DOI: https://doi.org/10.52131/pjhss.2023.1101.0384

Pakistan Journal of Humanities and Social Sciences

Volume 11, Number 01, 2023, Pages 682–691
Journal Homepage:
https://journals.internationalrasd.org/index.php/pjhss

PAKISTAN JOURNAL OF HUMANITIES AND SOCIAL SCIENCES (PJHSS)
INTERNATIONAL RESEARCH ASSOCIATION FOR SUSTAINABLE DEVELOPMENT

Research on Evolutionary Game of Low-carbon Knowledge Sharing in Enterprise Strategic Alliance Considering Multiple Factors

Xi Tang[1], Junwen Feng[2], Bo Feng[3], Zhenping Bai[4]

[1] College of Economics and Management, Nanjing University of Science and Technology, Nanjing, China.
[2] College of Economics and Management, Nanjing University of Science and Technology, Nanjing, China.
[3] College of Intellectual Property, Nanjing University of Science and Technology, Nanjing, China.
[4] College of Marxism, Nanjing University of Science and Technology, Nanjing, China. Email: lili1718188@163.com

ARTICLE INFO

Article History:
Received: February 02, 2023
Revised: March 30, 2023
Accepted: March 30, 2023
Available Online: March 31, 2023

Keywords:
Enterprise Strategic Alliance
Low-Carbon Knowledge Sharing
Opportunity Cost
Evolutionary Game

Funding:
This work was supported by *Postgraduate* Research & Practice Innovation Program of Jiangsu Innovation Program of Jiangsu Province No. (KYCCX22_0551, No. KYCX22_0561)

ABSTRACT

Knowledge sharing is an important way for enterprise strategic alliance to participate in enterprise learning and dissemination of low-carbon knowledge. According to the different enterprise size and knowledge level of strategic alliance participating enterprises, considering all kinds of influencing factors of knowledge sharing willingness of participating enterprises, this paper constructs enterprise strategic alliance knowledge sharing evolutionary game payment matrix and obtains evolutionary equilibrium solution. In view of the different values of the absorption and transformation ability coefficient of knowledge, the degree of complementarity of knowledge, and the degree of knowledge sharing, the influence of simulation on the knowledge sharing intention of enterprises is simulated. The research shows that the coefficient of knowledge absorption and transformation ability and the degree of knowledge complementarity have a great influence on the willingness of participating enterprises to knowledge sharing. The knowledge sharing willingness of enterprise strategic alliance participating enterprises is sensitive to the knowledge sharing degree of the two enterprises, and the sharing degree of enterprises with different knowledge levels has different effects on the knowledge sharing willingness of the two enterprises.

Corresponding Author's Email: lili1718188@163.com

1. Introduction

The global environmental problem caused by carbon emissions has become increasingly serious (Miyamoto & Takeuchi, 2019), which seriously affects the sustainable development of the world (Nodehi & Taghvaee, 2022). Therefore, how to carry out low-carbon technology innovation, reduce carbon emissions, so as to achieve low-carbon development has become the focus of relevant scholars. Enterprise strategic alliance is an important carrier for enterprises to realize innovation through the integration of technical resources and elements(González-Tokman et al., 2020). It is also an effective way to accelerate the integrated innovation of core industries and improve the technological level of enterprise innovation. More and more enterprises are willing to use knowledge sharing through enterprise strategic alliance to exchange knowledge and information with each other, recombine, refine and form innovative knowledge and innovation technology, so that the gold content of enterprise knowledge and technology can be added value, so as to continuously enhance the core competitiveness of enterprises (Drewniak & Karaszewski, 2020). Because of the heterogeneity and monopoly of knowledge, it leads to the difficulty of knowledge acquisition. However, the knowledge of low-carbon technology is more complex. Therefore, knowledge sharing is needed to solve the problem of knowledge acquisition. Therefore, it is of certain theoretical and practical value to discuss the knowledge sharing of low carbon technology in enterprise strategic alliance.

Relevant scholars have carried out many research on knowledge sharing among enterprises. Panahi, Watson, and Partridge (2013) believed that the development and innovation of knowledge sharing can be accelerated by using network platform and modern information technology. (Carnahan et al., 2010) found that with the help of knowledge sharing, between internal employees, enterprises can enhance their original value, but also enhance the core competitiveness of enterprises. Liu, Lin, and Yu (2023) empirically tested the positive effect of knowledge sharing on enterprise innovation ability through structural equation model. Berraies, Lajili, and Chtioui (2020) empirically tested the promoting effect of excellent employees on internal knowledge sharing in enterprises. Because the knowledge sharing behavior between enterprises involves the participation of multiple parties, therefore game theory has been widely used in the research of enterprise knowledge sharing behavior. Wang, Jiang, Yu, Fu, and Mo (2021) pointed out that knowledge sharing among enterprises is an important way for enterprises to obtain external resources based on signal game theory. Gao, Liu, Yu, and Guo (2021) used the evolutionary game model to verify the promotion effect of external effects on knowledge sharing among enterprises, such as government incentives. Kong, Xu, and Zhu (2019) used an evolutionary game model to study the knowledge sharing problem of enterprises in industrial clusters, and provided relevant suggestions for the future development of industrial clusters. Li, Wang, Wang, Su, and Zhang (2020) pointed out that knowledge sharing enterprises should increase mutual trust and reduce sharing costs based on stochastic evolutionary games.

