A Study on Quality Supervision and Coordination of Three-Level Logistics Based on Risk Aversion

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Abstract

This paper studies the quality supervision and coordinated decision-making of three level logistics risks. With the growth of market demand and the increase of logistics service business, the increase of logistics service cooperation level leads to more complicated behavior factors among members of the supply chain. Therefore, this article will be introduced the risk-averse behavior factors to logistics service supply chain, and proves the conclusion through the game model analysis and simulation, and provides a strong basis and decision-making for three levels of logistics service quality supervision and coordination of the supply chain to ensure normal operation of logistics supply.

Keywords

Risk aversion, Logistics service supply chain, Quality supervision and coordination,Game model.

1. Introduction

Under the background of economic globalization, the rapid development of e-commerce has urged the growth of logistics business. Traditional logistics has been unable to meet the growing business demand, and third-party logistics has gradually become the main form of logistics industry. As the logistics service business increases, the logistics service cooperation level leads to more complicated behavior factors among the members of the supply chain. The emergence of third-party logistics can not only improve the efficiency of production transactions, but also enable enterprises to enhance their competitiveness around their core business [1].

Due to the multi-level outsourcing of logistics business, this organizational structure of logistics service supply chain has solved some problems of wasting resources of human and material. The logistics service provider does not directly sign a cooperation contract with the customer, but contracts with the logistics service integrator. If there is no supervision, the logistics service provider may reduce the quality of the provided logistics service, affecting the customer experience, and the supply chain revenue and long-term development. For example, the former owner of Sichuan Transportation Company, Liu Yuanbao, took away the customer's 30 million yuan in payment. It is not only affected the development of Sichuan Transportation Company, but also the reputation of the entire Sichuan supporting industry. In contrast, as a logistics service integrator, Sichuan Dongyun Company, will sort the many logistics service providers of its subsidiaries according to the different risk attitudes of the providers, and select the providers with risk attitudes within a certain range to ensure logistics Service quality can satisfy customers [2].

Obviously, risk evasion research on the quality of logistics service supply chain is particularly important. Requiring multiple logistics services to be completed, the customer wastes resources to cooperate with multiple third-party logistics service companies. Therefore, the multi-level cooperation of the logistics service supply chain needs to consider the risk avoidance behavior factors.

In view of this, this study incorporates the risk aversion behavior factor into the quality supervision system of the three-level supply chain, and considers how to adopt risk aversion to coordinate and improve the quality of the supply chain.

2. Literature review

2.1 Research status

Throughout the literature on the coordination of supply chains at home and abroad, the perspectives and methods of logistics research based on risk aversion are different. Gan et al used a case study method to analyze and establish a contract to improve the retailer's supply chain status and ensure the lowest profit of the supplier when the retailer has risk aversion behavior. The channel coordination is achieved[3, 4]; Wang Xinhui et al have studied the influence of information asymmetry and risk aversion factors on supply chain coordination, indicating that contract design is an effective method for supply chain coordination [5]; Wang Daoping et al applied conditional risk value to measure the risk value of manufacturers and retailers, and introduces the repurchase contract In the supply chain, a supply chain coordination model for joint and unconventional emergencies under joint promotion and risk avoidance is established, which shows that the adjustment of contract parameters can make the supply chain reach the coordination state under the demand disturbance [6]; Xu Minli used the Nash game model and the Stankelberg model to study the supply chain risk avoidance behavior, and analyzed the mechanism of supply chain coordination and coordination contract selection and game mechanism selection under different risk aversion levels [7].

Most of the above studies on risk aversion in the supply chain, however, have remained in the study of individual cases and have not been clearly stated. In the quality and supervision system of logistics, there is little game model to solve the problem of risk aversion at the macro level from the overall aspect of logistics, so further research is necessary.

2.2 Questions description

Behavioral economics believes that policy makers tend to circumvent various external factors that adversely affect themselves, which means they are manifested as risk aversion. Because the members of the supply chain understand the information and the external factors they face when making decisions, in the cooperation of members of the supply chain, each member often shows risk aversion when making decisions. Because in the cooperation of the supply chain, each enterprise has different goals and expected benefits, different companies have different tolerances for various uncertain factors. If the cooperative members show risk avoidance, they will often make the coordination contract invalid.

