Enterprise strategy analysis of synergy between cross-border e-commerce and logistics in a dynamic environment

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ABSTRACT
In order to explore how cross-border e-commerce and logistics companies make decisions during synergy in a dynamic environment, this paper first establishes an evolutionary game model to study the influencing factors of enterprises’ strategies in the process of synergy in a dynamic environment. Then the study uses sensitivity analysis and numerical simulation to analyse the impact of different enterprises’ strategies on synergy. Finally, the synergistic strategies of enterprises in different dynamic environments are discussed. We found that: (1) capital and labour input of cross-border e-commerce platforms will affect the synergy. In a highly dynamic environment, the influences are greater. (2) There is a positive correlation between the technical level of the platform and synergistic degree, while the high technical level of logistics enterprises will inhibit synergy. However, in an unstable environment, the positive effect still exists, and the change in the logistics enterprise technology level has little effect on synergy. (3) The technical level of the cross-border e-commerce platform has the greatest impact on the benefits of both parties, and then is the lower cost of labour and capital input, while the technical level of logistics companies has little impact.

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1. Introduction
With the development of information technology and the global popularization of the Internet, China’s cross-border e-commerce industry has been gaining momentum. According to Prospective Industry Research Institute, the scale of cross-border e-commerce transactions in China reached 1.05 billion yuan in 2019. And the export transactions reached 8.03 trillion yuan, a year-on-year increase of 13.09%. However, the improvement of consumers’ service demand in the field of logistics has necessitated the creation of a new business model. This business model requires strong coordination between cross-border e-commerce and cross-border logistics (Giuffrida et al., 2020). Cross-border logistics and cross-border e-commerce are complementary and can promote the development of each other (Yuan, 2019). The synergy of cross-border e-commerce and cross-border logistics can break through the boundaries of industries and realize the coordinated operation of products, services and technologies (Zhang, 2018).

But on the one hand, the synergy between China’s cross-border e-commerce and cross-border logistics is still at a low level (Zhang, 2020). On the other hand, due to the impact of COVID-19, the uncertainty of demand and the chaos of the logistics network have severely destroyed the global economy (Sharma et al., 2020). China’s cross-border e-commerce is also suffering. Cross-border e-commerce platforms and cross-border logistics companies urgently need to take advanced actions to improve their synergy to gain market and compete with existing competitors. However, almost no scholars have studied the synergy between platforms and logistics companies in a dynamic environment.

In terms of the synergy between cross-border e-commerce and cross-border logistics, existing research mainly includes three aspects: (1) synergistic mechanism: a few factors affect the collaboration of cross-border e-commerce and cross-border logistics, such as collaborative environment, collaborative capabilities, willingness to collaborate, and so on (Qian & He, 2017). It acts on the strategic layer, function layer, and business layer of the enterprise (Zhang, 2018). (2) Evaluation of synergy: the coupling and coupling coordination degree between the two systems is increased year by year, but overall cross-border e-commerce and logistics system coordination development level still belongs to the low collaborative development stage (Zhang, 2020; Zhang et al., 2018). (3) Synergistic impact: the collaboration of cross-border e-commerce and logistics can promote the development of cross-border e-commerce logistics.
chains. It is an important way to maximize the benefits of cross-border e-commerce supply chains (Li & Zhao, 2019). In general, existing studies are based on the macro-level to explore the mechanism and effects of the two parties’ synergy. But few scholars have analysed it from the micro-level. Companies still do not know how to make decisions in a collaborative environment, such as technological level, labour and capital investment.

Environmental dynamism is the rate of change in the environment over time in terms of its speed and strength, including technologies, markets, competitors and customers (Seo et al., 2020). There are few studies on the impact of the dynamic environment on cross-border e-commerce, but scholars have realized that an unstable environment will have an important impact on cross-border e-commerce. First, an unstable environment affects logistics and supply chains, such as logistics demand reduction, disruption of logistics network and the increase in operating costs (Sharma et al., 2020). Cross-border logistics companies are more likely to opt out of synergy due to opportunism (Huo et al., 2018). Secondly, it can bring new opportunities to cross-border e-commerce. COVID-19 has shifted shopping channels from offline to online, cultivating a large number of potential consumers. Countries are also paying more attention to the development of cross-border e-commerce (Ma & Pan, 2020). Cross-border e-commerce and cross-border logistics must respond to the effects of the changing environment, and maintain synergy between them under the influence of the epidemic. But no scholars have studied how the dynamic environment affects the collaboration of cross-border e-commerce and logistics and what strategies enterprises should adopt at present. In summary, this paper contributes to the following aspects:

1. Analyse the factors that affect the synergy of cross-border e-commerce and cross-border logistics through micro-level analysis. These factors include enterprise’s individual decision-making, such as technological level, labour and capital investment.