The above research is of great theoretical and practical value to promote the development of the enterprise development alliance through knowledge sharing, but there are still some problems:(1) The relevant influencing factors of the knowledge sharing intention of participating enterprises are not comprehensive enough, for example, some literature only consider some factors such as knowledge reserve, knowledge disclosure, absorption conversion ability, etc. In addition, without considering the characteristics of low-carbon technology knowledge sharing itself. (2) When many scholars construct game matrix, they ignore the influence of opportunity cost after knowledge sharing, and because the knowledge sharing effect between, enterprise strategic alliance members, the inherent attribute of knowledge, will show stronger profitability, and with the increase of the degree of knowledge sharing, the linear relationship between the benefits of alliance members caused by knowledge sharing behavior will be more complex.

Therefore, this paper makes use of the method of evolutionary game, and comprehensively considers the various influencing factors of enterprise knowledge sharing's willingness to participate in the enterprise knowledge sharing will, and constructs the knowledge sharing evidential game payment matrix. In this paper, the evolution equilibrium solution is obtained, and the knowledge sharing behavior is further explored through the numerical simulation, the absorption and conversion capability coefficient of the simulation knowledge ,the degree of complementarity of the knowledge, the related parameters of the knowledge and the influence of the relevant parameters on the knowledge sharing will of the participating enterprises. It can not only provide reference for future research on knowledge sharing, but also provide assistance for the promotion of low-carbon technology innovation in enterprises, which undoubtedly has important theoretical and practical significance.

2. Model and Analysis

This paper, based on the strategic alliance's participation in different enterprise scale and knowledge level of the enterprise, comprehensively considers the various influencing factors involved in the knowledge sharing will, and puts forward the following parameters:

1. There are members in the enterprise strategic alliance A、B,Among them, A has the advantages of information resources, and high knowledge level, while B knowledge level is general.
2. There are only two choices for the members of the strategic alliance, that is, knowledge sharing or not. $x \subseteq [0,1], y \subseteq [0,1]$ represent the willingness of participating members A、B knowledge sharing respectively, The probability of A、B not sharing knowledge is $1-x, 1-y$
3. Set $R_i(i = A,B)$ as the knowledge reserve of participating enterprises, P_A as the knowledge reserve of enterprises A, P_B as the knowledge reserve of enterprises B ,and $P_A > P_B$.
4. When both sides share knowledge, the direct benefit of one party's acquiring the other's knowledge depends on the ability of knowledge absorption and transformation $\alpha_i(i = A,B)$ .That is, the enterprise A can obtain $\alpha_A P_B R_B(1-T_B)$,the enterprise B can obtain $\alpha_B P_A R_A(1-T_A)$.

5. When enterprises of both sides share knowledge at the same time, synergy will be formed due to the generation of new knowledge. The magnitude of synergy depends on:

1)The complementary degree of knowledge of both parties β ,and $0 < \beta < 1$.

2)The ability to absorb and transform the knowledge of both parties $\alpha_i(i = A,B)$,and $0 < \alpha_B < \alpha_A < 1$.

3)The price of new knowledge P .

Therefore, the enterprise A can obtain the synergy benefit $\alpha_A \beta P(R_A T_A + R_B T_B)$, and the enterprise B can obtain the synergy benefit $\alpha_B \beta P(R_A T_A + R_B T_B)$.

6. Knowledge sharing in enterprises will produce certain costs $C_i(i = A,B)$.At the same time, the party who shares knowledge will also produce opportunity cost (the benefit that the other party loses by using the acquired knowledge). The size of opportunity cost depends on the opportunity cost coefficient $\gamma_i(i = A,B)$. Among them, the opportunity cost coefficient γ_A of the enterprise is, the opportunity cost coefficient γ_B of the enterprise is, and $\gamma_A > \gamma_B > 1$.

Therefore, according to the above assumptions, the game payment matrix is shown in Table 1.

Table 1: Payment Matrix of Strategic Alliance Participating in Enterprise Knowledge Sharing

	Strategic Alliance Enterprise B	
	Share y	Share $1-y$
Strategic alliance enterprise A Share x	$P_A R_A(1-T_A)+\alpha_A P_B R_B(1-T_B)+\alpha_A \beta P(R_A T_A + R_B T_B)-\gamma_A C_A$ $P_B R_B(1-T_B)+\alpha_B P_A R_A(1-T_A)+\alpha_B \beta P(R_A T_A + R_B T_B)-\gamma_B C_B$	$P_A R_A(1-T_A)-\gamma_A C_A$ $P_B R_B + \alpha_B P_A R_A(1-T_A)-C_B$
Not shared $1-x$	$P_A R_A + \alpha_A P_B R_B(1-T_B)-C_A$ $P_B R_B(1-T_B)-\gamma_B C_B$	$P_A R_A$ $P_B R_B$

The expected benefits for enterprises A to choose knowledge sharing are:

$$E_{11} = y[P_A R_A(1-T_A)+\alpha_A P_B R_B(1-T_B)+\alpha_A \beta P(R_A T_A + R_B T_B)-\gamma_A C_A]+(1-y)[P_A R_A(1-T_A)-\gamma_A C_A]$$
$$= P_A R_A(1-T_A)+y\alpha_A P_B R_B(1-T_B)+y\alpha_A \beta P(R_A T_A + R_B T_B)-\gamma_A C_A$$