The interaction and mutual influence of decision-making among members of the supply chain, as well as the status of decision making by each member as a rational person in their own interests, indicate that there is a game behavior among members of the supply chain. The use of game theory to establish a game model to solve decision problems in supply chain systems has become a common means in supply chain research. The Nash equilibrium of each decision-making body in the supply chain refers to a combination of strategies of the participants in the supply chain. Under this combination strategy, no one can change the strategy to benefit themselves and others. This combination of strategies is Nash equilibrium [7]. When the game system obtains the Nash equilibrium solution, it indicates that all the players currently selected by the game participants are the optimal strategies.

2.3 Symbol definition

For the convenience of the narrative, we will define the symbols as shown Table1.

Table1. Symbol definition

Symbol	definition
λ_I	**the Risk Aversion Coefficient of LSI.** λ_I =0 is the risk neutral of LSI, λ_I >0 is the risk aversion of LSI.

λ_s	**the Risk Aversion Coefficient of FLSP.** λ_s=0 is the risk neutral of FLSP, λ_s>0 is the risk aversion of FLSP.
$k_1 w$	**FLSP fixed income from LSI.** w is the fixed income obtained by FLSP when risk neutral. $k_1 = 1 - a_1\lambda_I$ is a risk factor, $a_1 > 0$ is a constant， $k_1 = 1$ is risk neutrality， $0 < k_1 < 1$ is risk aversion.
$k_2 r$	**FLSP's coefficient of gain from cooperation with LSI.** r is the revenue sharing coefficient. $k_2 = 1 - a_2\lambda_2$ is a risk factor, $a_2 > 0$ is a constant, $k_2 = 1$ represents a risk-neutral, $0 < k_2 < 1$ represents a risk aversion;
$f(q)$	**Supervisory cost when LSI supervises FLSP** $f(q) = h(q) + \eta$, q is the supervisory effort level of LSI, h(q) is a monotonically increasing function of q. $\eta \in (0, \sigma_\eta^2)$ indicates an uncertainty factor that has an impact on the cost of supervision, subject to a normal distribution;
$k_3\theta$	θ indicates the risk is neutral, the LSI monitors the penalty value of the FLSP when the FLSP cooperates to spoof. $k_3 = 1 - a_3\lambda_I$ is a risk factor, $a_3 > 0$ is a constant, $k_3 = 1$ represent risk-neutral, $0 < k_3 < 1$ is risk avoidance;
$k_4\varphi$	φ is the private interest obtained by FLSP through cooperative deception when risk neutral, $k_4 = 1 - a_4\lambda_S$ is a risk factor, $a_4 > 0$ is a constant, $k_4 = 1$ represent risk-neutral, $0 < k_4 < 1$ is risk avoidance;
u_1	The influence factor of risk mitigation of FLSP on the expected return of LSI, $0 \le u_1 \le 1$;
u_2	The coefficient of influence of LSI's risk attitude on the expected return of FLSP, $0 \le u_2 \le 1$;
τ	The penalty strength of the primary LSI to the secondary LSI;
x	Supervisory probability of secondary LSI supervising FLSP. x'' represents the optimal monitoring probability of the secondary LSI when considering the risk aversion behavior;
y	Probability of FLSP integrity cooperation. y'' represents the best honest cooperation probability of FLSP when considering risk aversion behavior;

3. Model composition

The third-level logistics service supply chain is composed of a first-level logistics service integrator (LSI), a secondary logistics service integrator, and a logistics service provider (FLSP). The specific cooperation structure is shown in Figure 1.

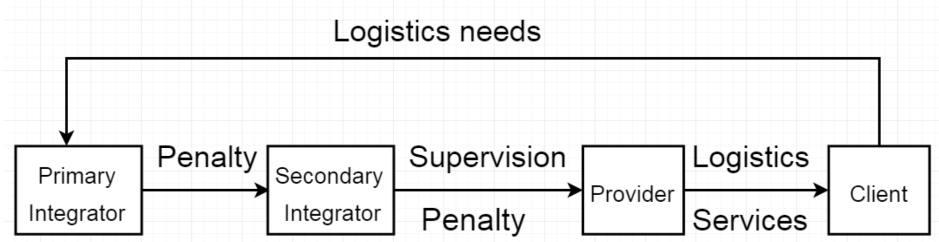

Figure1. The composition of the three-level logistics service supply chain.