2. Analyse the impact of a dynamic environment on the synergy between cross-border e-commerce platform and logistics, and give suggestions for both sides to adjust to optimal strategies in different environments.

The rest of this paper is organized as follows. Section 2 introduces the evolutionary game model of the synergy between cross-border e-commerce platform and logistics enterprise. Section 3 analyses the influence of factors on synergy through numerical simulation. Section 4 provides the sensitivity analysis of the benefits of the factors. Section 5 presents the impact of high environmental dynamics on enterprise synergistic decision-making. Finally, Section 6 concludes the paper.

2. Method

2.1. Factor analysis

External factors refer to objective factors that affect the synergy of cross-border e-commerce platform and logistics, but are not dominated by them, such as a collaborative environment. The synergy of cross-border e-commerce and logistics involves the political systems, customs’ culture and trade policies of different countries. Therefore, unbalanced economic level and technological development between different regions and fluctuation of foreign exchange rates impact the synergy of cross-border e-commerce platform and logistics.

Internal factors come from the cross-border e-commerce platform and the logistics enterprise collaborative system, and can be actively changed by enterprises (Huo et al., 2018; Li et al., 2019; Qian & He, 2017).

1. The scale of enterprises. The synergy of cross-border e-commerce and cross-border logistics will expand the scale of enterprises. Excessive scale causes increased operating costs for enterprises. Companies may give up coordination in order to reduce losses.

2. The technical level of enterprises. When an enterprise improves its technological level, it can reduce resource input and promote synergy. However, when the technical level of the two parties in the synergy differs greatly, the company may abandon the synergy.

3. Opportunity cost. Companies will consider the opportunity cost of resources invested when making decisions. If the same elements of labour and capital can be invested in other sectors to get more benefits, then enterprises will choose to abandon synergy.

2.2. Modelling

In the process of synergy, when cross-border e-commerce platforms and logistics enterprises are committed to providing good service quality for consumers, they will form a mutually beneficial relationship and achieve win–win results. However, when there is information asymmetry or a negative impact from the outside world, in order to ensure the maximization of their own interests, both parties may have opportunistic behaviours. It may cause damage to revenue and reduce the willingness of cross-border e-commerce platforms and logistics enterprises to synergy.

Since there is a game relationship in the synergy between cross-border e-commerce and logistics, it is suitable to use game models to solve problems. So based
on the previous analysis of factors, we establish an evolutionary game model. It analyses the impact of different behaviours of cross-border e-commerce platforms and logistics enterprises on the degree of synergy in a dynamic environment. The assumptions are summarized as follows:

1) There are two players in the evolutionary game: cross-border e-commerce platforms and logistics enterprises. Each player has three alternative strategies: option A: high synergy; option B: general synergy and option C: no synergy.

2) Logistics companies provide labour and capital, and cross-border e-commerce platforms provide profit-sharing. $L_A, L_B, K_A, K_B$ is the labour (L) and capital (K) provided by the logistics enterprises under plan A and plan B, respectively. When the choices of both parties are inconsistent, the logistics company provides labour and capital with the following rules:

(Enterprise 1, Enterprise 2): $(A, B) \rightarrow (L_A, K_B)$, $(B, A) \rightarrow (L_B, K_A)$. When either party chooses not to cooperate, the two parties will not cooperate.

3) In a dynamic environment, market demand is uncertain. Assuming that the sales volume of goods is a discrete variable, when the environmental dynamics is low, all the goods produced by the platform can be sold. The sales volume is Q. When the environmental dynamics are high, the sales volume of the platform is $aQ (0 < a < 1)$. The probability of predicting the low dynamics of the environment is $k$, then the sales volume of the product is $Q_d = kQ + (1 − k)aQ$ (Liu & Zhao, 2019; Qiu et al., 2016).

4) The commodity price is P and the commodity cost is $C = aQ + \lambda Q^2 + \sigma Q^3$.

Quoting Cobb–Douglas, the product output is $Q = AL^aK^b$ (A is technical level) (Bannova & Aktaev, 2019).

5) The cross-border e-commerce platform provides profit-sharing based on the labour and capital provided by the logistics company: $nL_K$.

6) The profit obtained by the cross-border e-commerce platform after collaboration is $S_1 = PQ_d − \omega Q − \lambda Q^2 − \sigma Q^3 − nL_K$.