The expected benefits of enterprises A choosing not to share knowledge are:

$$E_{12} = y[P_A R_A + \alpha_A P_B R_B(1-T_B)-C_A]+(1-y)P_A R_A$$
$$= P_A R_A + y\alpha_A P_B R_B(1-T_B)-yC_A$$

The average income of enterprises A choosing mixed strategy is:

$$\overline{E} = xE_{11} + (1-x)E_{12}$$
$$= x[P_A R_A(1-T_A)+y\alpha_A P_B R_B(1-T_B)+y\alpha_A \beta P(R_A T_A + R_B T_B)-\gamma_A C_A]+(1-x)[P_A R_A + y\alpha_A P_B R_B(1-T_B)-yC_A]$$

Therefore, the replication dynamic equation of an enterprise A is:

$$F(X) = \frac{dx}{dt} = x(E_{11} - \overline{E})$$
$$= x(1-x)[y\alpha_A \beta P(R_A T_A + R_B T_B)-P_A R_A T_A - \gamma_A C_A + yC_A]$$

Similarly, the replication dynamic equation of an enterprise B is:

$$F(Y)=\frac{dy}{dt}=y\left(E_{21}-\overline{E}\right)$$
$$=y(1-y)\left[x\alpha_B\beta P\left(R_AT_A+R_BT_B\right)-P_BR_BT_B-\gamma_BC_B+xC_B\right]$$

Five local stable points $E_1(0,0)$ 、 $E_2(0,1)$ 、 $E_3(1,0)$ 、 $E_4(1,1)$ 、 $E_5\left(\frac{P_BR_BT_B+\gamma_BC_B}{\alpha_B\beta P(R_AT_A+R_BT_B)+C_B},\frac{P_AR_AT_A+\gamma_AC_A}{\alpha_A\beta P(R_AT_A+R_BT_B)+C_A}\right)$ can be obtained by the sum $F(X)$ and $F(Y)$ equal to 0. The Jacobian matrix J of knowledge sharing dynamic evolution system of strategic alliance can be obtained by partial derivation of replication dynamic equation of participating enterprises A 、 B :

$$J=\begin{bmatrix}(1-2x)\left[y\alpha_A\beta P\left(R_AT_A+R_BT_B\right)-P_AR_AT_A-\gamma_AC_A+yC_A\right] & x(1-x)\left[\alpha_A\beta P\left(R_AT_A+R_BT_B\right)+C_A\right]\\ y(1-y)\left[\alpha_B\beta P\left(R_AT_A+R_BT_B\right)+C_B\right] & (1-2y)\left[x\alpha_B\beta P\left(R_AT_A+R_BT_B\right)-P_BR_BT_B-\gamma_BC_B+xC_B\right]\end{bmatrix}$$

When an equilibrium point can make Jacobian matrix $\det J>0$ and trace of Jacobian matrix $tr(J)<0$, we can judge whether the local equilibrium point is in the state of local asymptotic stability. If so, it is the evolutionary stability strategy of the system. The results of local stability analysis of the system are shown in Table 2.

Table 2: Local Stability Analysis Results of Knowledge Sharing in Enterprise Strategic Alliance