The three-level logistics service supply chain has one more LSI than the second-level logistics service supply chain. When the secondary LSI supervises and punishes the FLSP, if the FLSP chooses cooperative fraud, the secondary LSI has no supervision or supervision, will be punished by the first-class LSI. If the secondary LSI discovers the cooperative fraud of the FLSP through supervision, it will not be punished by the primary LSI. In the process of cooperation, the primary LSI does not supervise the secondary LSI, but directly determines whether to punish the secondary LSI through the quality of the logistics service.

3.1 Hypothesis

This article only addresses the case where the secondary LSI does not have the logistics service capability, that is, the secondary LSI completely obtains the logistics service business from the primary LSI, and then completely outsources the logistics service business to the FLSP, and does not provide the logistics service itself. Since this paper mainly studies the relationship between LSI and FLSP, when studying the quality supervision and coordination game model of the three-level logistics service supply chain considering risk aversion behavior, it is assumed that the primary LSI is risk neutral, and the secondary LSI and FLSP are risk aversion.

3.2 Deduction

When FLSP chooses to cooperate in good faith, its effort level is p_1, logistics service cost is $c(p_1)$,then the total revenue of the secondary LSI and FLSP is $\pi(p_1)$,then the revenue of FLSP is $k_1 w + k_2 r(\pi(p_1) - k_1 w) - c(p_1)$.If the secondary LSI chooses not to supervise the FLSP, the secondary LSI revenue is $(1-k_2 r)(\pi(p_1) - k_1 w)$, and if supervision is selected, the revenue is $(1-k_2 r)(\pi(p_1) - k_1 w) - f(q)$.

When FLSP chooses to cooperate in good faith, its effort level is p_2, logistics service cost is $c(p_2)$, then the total revenue of the secondary LSI and FLSP is $\pi(p_2)$, FLSP can obtain private interest $k_4\varphi$ through cooperative deception. If the secondary LSI chooses not to supervise, the profit of FLSP is $k_1 w + k_2 r(\pi(p_2) - k_1 w) - c(p_2) + k_4\varphi$, and the secondary LSI does not find the cooperation fraud of FLSP, and the quality of logistics service is low, it will be subject to the first-level LSI. Penalty, the benefit of then secondary LSI is $(1-k_2 r)(\pi(p_2) - k_1 w) - \tau$; if the secondary LSI chooses to supervise, the probability of FLSP cooperative deception is found by supervision to be ρ. Then the revenue of the FLSP is $k_1 w + k_2 r(\pi(p_2) - k_1 w) - c(p_2) + k_4\varphi - \rho k_3\theta$, the revenue of the secondary LSI is $(1-k_2 r)(\pi(p_2) - k_1 w) - f(q) + \rho k_3\theta - (1-\rho)\tau$.

In summary, the quality supervision and coordination game model of the three-level logistics service supply chain considering risk avoidance can be derived as shown in Table 2:

Table2. Quality Supervision and Coordination Game Model of Three-Level Logistics Service Supply Chain Considering Risk Avoidance

FLSP/LSI		LSI: Supervision (x)	LSI: No Supervision (1-x)
FLSP	Integrity (y)	FLSP: $k_1 w + k_2 r(\pi(p_1) - k_1 w) - c(p_1)$ LSI: $(1-k_2 r)(\pi(p_1) - k_1 w) - f(q)$	FLSP: $k_1 w + k_2 r(\pi(p_1) - k_1 w) - c(p_1)$ LSI: $(1-k_2 r)(\pi(p_1) - k_1 w)$
FLSP	Deceive (1-y)	FLSP: $k_1 w + k_2 r(\pi(p_2) - k_1 w) - c(p_2) + k_4\varphi - \rho k_3\theta$ LSI: $(1-k_2 r)(\pi(p_2) - k_1 w) - f(q) + \rho k_3\theta - (1-\rho)\tau$	FLSP: $k_1 w + k_2 r(\pi(p_2) - k_1 w) - c(p_2) + k_4\varphi$ LSI: $(1-k_2 r)(\pi(p_2) - k_1 w) - \tau$