The additional benefits of the logistics platform after cooperation (considering opportunity cost) are: $S_2 = nL_K − A_2L^aK^b$ ($A_2$ is the technical level of logistics enterprises).

Therefore, the evolutionary game model is shown in Table 1.

### 2.3. Stability analysis

According to the replicated dynamic equations of two participators, we can get nine equilibrium points which can be obtained as $(0,0,0,1), (1,0,0,0), (0,1,0,0), (0,0,1,0), (0,0,0,1), (1,0,1,0), (1,0,0,1), (0,1,1,0), (0,1,0,1)$. To figure out the stability of the nine equilibrium points, we calculate the Jacobian matrix $J$. Then we find that $(0,0,0,0), (0,0,0,1), (1,0,1,0), (1,0,0,1), (0,1,1,0)$ and $(0,1,0,1)$ are unstable, the other equilibrium points $(1,0,1,0), (1,0,0,1), (0,1,1,0)$ and $(0,1,0,1)$ can be evaluated by adding conditions. Let $P_k + a − ak − \omega = \mu$, the following relationship is obtained:

1) Scenario 1: when the condition $\left(\frac{\mu(Q_{AB} - Q_{AA}) - \lambda(Q_{AB} - Q_{AA}) - \sigma(Q_{AB} - Q_{AA})}{nL_K(\lambda - \mu)}\right) > n$ and $\left(\frac{nL_K(K_{AA} - K_{AB})}{\lambda - \mu}\right) > A_2$ is met, the system evolves to $(1,0,1,0)$. In this scenario, the additional benefits of cross-border e-commerce platform and logistics company are positive, and any party that reduces the degree of synergy will cause losses. Ultimately, the system evolves to a high synergy state.

2) Scenario 2: when the condition $\left(\frac{\mu(Q_{AB} - Q_{AA}) - \lambda(Q_{AB} - Q_{AA}) - \sigma(Q_{AB} - Q_{AA})}{nL_K(\lambda - \mu)}\right) < n$ and $\left(\frac{nL_K(K_{AA} - K_{AB})}{\lambda - \mu}\right) > A_2$ is met, the system evolves to $(0,1,1,0)$. At this moment, one player in the game chooses option A, and the other party chooses option B. The additional benefits obtained by both are positive, but if either party reduces or increases the degree of synergy, it will reduce the company’s revenue. After a period of gaming, the system evolves to a state of regular synergy.

3) Scenario 3: when the condition $\left(\frac{\mu(Q_{AB} - Q_{AA}) - \lambda(Q_{AB} - Q_{AA}) - \sigma(Q_{AB} - Q_{AA})}{nL_K(\lambda - \mu)}\right) > n$ and $\left(\frac{nL_K(K_{AA} - K_{AB})}{\lambda - \mu}\right) > A_2$ is met, the system evolves to $(1,0,0,1)$. If any party improve the degree of synergy, both of them will get losses, and eventually, the system will evolve to a low level of synergy.

### 3. Simulations

Numerical simulation can help understand the impact of parameter changes on system operation. In this section,
we use numerical simulations to further investigate the decision-making processes of cross-border e-commerce platforms and logistics enterprises on the synergy.

### 3.1. Influence of labour input

In Figure 1, the values of labour input \( (L_0) \) are 1, 11, 21 and 31, respectively. \( X_1 \) represents the proportion of selected strategy A (highly coordinated) in cross-border e-commerce platforms, and \( Y_1 \) represents the proportion of selected strategy A (highly coordinated) in logistics companies. Figure 1 shows labour input \( (L_0) \) has a negative impact on the degree of synergy. By analysing the time required for the system to stabilize, we found cross-border e-commerce platforms are more sensitive to higher and lower labour input. A proper amount of initial labour input will help the two parties collaborate, but too much input will lead to excessive operating costs. In order to reduce losses, companies choose to lower the degree of synergy. Therefore, cross-border e-commerce platforms need to pay attention to controlling their own scale and improving efficiency.

### 3.2. Influence of capital input

As shown in Figure 2, the degree of synergy between the two parties increases firstly and then decreases with the increase of capital investment \( (K_0) \). When the initial capital investment increases from small, the capital utilization rate is improved and the productivity of the enterprise increases. At this time, synergy can bring more benefits. However, if too much capital is invested, the company’s labour and capital ratio will become unbalanced, and the excess capital will not produce benefits. In order to reduce losses, companies opt out of synergy. Cross-border e-commerce platforms can increase initial capital investment to a certain extent to promote the

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**Figure 1.** Influence of \( L_0 \).