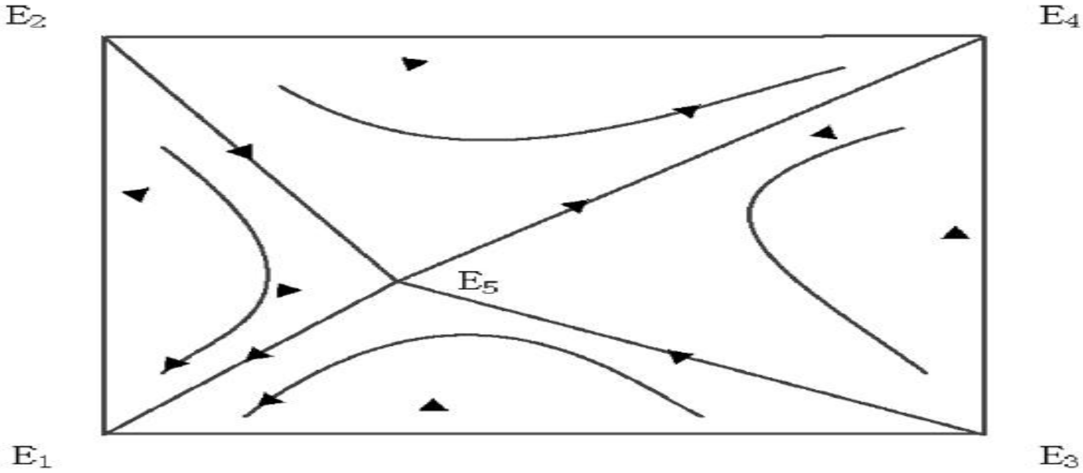
Equilibrium point	Determinant (symbol) of J	Trace (symbol) of J	Result
$E_1(0,0)$	$\left(P_AR_AT_A+\gamma_AC_A\right)\left(P_BR_BT_B+\gamma_BC_B\right)$ $(+)$	$-\left(P_AR_AT_A+\gamma_AC_A\right)-\left(P_BR_BT_B+\gamma_BC_B\right)$ $(-)$	ESS
$E_2(0,1)$	$\begin{bmatrix}\alpha_A\beta P\left(R_AT_A+R_BT_B\right)-P_AR_AT_A\\ -\gamma_AC_A+C_A\end{bmatrix}$ $\left(P_BR_BT_B+\gamma_BC_B\right)$ $(+)$	$\begin{bmatrix}\alpha_A\beta P\left(R_AT_A+R_BT_B\right)-P_AR_AT_A\\ -\gamma_AC_A+C_A\end{bmatrix}$ $+\left(P_BR_BT_B+\gamma_BC_B\right)$ $(+)$	Instable
$E_3(1,0)$	$\begin{bmatrix}\alpha_B\beta P\left(R_AT_A+R_BT_B\right)-P_BR_BT_B\\ -\gamma_BC_B+C_B\end{bmatrix}$ $\left(P_AR_AT_A+\gamma_AC_A\right)$ $(+)$	$\begin{bmatrix}\alpha_B\beta P\left(R_AT_A+R_BT_B\right)-P_BR_BT_B\\ -\gamma_BC_B+C_B\end{bmatrix}$ $+\left(P_AR_AT_A+\gamma_AC_A\right)$ $(+)$	Instable
$E_4(1,1)$	$\begin{bmatrix}\alpha_A\beta P\left(R_AT_A+R_BT_B\right)-P_AR_AT_A\\ -\gamma_AC_A+C_A\end{bmatrix}$ $\begin{bmatrix}\alpha_B\beta P\left(R_AT_A+R_BT_B\right)-P_BR_BT_B\\ -\gamma_BC_B+C_B\end{bmatrix}$ $(+)$	$-\begin{bmatrix}\alpha_A\beta P\left(R_AT_A+R_BT_B\right)-P_AR_AT_A\\ -\gamma_AC_A+C_A\end{bmatrix}$ $-\begin{bmatrix}\alpha_B\beta P\left(R_AT_A+R_BT_B\right)-P_BR_BT_B\\ -\gamma_BC_B+C_B\end{bmatrix}$ $(-)$	ESS
E_5	$\left(\frac{P_BR_BT_B+\gamma_BC_B}{\alpha_B\beta P(R_AT_A+R_BT_B)+C_B},\frac{P_AR_AT_A+\gamma_AC_A}{\alpha_A\beta P(R_AT_A+R_BT_B)+C_A}\right)$		saddle point

As can be seen in Table 2,only a bit of $(0,0)$ and a point $(1,1)$ are the evolution stabilization points (ESS) in the five local stability points of the enterprise's enterprise knowledge sharing system, and the knowledge sharing and the knowledge sharing are selected for both the strategic alliance participating enterprise A and B respectively. In addition, both the point $(0,1)$ and the point $(1,0)$ of the, enterprise strategic alliance knowledge sharing evolution system are unbalanced, and the point E_5 is the saddle point of the evolutionary game system.

The evolution phase diagram of enterprise strategic alliance participating enterprise knowledge sharing is shown in figure 1.

(1) figure 1 illustrates that, in the case of $P_A R_A(1-T_A)+\alpha_A P_B R_B(1-T_B)+\alpha_A \beta P(R_A T_A + R_B T_B) > \gamma_A C_A$, the policy of the enterprise A will vary with the policy change of the enterprise B. When enterprise B chooses knowledge sharing policy, the profit of knowledge sharing of A is larger, and when enterprise B chooses no knowledge sharing, the income of knowledge sharing of A is small, so it tends to choose the policy of not sharing. In contrast, enterprise B can get the same conclusion by choosing different strategy analysis. Therefore, under the premise that the benefits brought by knowledge sharing are greater than the cost, the participating enterprises will choose to maximize their own interests according to the strategy of the other party. Therefore, when the effective trust relationship is established between enterprise strategic alliance enterprises, the participating users A and B will choose the knowledge sharing policy at the same time, which corresponds to the $E_2E_5E_3E_4$ region. At this time, the sharing behavior of, enterprise strategic alliance participating enterprises will gradually evolve to (1, 1) points, and finally converge to the equilibrium point. E_4:

Figure 1: Evolution Phase Diagram of Enterprise Strategic Alliance Participating in Enterprise Knowledge Sharing



(2) In the case of $P_A R_A(1-T_A)+\alpha_A P_B R_B(1-T_B)+\alpha_A \beta P(R_A T_A + R_B T_B) < \gamma_A C_A$,. When the benefit of enterprise strategic alliance participating in enterprise knowledge sharing is less than the cost, for enterprise A, no matter what kind of choice enterprise B makes, the profit of, A knowledge sharing will be less than the shared cost, so it will choose not to share strategy. Because of the symmetry of the game, the same conclusion can be obtained in the analysis of enterprise B strategy, which corresponds to $E_2E_5E_3E_1$. At this time, the knowledge sharing behavior of, enterprise strategic alliance participating enterprises will gradually evolve to (0, 0) points, and finally converge to the equilibrium point E_1. In this case, there will be few exchanges between the participating enterprises of strategic alliance, and there will be no cooperation between enterprises to produce new knowledge, enterprise strategic alliance will survive in name.

