Study on Digital Technology Collaboration Strategy of Supply Chain Enterprises Based on Evolutionary Game

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Abstract. Under changing trend of the digital transformation of the supply chain, with the introduction of technology transfer to construct the digital transformation of the supply chain enterprises third-order game model, analyzes the core and the small and medium-sized enterprises the supply chain decision strategies of the transformation of digital evolution process, and discusses the small and medium-sized enterprises the third strategy choice digital upgrade (unilateral) impact on the stability of the bilateral cooperation. In addition, the influencing factors of digital technology collaboration under different parameter constraints are simulated and analyzed. It is found that in the evolution of digital transformation decision-making strategies of the supply chain core and SMEs, cooperation is the optimal equilibrium strategy of the game, the third strategy of SMEs has a great impact on the stability of digital technology cooperation between the two sides, and its initial proportion is negatively correlated with the probability of cooperation between the two sides. When core enterprises cooperate in digital technology, the smaller the ratio of secondary revenue, the larger the incentive cost, the greater the success rate of cooperation and the greater the technological potential difference, which will accelerate the evolution speed of digital technology cooperation between the two sides.

Keywords: Digitization; Technical collaboration; Evolutionary game; Autonomous systems of differential equations

1 Introduction

Since the innovation and application of the supply chain has been promoted to the national strategy, the supply chain has gradually risen to an important level, and the digital transformation of the supply chain enterprises has also attracted widespread attention[1]. Shao Jingting[2]studied and found that digital technology could effectively improve management efficiency, comprehensive services, technical support and collaborative development among members of the supply chain enterprises. Pietro De Giovanni[3] discussed the prominent role of artificial intelligence technology in coordinating the earnings and environmental performance of each the supply chain enterprise through

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interaction with all participants. Through empirical analysis, Zouari et al.[4] concluded that the application of the supply chain digitalization can improve the resilience of the supply chain enterprises to cope with unexpected turbulence and enhance the resilience of the supply chain. Chen Jian[5] et al. believe that enterprise operation management in the digital environment can improve the operation efficiency of the supply chain enterprises, optimize the operation system and create higher business value. Abubaker and Anshuman[6] also found that digital the supply chain improved lean operation practices and significantly improved the overall the supply chain and business performance. Digital transformation of enterprises brings many advantages, but how to transform enterprises? According to the research of Wang Chuanlei [7] et al., the supply chain control tower can enable the digital transformation of enterprises. In addition, in the "14th Five-Year Plan" and 2035 development strategic plan, it is emphasized to accelerate the digital transformation of logistics in China and realize the green and sustainable development of logistics the supply chain enterprises[8]. Allen Thomas[9] believes that technology transfer can be used in different fields, such as cooperation between enterprises and enterprises and between enterprises and governments.

This article innovation points, one is facing the change trend of the digital transformation, the introduction of the third strategy digital technology to the supply chain collaboration (cooperation) strategy selection, the second is using the differential equation of autonomous systems analysis of core and small and medium-sized enterprise the supply chain cooperation strategy evolution process, It explores the influence of the third strategy and the variation of each parameter on the stability of system collaboration, and provides a quantitative reference for the strategy selection and collaboration of digital transformation of the supply chain enterprises.

2 Evolutionary game model

2.1 Model Hypothesis

Hypothesis 1: The supplier enterprise has strong digital and intelligent technical advantages in the supply chain system, and the initial revenue is assumed w_1, There are obvious technological disadvantages to improve the level of digitalization of small and medium-sized enterprises, initial income w_2, The energy, time and other costs spent by the supply and demand parties in the cooperation process are respectively C_1 and C_2. The digital level of supply and demand is T_1, T_2, $T_1 \geq T_2$. The demander's income after digital technology transformation is reflected by the transformation coefficient (K_2) of potential difference $(T_1 - T_2)$ into income ability.

Hypothesis 2: The success rate of the demander's unilateral digital upgrade is $0 \leq \beta \leq 1$,The success rate of digital transfer cooperation between the two parties is $0 \leq \alpha \leq 1$,Considering the technical advantages of the supplier, $\alpha \geq \beta$ .The income

obtained by the demander after the transfer shall be distributed proportionally. The revenue ratio of the supplier is $0 \le b \le 1, 1-b$ is the proportion of demander's income. In order to improve the overall supply chain efficiency, the supplier gives incentive subsidies to digital transformation enterprises IR, The motivating factor is I, It is affected by the closeness of the two industries, the degree of trust and other factors.

Hypothesis 3: The proportion of suppliers choosing no digital cooperation strategy is $0 \le x \le 1$, Cooperation for $1-x$. The proportion of buyers who choose not to cooperate is $0 \le y_1 \le 1$, The proportion of unilateral digital transformation is $0 \le y_2 \le 1$, Then, the strategy proportion of technology transfer cooperation is $1-y_1-y_2$, among them $0 \le 1-y_1-y_2 \le 1$.