From Table 3, the expected utility functions of the secondary LSI and FLSP considering risk avoidance can be obtained: The expected utility function of the secondary LSI is:

$$\begin{aligned}U_I^R(x,y)=&x\{y[(1-k_2r)(\pi(p_1)-k_1w)-f(q)]+(1-y)[(1-k_2r)(\pi(p_2)-k_1w)-f(q)+\rho k_3\theta-(1-\rho)\tau]\}\\&+(1-x)\{y[(1-k_2r)(\pi(p_1)-k_1w)]+(1-y)[(1-k_2r)(\pi(p_2)-k_1w)-\tau]\}\\&-\frac{1}{2}(\lambda_I+u_1\lambda_S)(x\sigma_\varepsilon^2+y\sigma_\eta^2)\end{aligned} \tag{1}$$

For the expected utility function of the second-level integrator (1), find the derivative of x, and let the derivation result be 0, then there is:

$$\frac{d(U_I^R(x,y))}{d_x}=-yf(q)+(1-y)[\rho k_3\theta-f(q)+\rho\tau]-\frac{1}{2}(\lambda_I+u_1\lambda_S)\sigma_\varepsilon^2=0$$

$$y''=\frac{\rho(k_3\theta+\tau)-f(q)-\frac{1}{2}(\lambda_I+u_1\lambda_S)\sigma_\varepsilon^2}{\rho(k_3\theta+\tau)} \tag{2}$$

At this point, for the logistics service provider FLSP, its utility function is:

$$\begin{aligned}U_S^R(x,y)=&x\{y[k_1w+k_2r(\pi(p_1)-k_1w)-c(p_1)]+(1-y)[k_1w+k_2r(\pi(p_2)-k_1w)-c(p_2)+k_4\varphi-\rho k_3\theta]\}\\&+(1-x)\{y[k_1w+k_2r(\pi(p_1)-k_1w)-c(p_1)]+(1-y)[k_1w+k_2r(\pi(p_2)-k_1w)-c(p_2)+k_4\varphi]\}\\&-\frac{1}{2}(\lambda_S+u_2\lambda_I)(y\sigma_\varepsilon^2+x\sigma_\eta^2)\end{aligned} \tag{3}$$

Correspondingly, there is：

$$x''=\frac{-T_1+\frac{1}{2}(\lambda_S+u_2\lambda_I)\sigma_\varepsilon^2}{k_3\rho\theta} \tag{4}$$

Especially, $T_1=k_2r\Delta\pi-[c(p_1)-c(p_2)]-k_4\varphi$.

Then, the mixed strategy Nash equilibrium solution of the three-level logistics service supply chain quality supervision and coordination game model considering risk avoidance is:

$$(x'',y'')=\left(\frac{-T_1+\frac{1}{2}(\lambda_S+u_2\lambda_I)\sigma_\varepsilon^2}{k_3\rho\theta},\frac{\rho(k_3\theta+\tau)-f(q)-\frac{1}{2}(\lambda_I+u_1\lambda_S)\sigma_\varepsilon^2}{\rho(k_3\theta+\tau)}\right) \tag{5}$$

Conclusions: It can be concluded from the hybrid strategy Nash equilibrium solution that the penalty strength of the primary LSI only affects the integrity cooperation probability of the FLSP, but has no effect on the supervised probability of the secondary LSI. Considering risk aversion, the risk mitigation of secondary LSI and FLSP is also feasible in the three-level logistics service supply chain. When the first-level LSI risk is neutral, and the secondary LSI and FLSP have risk aversion behavior, the optimal supervision probability of the secondary LSI and the best integrity cooperation probability of the FLSP are (x'',y'').when the secondary LSI and FLSP have risk aversion behavior, it is not conducive to the overall efficiency and benefits of the secondary LSI and FLSP. The risk aversion behavior factor has a negative impact on the quality coordination of the logistics service supply chain.