3. Numerical Simulation

In the simulation, according to the relevant information, it is assumed that R_A of enterprise A is 50, the knowledge sharing degree T_A is 0.4,and the knowledge price P_A is 30 before sharing knowledge. The knowledge reserve R_B of enterprise B is 30,the knowledge sharing degree T_B is 0.6,and the knowledge price P_B is 15.The enterprise A's knowledge-absorbing conversion capacity factor α_A is 0.5, and the knowledge-absorbing conversion capacity coefficient α_B of the enterprise B is 0.3. The degree of knowledge complementarity coefficient β between enterprise A and enterprise B is 0.6. After knowledge sharing, the price

P of the new knowledge generated is 85;the cost C_A of enterprise A knowledge sharing is 10, the opportunity cost coefficient γ_A is 5;The cost C_B of enterprise B knowledge sharing is 8, and the opportunity cost coefficient γ_B is 3.

3.1. The Effect of Enterprise Knowledge Absorption and Transformation Capability Factor α_A and α_B Changes on the Evolution Result

Figure: 2 The Influence of the Change of Enterprise Knowledge Absorption and Transformation Ability Coefficient α_A on the Evolution Results

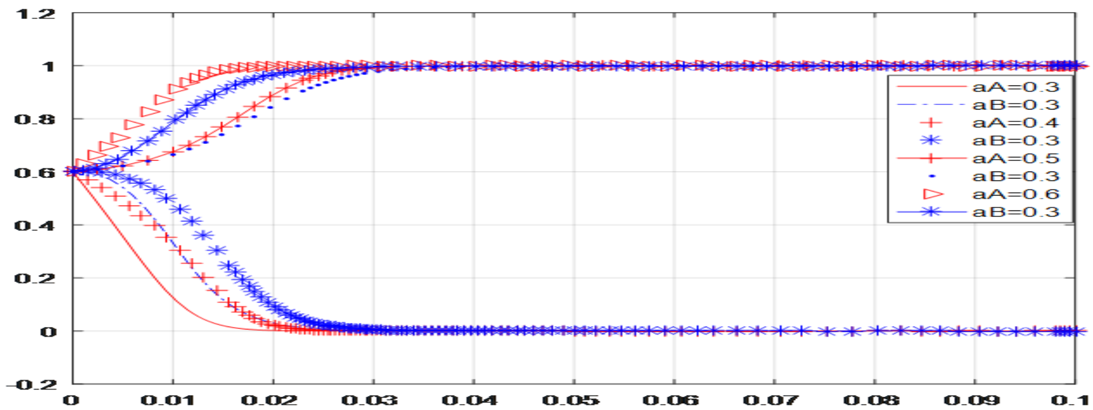
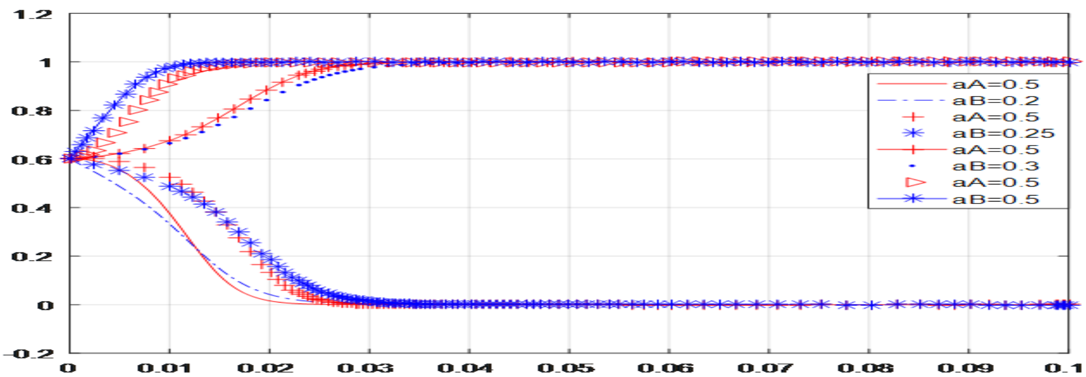


Figure 3: The Influence of the Change of Enterprise Knowledge Absorption and Transformation Ability Coefficient α_B on the Evolution Results



Figs. 2 and 3 show the influence of, enterprise strategic alliance participation in enterprise knowledge absorption and transformation ability coefficient α_A , α_B on the knowledge sharing strategy of participating enterprises under the condition that other parameters remain unchanged.

（1）As can be seen from FIG.2, in the case of the knowledge-absorbing conversion capability coefficient α_A of the enterprise B, the threshold value of the knowledge-absorbing conversion capability coefficient α_A of the enterprise A is between 0.4~0.5. This is because when given the knowledge absorption and transformation ability of enterprise B, the stronger the knowledge absorption and transformation ability of enterprise A, the more income will be obtained; when the α_A is less than this threshold, enterprise A will choose not to carry out knowledge sharing. This is because the transformation ability of A can not well transform the knowledge and new knowledge shared by other enterprises in strategic alliance into the benefits of their own enterprises, but the knowledge shared by themselves will be absorbed by other enterprises, which will cause losses to enterprises.