**Figure 2.** Influence of \( K_0 \).

**Figure 3.** (a) Influence of \( A_1 \). (b) Influence of \( A_2 \).
synergy of both parties, but the ratio of labour and capital needs to be adjusted in time.

### 3.3. Influence of technical level

In Figure 3(a), the technical level of cross-border e-commerce platforms ($A_1$) has a positive impact on synergy. The improvement of technology has improved the labour productivity of enterprises, and a stable cooperative relationship can bring more profits to both parties. Therefore, the degree of coordination between the two sides of the game is improved. Cross border e-commerce platforms can promote collaboration by improving the technical level.

The technical level of logistics companies ($A_2$) has a negative impact on synergy, and logistics companies are more sensitive in Figure 3(b). When the technological level of logistics enterprises is high, investing labour and capital in other purposes, logistics enterprises will obtain more returns. Therefore, considering the opportunity cost, logistics enterprises will not choose to collaborate. Cross-border e-commerce platform companies should ensure that their technical level is relatively higher, so they can have a high degree of synergy.

### 3.4. Influence of dynamic environment

In Figure 4, with the improvement of environmental dynamics, the degree of collaboration between cross-border e-commerce platforms and logistics companies gradually decreases. The unstable market environment has led to a decrease in the sales volume of goods, and the revenue of both parties has reduced. So the cooperative relationship cannot be maintained. Therefore, cross-border e-commerce platforms and logistics companies need to take measures to deal with the impact of changing environment. We also found that when $k$ increases from 0.6 to 0.8, the system only slightly accelerates the evolution speed, so there is no need for companies to blindly pursue a highly stable market environment.

### 4. Sensitivity analysis

In this section, we use sensitivity analysis to explore the sensitivity of cross-border e-commerce platforms and logistics companies to parameters in stable ($k = 0.8$) or unstable ($k = 0.4$) market environments. When the enterprise’s investment strategy $x$ changes, the corresponding cross-border e-commerce platform’s income is $S_1$, and the logistics enterprise’s income is $S_2$. Then the sensitivity of $S_1$ to $x$ is $S(x, S_1) = \frac{\Delta S_1}{\Delta x}$ (Qiu et al., 2016). The sensitivity of $S_2$ to $x$ is $S(x, S_2) = \frac{\Delta S_2}{\Delta x}$ (Qiu et al., 2016). The results are shown in Figures 5–8, where the abscissa is the percentage of decrease in various inputs of the enterprise, including labour, capital and technology levels. The ordinates are the sensitivity of cross-border e-commerce platforms and logistics companies’ revenue to input.

![Figure 5. Sensitivity of $S_1$ and $S_2$ to $L_0$.](image1)

![Figure 6. Sensitivity of $S_1$ and $S_2$ to $K_0$.](image2)
Figure 7. Sensitivity of $S_1$ and $S_2$ to $A_1$.

Figure 8. Sensitivity of $S_1$ and $S_2$ to $A_2$.

4.1. Labour input

Figure 5 shows that when $L_0$ is decreased, the sensitivity of $S_1$ is decreased firstly and then increased, while the sensitivity of $S_2$ changes very little. In addition, the overall trend of sensitivity remains unchanged in an unstable environment, but the turning point is delayed. Therefore, cross-border e-commerce platforms should combine their own stage characteristics and appropriately adjust labour input to reduce losses and improve coordination. But the platform must pay attention to changes in labour input within a specific range to cause drastic changes in corporate benefits. When making relevant decisions, companies should try to avoid the flat areas in the middle.

4.2. Capital input

In Figure 6, the sensitivity of $S_1$ is increased with the decrease of $K_0$. While the sensitivity of $S_2$ is showing a downward trend in a stable environment, in an unstable environment, it shows a small increase and then decreases. Cross-border e-commerce platforms can improve their returns by adjusting capital investment, but it should be noted that the impact of capital on returns in an unstable environment is lower than that in a stable environment. Compared to Figure 5, it can be seen that the sphere of influence of labour and capital changes on both sides is basically the same. Therefore, enterprises can choose the one with lower cost when making labour and capital investment decisions.

4.3. Technical level

As $A_1$ gradually decreases in Figure 7, the sensitivity of $S_1$ is first kept unchanged and then gradually decreased, and the peak of sensitivity in a stable environment is higher than that in an unstable environment. While under different environmental dynamics, the sensitivity of $S_2$ is first increased and then decreased in a small range. It can be seen that in an unstable environment, the change in technical level has less impact on income. When the technical level of the platform is high, while changing the technical level, the sensitivity remains almost unchanged. Therefore, when the technical level of a cross-border e-commerce platform is high, the impact of small-scale adjustment of the technical level is very small.

