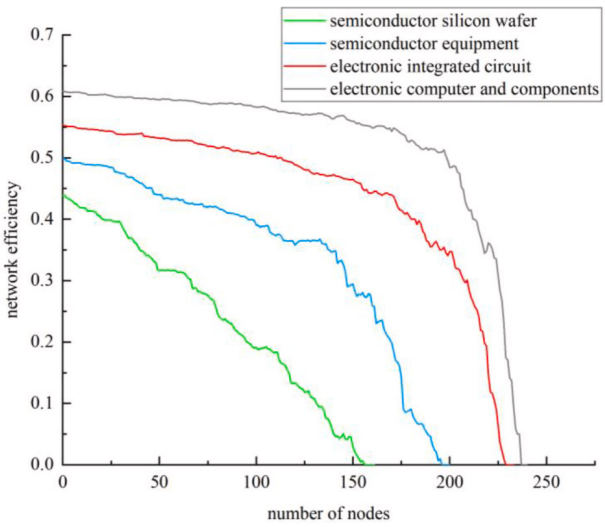

Figure 2. Experimental results.

4. Discussion

Suppose that $S_1=6, S_2=7, H_1=3, H_2=2$ holds, and let $\Delta S_1=1$ and $\Delta S_2=1$. If participants gain more expected returns from indirect network effects through gaming, they will engage in gaming rather than cooperation, no matter their situation. In this case, the confrontation between the two sides will continue until the system becomes confrontational (Patrickson, 2021). The paper then studies the role of initial cooperation intentions between firms to balance strategic convergence. Partners' strategic decisions are influenced both by network effect expectations and by partners' resource dependencies. In ICP organisations with widely different positions (Rauf, 2021), Chinese people tend to be more active and willing to cooperate, and the initial cooperation intentions of Organisation 2 are $\beta=0.3$ and $\beta=0.8$, respectively, then the corresponding ones are $\alpha=0.7$ and $\alpha=0.2$. People will conduct a comparative analysis. The proportion of cooperation strategies chosen by both parties changes with time T.

When a company adopts a confrontational strategy, no matter how the initial cooperation intention changes, it will adopt a confrontational rather than a cooperative strategy (Srinivasan et al., 2021). In such a situation, the two will continue to confront each other, and the overall evolutionary system will tend to be in opposition. On the contrary, if a confrontational strategy is adopted, the expected return of the indirect network effect is lower than that of a collaborative strategy. Moreover, the initial intention to cooperate will also affect its final decision.

First, if cooperation intention α exceeds the critical value, but β does not exceed the critical value, there are two possible evolutionary outcomes: one is to evolve to (1,1); the other is to evolve to (0,0). Since the threshold is set at (0.5, 0.5), the initial cooperation intention α of Organisation 1 is 0.6, 0.7, 0.8, and 0.9, respectively, and the initial cooperation intention α of Organisation 2 is 0.1, 0.2, 0.3, and 0.4, respectively, and the evolutionary path of this strategy is obtained. The study found that if α exceeds the threshold, and β does not exceed the threshold, then the evolutionary outcome of the two organisations will tend to be cooperative or non-cooperative (Chen, 2021).

Secondly, since the threshold is set at (0.5, 0.5), when the initial cooperation intentions, α and β, are more significant than the critical value, and the initial cooperation intention, α, of Organisation 1 takes 0.6, 0.7, 0.8, and 0.9, respectively, and the initial cooperation intention, β, of Organisation 2 takes 0.6, 0.7, 0.8, and 0.9, respectively, thus obtaining the evolutionary path of the countermeasure system. The study found that when α and β are more significant than the critical value, Organisation 1 and Organisation 2 will tend to cooperate in evolution (Arya et al., 2022).

In addition, the values of α and β will also have a particular impact on the cooperative tendency of the strategy system. When α takes the same value, such as

$\alpha = 0.6$, it can be assumed that the larger the value of β, the more likely the strategy system will be to cooperate. However, when β and $\beta = 0.9$ are the same as α increases, the rate at which the countermeasure system tends to cooperate will also accelerate. The values of α and β also affect the rate at which the countermeasure system tends to become confrontational. When the initial cooperation intention does not exceed the organisational threshold, as the initial cooperation intention decreases, the network's tendency toward competitive behaviour will also accelerate.

5. Conclusion

Terminating or maintaining a cross-border economic and trade cooperation strategy mainly depends on whether cross-border economic and trade cooperation can achieve the expected benefits in multiple aspects. Increased income will help promote the cooperation between the two countries. In addition, both parties' resource dependence, excess income levels and cooperation costs will impact their strategic decisions. The two countries' resource dependence and resource complementarity affect the intention to cooperate. However, if the scope of cooperation is expanded, but the corresponding expected benefits are not achieved, the reduction in this equilibrium state will spread to other regions, causing competition to expand from a particular region to the entire region. The actual rate of action is determined by the degree of impact of the fundamental interests of each region on the overall interests. A low level of import protection is very attractive to direct investment oriented towards trade and export; on the contrary, a high level of protection barriers is likely to lead to a large influx of direct investment aimed at evading tariffs or occupying local markets.

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Mr Kailin Zhu is a male of Han ethnicity born in May 1993. He obtained his Master's degree from Royal Roads University in Canada on 20 May 2021. Currently, He is affiliated with Universiti Utara Malaysia as a student. His primary research area is in Public Administration. With a strong academic background and a passion for contributing to the field of public management, he is committed to making meaningful contributions to the academic and professional community.

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