（2）It can be seen from fig. 3 that under the condition of the knowledge absorption and conversion ability coefficient $\alpha_A = 0.5$ corresponding to A, the threshold of the knowledge absorption and conversion capacity coefficient $0.25\sim0.3$ corresponding to B is between α_B. When the α_B is greater than this threshold, the enterprise tends to knowledge sharing. In a strategic alliance, the reason for enterprise B sharing is consistent with the reason for enterprise A sharing.

（3）The threshold of α_B is smaller than α_A, because the knowledge stock and original knowledge price of enterprise A are obviously higher than the quality of knowledge shared by enterprise B, that is to say, it is very high. Therefore, for enterprise B, it only needs a certain amount of knowledge absorption and transformation ability to obtain considerable benefits.

To sum up, there is a positive correlation between the ability of knowledge absorption and transformation α_A, α_B and the willingness of enterprise strategic alliance to participate in knowledge sharing. Only when the knowledge absorption ability of the two enterprises is stronger, the willingness to participate in the sharing of knowledge will be stronger. At the same time, the knowledge absorption ability of high knowledge level enterprises must be stronger than that of low knowledge level enterprises, so as to ensure that they can obtain the corresponding benefits in the process of knowledge sharing.

3.3. The Influence of the Change of Enterprise Strategic Alliance on the Evolutionary Results of Enterprise Strategic Alliance Participation in the Degree of Knowledge Complementarity of Enterprises

Figure 4: Influence of Knowledge Sharing Degree β on Participating Enterprise Knowledge Sharing Policy without Changing other Parameter Conditions

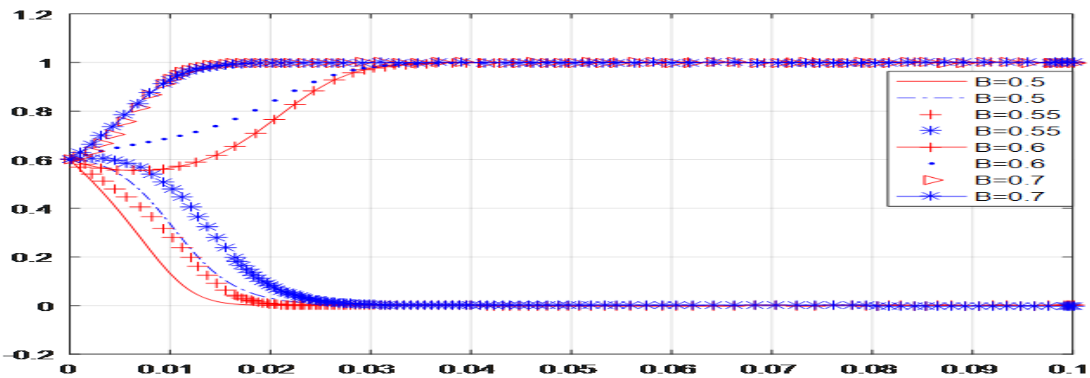


Fig. 4 shows the influence of β on the knowledge sharing strategy of enterprise strategic alliance participating enterprises with the same other parameter conditions. As can be seen from figure 4, the threshold of knowledge complementarity β is between $0.55\sim0.6$. When β is below the threshold, the enterprise A and the enterprise B will gradually converge to 0, and will eventually tend to (0, 0) points, that is, no knowledge sharing. This is because knowledge sharing is meaningless when the knowledge match between the two sides is not high. Not only is it possible to gain the knowledge required by the enterprise, but also to disclose the key information of the enterprise and cause losses, which is very unfavorable to the development of the enterprise. When the β is greater than the threshold, Enterprise A and Enterprise B will gradually converge to 1, and will eventually tend to (1, 1) points, that is, knowledge sharing. This is because when the degree of knowledge matching between the two sides is high enough, not only the information needed for the development of the enterprise can be obtained through knowledge sharing, but also because of the matching of the knowledge of the two sides, it is possible to create new knowledge of great value, which is very beneficial to the future development of the enterprise.

It can be shown that there is a positive correlation between the degree of knowledge complementarity β and the willingness of enterprise strategic alliance to participate in knowledge sharing. The stronger the knowledge complementarity of the two enterprises, the stronger the willingness to participate in the sharing of knowledge.

3.4. The influence of the change of knowledge sharing degree T_A, T_B on the Evolutionary results of enterprise strategic alliance participating Enterprises

Figure 5: The Influence of the Change of Enterprise Knowledge Sharing Degree T_A on the Evolution Result

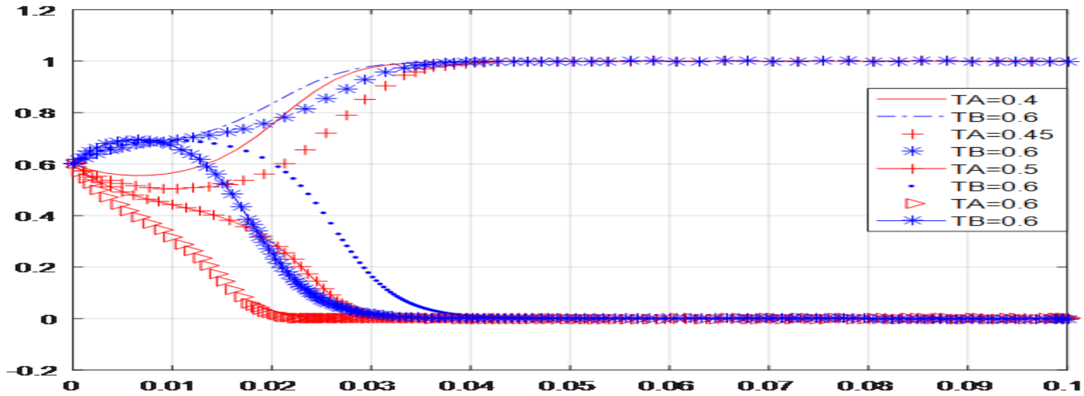


Figure 6: The Influence of The Change of Enterprise Knowledge Sharing Degree T_B on the Evolution Result