2.2 Model Construction

Revenue of the supplier:

$$\begin{aligned} S_1 &= y_1 W_1 + y_2 (W_1 - IR) + (1 - y_1 - y_2) W_1 \\ S_2 &= y_1 (W_1 - C_1) + y_2 (W_1 - IR - C_1) + (1 - y_1 - y_2)(W_1 + f - IR - C_1) \\ \overline{S} &= W_1 + (1-x)\left[(1-y_1-y_2) f - C_1\right] - IR(1-y_1)(1-x) - x y_2 IR \end{aligned} \tag{1}$$

Revenue of the demander:

$$\begin{aligned} N_1 &= x W_2 + (1-x) W_2 \\ N_2 &= x(W_2 + n + IR) + (1-x)(W_2 + n + IR) \\ N_3 &= x(W_2 - C_2) + (1-x)(W_2 + p + IR - C_2) \\ \overline{N} &= W_2 + (1-y_1-y_2)\left[(1-x)(p+IR) - C_2\right] + y_2 (n + IR) \end{aligned} \tag{2}$$

Based on Equations (1) and (2), the replication dynamic equations of x, y_1 and y_2

$$\begin{cases} U_1(x, y_1, y_2) = \dfrac{dx}{dt} = x(S_1 - \overline{S}) = x(1-x)\left[C_1 + (1-y_1-y_2)(IR - \mathrm{f})\right] \\ U_2(x, y_1, y_2) = \dfrac{dy_1}{dt} = y_1(N_1 - \overline{N}) = y_1(1-y_1-y_2)\left[C_2 - (1-x)(p+IR)\right] - y_1 y_2 (n + IR) \\ U_3(x, y_1, y_2) = \dfrac{dy_2}{dt} = y_2(N_2 - \overline{N}) = y_2(1-y_1-y_2)\left[C_2 - (1-x)(p+IR) + (n+IR)\right] + y_1 y_2 (n + IR) \end{cases} \tag{3}$$

The equilibrium point is obtained by using the autonomous system of differential equations as follows:

$H_1(0,0,0)$, $H_2(0,1,0)$, $H_3(1,0,0)$, $H_4(1,1,0)$, $H_5(\frac{p+IR-C_2}{p+IR}, \frac{f-IR-C_1}{f-IR}, 0)$, $H_6(0,0,1)$, $H_7(1,0,1)$, $H_8(\frac{p-n-C_2}{p+IR}, 0, \frac{f-IR-C_1}{f-IR})$.

3 Equilibrium point evolution analysis

According to the content, the results are as follows:

$$A(x', y_1', y_2') = \begin{pmatrix} \partial U_1/\partial x & \partial U_1/\partial y_1 & \partial U_1/\partial y_2 \\ \partial U_2/\partial x & \partial U_2/\partial y_1 & \partial U_2/\partial y_2 \\ \partial U_3/\partial x & \partial U_3/\partial y_1 & \partial U_3/\partial y_2 \end{pmatrix} \tag{4}$$

When $n+IR>0$ is given in Equation (5), the stable equilibrium point of the evolution of the autonomous system of differential equations is $H_7(1,0,1)$.

Obviously, the characteristic roots $-C_1$, $-(n+IR)$, and $-C_2$ are all less than 0, so equilibrium $H_7(1,0,1)$ is a stable equilibrium. In the same way, $H_1(0,0,0)$ and $H_4(1,1,0)$ are the stable equilibrium point of the system.

4 Simulation analysis

The following array can be assumed based on scholars' research and industry data. $\beta=0.1, I=1, R=20, K_2=300, T_1=10, T_2=4, C_1=C_2=50, C_3=300, b=0.6$. Put the array into the replication dynamic equation (3), For the analysis of reward factor I, take I =1, 8, 15, and the numerical simulation is shown in Figure1.

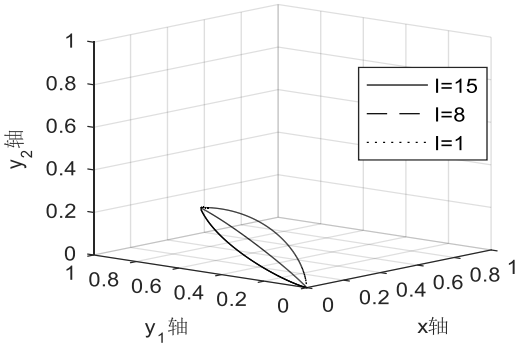

Fig. 1. Influence of parameters I on the evolution of cooperation

5 Conclusion

The study found that for small and medium-sized enterprises the success probability of the third strategy is negatively correlated with cooperation state, when the two sides have technical willingness to cooperate, can technology transfer cooperation of secondary income ratio, the successful conversion, the respect such as reputation material incentive subsidies to coordinate, to strengthen the stability of the cooperation, create win-win synergy and regional industry value.

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References

[1] Wu Weinan. Cloth Software: Reconstructing the Core Enterprise Intelligent Ecological Supply Chain [J]. Energy, 2021(08): 72–74.

[2] Shao Jingting. Research on the reconstruction of enterprise value chain by digital and intelligent technology [J]. Economic Review, 2019(09): 95–102.

[3] De Giovanni Pietro. Smart Supply Chains with vendor managed inventory, coordination, and environmental performance[J]. European Journal of Operational Research, 2021, 292(2): 515–531.

[4] Zouari Dorsaf, Ruel Salomée, Viale Laurence. Does digitalising the supply chain contribute to its resilience?[J]. International Journal of Physical Distribution & Logistics Management, 2021, 51(2): 149–180.

[5] Chen Jian, Huang Shuo, Liu Yunhui. From enabling to enabling: Enterprise operation management in digital environment [J]. Management World, 2020, 36(02): 117-128.

[6] Haddud Abubaker, Khare Anshuman. Digitalizing supply chains potential benefits and impact on lean operations[J]. International Journal of Lean Six Sigma, Emerald Publishing Limited, 2020, 11(4): 731–765.

[7] Wang Chuanlei, Hu Chunhui, Zhang Yu, et al. Supply chain control tower enables enterprise digital transformation [J]. Information Theory & Practice, 2019, 42(9): 7.

[8] He Liming. Review on the development of China's logistics industry in 2020 and prospect in 2021 [J]. China Circulation Economy, 2021, 35(03): 3–8.

[9] Allen Thomas. Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization[M]. 1977.