As shown in Figure 8, in a stable environment, as $A_2$ is reduced, the sensitivity of $S_1$ is also continuously reduced, and the sensitivity of $S_2$ is firstly increased, and then basically remains unchanged. However, the sensitivity of $S_1$ and $S_2$ to $A_2$ are 0 in an unstable environment. Therefore, in a stable environment, logistics companies can increase their profits by adjusting their technological level, while in an unstable environment, logistics companies do not need to change their technical level.

In this section, we found that the change of $A_1$ has the greatest impact on $S_1$ and $S_2$, followed by $L_0$ and $K_0$. Therefore, when making investment decisions, cross-border e-commerce platforms can consider changing the technical level firstly, and then adjust the lower cost of labour and capital investment. However, only in a stable environment, logistics companies can increase their profits and promote cooperation by changing their technological level.

5. Impact of environmental dynamics on enterprise strategy

We have obtained that under different environmental dynamics, the investment of enterprises will cause different synergistic effects. In this section, numerical simulation is used to analyse the impact of an unstable
Figure 9. Impact of a highly dynamic environment on $L_0$.

environment ($k = 0.4$) on various investment strategies of enterprises.

5.1. Impact of a highly dynamic environment on labour input

In Figure 9, as $L_0$ increases, the willingness of both parties to cooperate first increases and then decreases. Compared with Figures 1 and 5, we found that the critical value for both sides to choose to give up collaboration has become smaller in a highly dynamic environment.

Conclusion 1: when the environment becomes more dynamic, cross-border e-commerce platforms need to increase or decrease labour input to upgrade the degree of synergy according to the situation and resist external influences. But this effect is limited. When the labour input is too high, the excessively operating cost becomes a burden on the platform, so the platform must reasonably increase the labour input.

Figure 10. Impact of a highly dynamic environment on $K_0$.

5.2. Impact of a highly dynamic environment on capital input

As shown in Figure 10, when $K_0$ increases, the degree of synergy of the system first increases and then decreases. Compared with Figure 2, in a highly dynamic environment, the impact trend of capital investment on synergy is basically the same, except that each turning point is advanced.

Conclusion 2: when the environment is highly dynamic, cross-border e-commerce platforms must adjust the size of the company. They can appropriately increase capital investment and capital utilization. This measure can mitigate the adverse effects of external changes and improve the level of coordination between the two parties.

5.3. Impact of a highly dynamic environment on the technical level

As shown in Figure 11(a), $A_1$ has a positive impact on synergy. Compared with Figure 3(a), increasing $A_1$ can

Figure 11. (a) Impact of a highly dynamic environment on $A_1$. (b) Impact of a highly dynamic environment on $A_2$. 
mitigate the adverse effects of the epidemic. And when \(A_1\) is at a higher level, the speed of evolving into a state of high coordination is faster in high environmental dynamics.

Conclusion 3: cross-border e-commerce platforms can improve the level of technology to buffer the impact from the outside world. In an unstable environment, cross-border e-commerce platforms should pay more attention to innovation and improve the level of technology.

Figure 11(b) shows when \(A_2\) increases, both parties choose to reduce the degree of synergy. And compared to Figure 3(b), under high environmental dynamics, \(A_2\) has less impact on the strategic choice of cross-border e-commerce platforms.

Conclusion 4: This indicates logistics companies cannot cope with the impact of dynamic environments and cross-border e-commerce platforms need to take measures to maintain a high degree of coordination.

6. Conclusions

This paper uses evolutionary game theory to study the decision-making and influencing factors of enterprises’ investment in the process of synergy in a dynamic environment and gives suggestions on how to make decisions. First, increasing the labour input will inhibit synergy, and capital input will first promote and then inhibit synergy. When the environment changes from stable to unstable, these effects are enhanced. Then, there is a positive correlation between the technical level of the platform and the degree of synergy, while the high technical level of logistics enterprises will inhibit synergy. In a highly dynamic environment, the improvement of cross-border e-commerce platform technology can transform the non-synergy relationship into collaboration. But the inhibitory effect of the high technological level of logistics enterprises on synergy becomes very small. Finally, the technical level of the cross-border e-commerce platforms has the greatest impact on the benefits of both parties, and then is the lower cost of labour and capital investment, while the technical level of logistics companies has little impact. But this article only refers to the impact of different capital investment and labour input. How to match the two correctly and reasonably under different circumstances is the direction of future research.

Data availability statement

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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