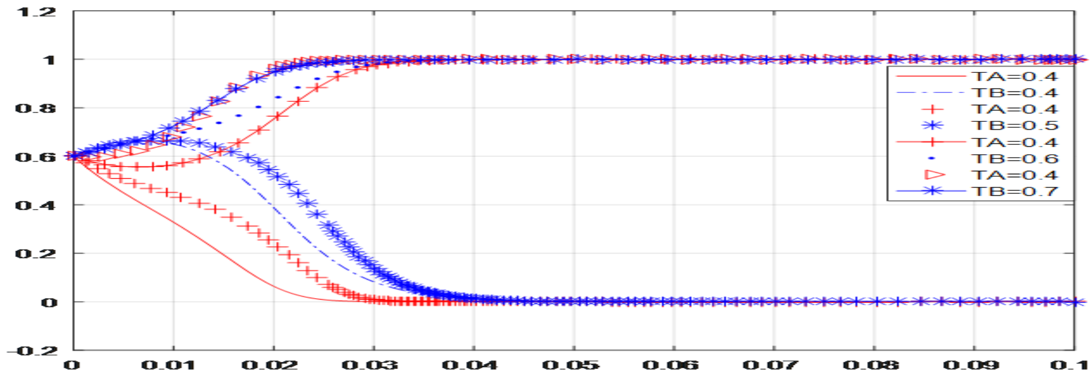


Figure 5 and figure 6 show the influence of the degree of, enterprise strategic alliance participation in enterprise knowledge sharing T_A, T_B on the participating enterprise knowledge sharing strategy when the other parameter conditions remain unchanged. As can be seen from figure 5, under the condition of sharing degree $T_B = 0.6$ of B, the threshold of knowledge sharing degree T_A of A is between 0.45~0.5. When T_A is greater than this threshold, Enterprise A will refuse to implement knowledge sharing in strategic alliance. This is because when the sharing degree of B is given, because of the high level of knowledge of A, if A shares too much knowledge, it will lead to the loss of key knowledge of A, which will result in the loss of enterprise benefit. The cost of, knowledge sharing is greater than the benefit. Figure 6 shows that the threshold of knowledge sharing degree T_B of enterprise B is between 0.5 and 0.6 under the condition of sharing degree $T_A = 0.4$ of enterprise A. When T_B is greater than this threshold, both Enterprise A and Enterprise B will eventually choose knowledge sharing. When T_B is below this threshold, Enterprise A and Enterprise B will eventually choose not to knowledge sharing. This is because the knowledge stock and knowledge price of enterprise B are not high enough compared with enterprise A. only B can share more of its own knowledge to make enterprise A produce knowledge sharing. Otherwise, when the sharing degree of enterprise B is too low, the knowledge shared may not be needed by A to a large extent, and enterprise A will not share knowledge.

It can be shown that the degree of, knowledge sharing has a great influence on the willingness of both sides of knowledge sharing, but the change of the degree of knowledge sharing of different enterprises will have different effects on the willingness of both sides of knowledge sharing. The degree of knowledge sharing of low knowledge level enterprises is positively correlated with the willingness of both sides of knowledge sharing, while the degree of knowledge sharing of high knowledge level enterprises is negatively correlated with the willingness of both sides of knowledge sharing.

4. The Conclusions and Suggestions of the Study

4.1. Research Conclusion

Enterprise strategic alliance participating enterprises have different enterprise size and knowledge level. At the same time, because of the related characteristics such as the ability of knowledge absorption and transformation and the degree of complementarity of knowledge between enterprises, the income obtained by participating in enterprise knowledge sharing can not be described simply by linear relationship. Therefore, based on the characteristics of the enterprise itself and the related characteristics of the inter-enterprise knowledge, the game payment matrix of the enterprise knowledge sharing is established, and the simulation analysis is carried out by using the Matlab software after the strategy stability point is obtained. The effect of relevant parameter changes on the enterprise knowledge sharing policy is discussed, and the following conclusions are drawn:

（1）The coefficient α_A, α_B of participating in knowledge absorption and transformation has a great influence on the willingness of enterprise strategic alliance to participate in knowledge sharing. There is a positive correlation between the coefficient of knowledge absorption and transformation ability and the willingness of enterprises to knowledge sharing. The higher the α_A and α_B, the stronger the willingness of enterprises to knowledge sharing. At the same time, the threshold of α_A is higher than that of α_B. This is because the quality of knowledge shared by enterprise A is higher than that of enterprise B. in order to make the income of sharing knowledge greater than the cost, enterprises must improve their own ability of knowledge absorption and transformation.