4. Simulation Analysis

To verify the conclusion, we prove it by case study. Set the simulation parameter values as follows:

Table3. Parameter settings

w	ρ	θ	$f(q)$	σ_ε^2	σ_η^2	r	$\pi(p_1)$	$\pi(p_2)$	$c(p_1)$	$c(p_2)$	φ	μ_n	a_n	τ
25	0.8	50	15	50	90	0.35	155	80	25	10	38	0.5	0.1	50

Note： $\mu_n=\mu_1=\mu_2=\mu_3=\mu_4$, $a_n=a_1=a_2=a_3$ .the value range of λ_I and λ_S is for $\lambda_I\in(0,0.75)$, $\lambda_S\in(0.63,0)$.

4.1 The impact of secondary LSI risk aversion on y''.

Substitute the values of the individual parameters: $y''=\frac{\rho(k_3\theta+\tau)-f(q)-\frac{1}{2}(\lambda_I+u_1\lambda_S)\sigma_\varepsilon^2}{\rho(k_3\theta+\tau)}$ .Set the values of λ_S take 0.6, 0.5, 0.4 respectively. Therefore, we can get the trend of the best integrity cooperation probability of FLSP.

Draw a simulation of Figure2, from which can get the following results:

According to the trend of λ_S, the three lines of 0.6, 0.5, and 0.4 can be obtained that when the risk avoidance of the secondary FLSP is constant, y'' will decrease as λ_I increased.

(2)When the risk avoidance of the secondary LSI is constant, y'' will decrease as λ_S increased. It can be seen that FLSP is more willing to cooperate with secondary LSI with lower risk aversion.

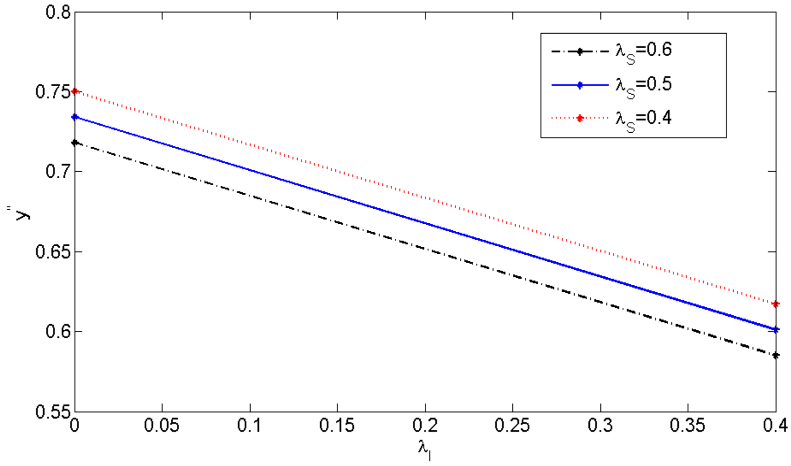

Figure2. The impact of secondary LSI risk aversion on y''

4.2 The impact of risk mitigation of FLSP on y''.

Substitute the values of the individual parameters $y''=\frac{\rho(k_3\theta+\tau)-f(q)-\frac{1}{2}(\lambda_I+u_1\lambda_S)\sigma_\varepsilon^2}{\rho(k_3\theta+\tau)}$ .Set $\lambda_I = 0.6$,the values of u_1 take 0.5,0.6 and 0.7 respectively. Therefore, we can get a change with λ_S and trend of the best monitoring probability of FLSP.

Draw a simulation of Figure 3, from which can get the following results:

(1)According to the trend of the three lines of $\mu 1$ values of 0.5, 0.6, and 0.7, it can be concluded that when the risk avoidance of the secondary LSI is constant, y'' will decrease as λ_S increased.

(2)In Figure 3, the slope of the three lines indicates that the effect of λ_S on y'' is more conspicuous when u1 increased(the risk avoidance of FLSP increases the expected benefit of LSI). Furthermore, the three lines of Figure 3 intersect at the point (0,0.613) . That is, when the attitude of FLSP is risk neutral, the probability of good cooperation of FLSP is certain under the determined degree of secondary LSI risk aversion.

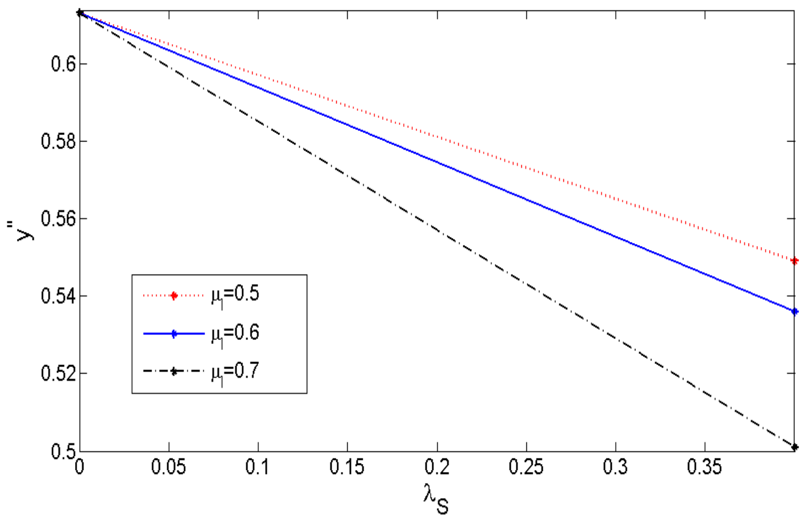

Figure 3.Impact of logistics service provider's risk aversion on y''

5. Theoretical Suggestions

According to the risk avoidance model analysis, several theoretical suggestions were proposed for strengthening the quality coordination of the three-level logistics service supply chain. First, the policy makers can reduce the level of logistics cooperation outsourcing and increase the degree of control over the number of outsourcing layers. Compared with the second-level cooperation, the level of outsourcing of logistics business is increased, quality control and coordination are more difficult to achieve, and the probability of customers being deceived is greater. Second, the supervisor should reasonably regulate the behavior of logistics service providers. For a three-tier logistics service integrator, when the logistics service provider chooses cooperative fraud, if the third-level logistics service integrator fails to supervise or supervise the discovery, it will face the loss of revenue and the punishment of the third-level logistics service integrator. Third, the department personnel should select an integrator with less cooperation level. Since the three-level logistics service integrator will increase the supervision and punishment of the secondary logistics service integrator, the logistics service providers regard the trust in cooperation as an important reference factor. Finally, logistics management, as the core system of the enterprise or supply chain and internal or external suppliers, sellers, distribution centers, intermediate customers or end customers, should focus on the quality and supervision of logistics.

References

[1] Weihua Liu, Jianhua Ji: *Service Supply Chain: New Trends in Supply Chain Research* (Beijing: China Press,2006).

[2] Smidts, A:The Relationship between Risk Attitude and Strength of Preference: a Test of Intrinsic Risk Attitude, Management Science,Vol. 43(1997)No. 3, p. 357–370.

[3] Gan X H, Sethi S P, Yan H M:Coordination of Supply Chains with Risk-Averse Agents, Production and Operations Management, Vol. 13(2004)No. 2, p. 135-149.

[4] Gan X H, Sethi S P, Yan H M: Channel Coordination with a Risk-neutral Supplier and a Downside-risk-averse Retailer, Production and Operations Management, Vol.14(2005)No.1, p. 80-89.

[5] Xinhui Wang, Xianyu Wang: Supply Chain Coordination with Bilateral Information Asymmetry Considering Vendor Risk Aversion, Chinese Management Science, Vol. 23(2015)No. 3, p. 97-107.

[6] Daoping Wang, Boqing Zhang: Supply Chain Coordination Strategy for Emergency Response Under Joint Promotion and Risk Avoidance, Control and Decision, Vol. 32(2017)No. 2, p .498-506.

[7] Huiyun Jian, Minli Xu: Comparison of Supply Chain Contracts Based on Stackelberg Game and Nah Bargaining Game Under Risk Avoidance, Journal of Management, Vol. 13(2016)No.3, p. 47-453.