（2）The degree of knowledge complementarity β of participating enterprises is positively correlated with the willingness of participating enterprises to knowledge sharing. Only the higher the degree of complementary β and the higher the degree of correlation, the higher the probability of knowledge innovation, and the stronger the willingness to participate in knowledge sharing.

（3）The degree of knowledge sharing has a great influence on the willingness of both sides of knowledge sharing, but the degree of knowledge sharing of enterprises with low knowledge level is positively correlated with the willingness of both sides of knowledge sharing, and the degree of knowledge sharing of enterprises with high knowledge level is negatively correlated with the willingness of both sides of knowledge sharing. Because the quality of their own knowledge is not high, in order to share knowledge, the knowledge sharing degree of enterprises must be higher. In order to prevent the leakage of key knowledge, enterprises with high knowledge level must set up a reasonable range of knowledge sharing degrees.

4.2. Countermeasures and suggestions

In view of the above research conclusions, this paper puts forward some suggestions to promote the willingness of enterprise strategic alliance to participate in the knowledge sharing of enterprises:

（1）Strategic alliance enterprises should strengthen the coefficient of knowledge absorption and transformation ability by introducing talents, improving the management mode of enterprises and improving the decision-making efficiency of enterprises. This way can not only improve the direct benefits of enterprises in knowledge sharing, but also improve the benefits of enterprises in knowledge innovation, in order to improve the willingness of enterprises to knowledge sharing.

（2）Enterprise strategic alliance must set up a reasonable access mechanism to allow enterprises in the same industry and related industries to enter the alliance. This can enhance the correlation of knowledge and the degree of knowledge complementarity among enterprises, improve the probability of knowledge innovation, and thus enhance the willingness of strategic alliance to participate in the knowledge sharing of enterprises.

（3）The enterprises in the strategic alliance must share as much knowledge as possible without disclosing the key information of the enterprise, and actively participate in the knowledge sharing activities of the strategic alliance in order to encourage the enterprise to carry out knowledge sharing;. The problem of knowledge sharing "degree" should be considered during the whole operation, and the key knowledge of the enterprise shall be prevented from being acquired by other enterprises in the strategic alliance.

References

Berraies, S., Lajili, R., & Chtioui, R. (2020). Social capital, employees' well-being and knowledge sharing: does enterprise social networks use matter? Case of Tunisian knowledge-intensive firms. *Journal of Intellectual Capital, 21*(6), 1153-1183. doi:https://doi.org/10.1108/JIC-01-2020-0012

Drewniak, R., & Karaszewski, R. (2020). Diffusion of knowledge in strategic alliance: empirical evidence. *International Entrepreneurship and Management Journal, 16*(2), 387-416. doi:https://doi.org/10.1007/s11365-019-00589-2

Gao, C., Liu, S., Yu, C., & Guo, P. (2021). External Incentive Mechanism Research on Knowledge Cooperation-Sharing in the Chinese Creative Industry Cluster. *Comput. Syst. Sci. Eng., 38*(3), 365-379. doi:https://doi.org/10.32604/csse.2021.016506

González-Tokman, D., Córdoba-Aguilar, A., Dáttilo, W., Lira-Noriega, A., Sánchez-Guillén, R. A., & Villalobos, F. (2020). Insect responses to heat: physiological mechanisms, evolution and ecological implications in a warming world. *Biological Reviews, 95*(3), 802-821. doi:https://doi.org/10.1111/brv.12588

Kong, X., Xu, Q., & Zhu, T. (2019). Dynamic evolution of knowledge sharing behavior among enterprises in the cluster innovation network based on evolutionary game theory. *Sustainability, 12*(1), 75. doi:https://doi.org/10.3390/su12010075

Li, H., Wang, F., Wang, L., Su, L., & Zhang, C. (2020). The stochastic evolution game of knowledge sharing in the infrastructure PPP supply chain network. *Complexity, 2020*, 1-17. doi:https://doi.org/10.1155/2020/8858845

Liu, L., Lin, M., & Yu, M. (2023). Relationship of internal institutions, knowledge sharing, and technological innovation in characteristic cultural enterprises: Evidence from China. *Managerial and Decision Economics, 44*(1), 515-524. doi:https://doi.org/10.1002/mde.3697

Miyamoto, M., & Takeuchi, K. (2019). Climate agreement and technology diffusion: Impact of the Kyoto Protocol on international patent applications for renewable energy technologies. *Energy policy, 129*, 1331-1338. doi:https://doi.org/10.1016/j.enpol.2019.02.053

Nodehi, M., & Taghvaee, V. M. (2022). Alkali-activated materials and geopolymer: A review of common precursors and activators addressing circular economy. *Circular Economy and Sustainability, 2*(1), 165-196. doi:https://doi.org/10.1007/s43615-021-00029-w

Panahi, S., Watson, J., & Partridge, H. (2013). Towards tacit knowledge sharing over social web tools. *Journal of knowledge management*. doi:https://doi.org/10.1108/JKM-11-2012-0364

Wang, Q., Jiang, Q., Yu, H., Fu, R., & Mo, C. (2021). Two-Period Reputation Model of Knowledge Sharing between Enterprises Based on Signal Game Analysis. *Mathematical Problems in Engineering, 2021*, 1-9. doi:https://doi.org/10.1155/2021/6620523