Research on Optimal Decision of Supply Chain Quality Improvement Consider Cultural Differences between China and the Countries Along the "Belt and Road"

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Abstract

Under the global epidemic situation, the issue of optimal decision of the supply chain quality between China and the countries along the "Belt and Road" has been studied. First, based on the Stackelberg non-cooperative game theory, the optimal decision-making model of the centralized supply chain and the manufacturer-led decentralized supply chain under the three scenarios is constructed, and the optimal quality improvement level, optimal cultural distance, and optimal profit are obtained. Regardless of centralized decision or decentralized decision, the retail price, demand, and supply chain profit under the optimal decision taking into account both cultural distance and quality improvement are the largest. On this basis, through comparative analysis, the relationship between retail price, demand and profit under centralized decision and decentralized decision is obtained and the above conclusions are verified by analysis of examples. The research has shown that cultural distance is inversely related to the retail price and demand. As cultural distance continues to increase, supply chain profit first increases and then decreases. Centralized decision-making has smaller retail price and greater demand than decentralized decision-making. The research has important theoretical and practical significance for making optimal quality decisions along the supply chain along the "Belt and Road" with cultural differences.

Keywords: *optimal decision; supply chain quality; cultural distance; quality improvement; "Belt and Road"*

I. Introduction

The sudden new pneumonia epidemic has caused a certain impact on all walks of life, leading to a slowdown in the global economy and a sharp drop in consumer desire for consumption, which has triggered many enterprises' operational crises. With the continuous spread of the epidemic worldwide, the normal operation of the global supply chain has been disrupted, making the operation of the supply chain along the "Belt and Road" more complicated and difficult. Because new coronaviruses have a very high spread rate, in order to prevent the further spread of the virus, countries along the "Belt and Road" and supply chain enterprises have paid more attention to product quality and improvement issues. There are many countries along the "Belt and Road", and there are significant cultural differences among countries along the political system, religious etiquette, social customs, ecological civilization, power distance, etc., making the supply chain along the line more complicated than the general supply chain, so cultural differences have become a key factor for supply chain quality decision-makers to carefully consider.

In reality, the supply chains along the "Belt and Road" are generally decentralized supply chains, whose members are all independent economic entities, and their goals are often different or even conflict with each other. In the face of cultural differences and improvement of supply chain quality, all members are based on the principle of maximizing their own interests and minimizing risks, resulting in damage to the overall interests of the supply chain, and adverse phenomena such as the bullwhip effect and double marginalization. How to solve the problem of optimal supply chain decision-making under cultural differences and quality improvement is an important issue

worthy of attention for decision-makers and researchers in the supply chain along the "Belt and Road" 错误!未找到引用源。.

Based on Stackelberg non-cooperative game theory, this paper constructs the optimal decision-making model of the centralized supply chain and the decentralized supply chain under the leadership of the manufacturer in three different situations, and obtains the optimal quality improvement level, optimal cultural distance and optimal profit. At the same time, the relationship between cultural distance and retail price, demand, quality improvement level and profit of each organization is studied, and the difference between the optimal decision-making model of the centralized and decentralized supply chain and the model in three situations is analyzed. The research has certain theoretical guiding significance for solving the problem of optimal quality decisions of supply chain along the "Belt and Road" with cultural differences.

II. Literature Review

In the research of supply chain quality decision-making, Dan et al. [0] studied how the quality level of a product affects a manufacturer's decisions and profits, and when a manufacturer decides to improve product quality, the impact of fixed improvement costs on its decisions. Su and Li 错误!未找到引用源。 and Li [I.[4]] used Stackelberg non-cooperative game to consider the supply chain coordination and risk sharing of product quality failure. Ren et al. [I.[3]] constructed a revenue model based on software quality and delivery time, and obtained the conclusion that customer companies have different basic requirements for software product quality and delivery time, and there are different situations in the optimal decisions of ERP vendors and APP vendors. Zhang et al. [I.[6]] constructed a decision model for supplier quality improvement under the asymmetric negotiation ability, and explored the influence of the asymmetric negotiation ability on supplier quality selection. Xiao and Pan [I.[6]] studied the quality coordination problem in the secondary supply chain composed of a single supplier and a single retailer based on the revenue sharing contract, and showed that when the change in sales volume is highly sensitive to product quality improvement, the coordination effect of the revenue sharing contract is better. Zhu et al. [I.[7]] studied the quality improvement of the supply chain considering the quality loss and deferred payment under the fair preference of the manufacturer, and obtained the optimal decision of the manufacturer and supplier to improve the quality in different situations. Li et al. [I.[8]] based on the game theory, considering the dual-channel supply chain coordination problem of quality improvement, found that there are market equilibriums in the three models, and the pure retail model in the mixed channel situation is the most beneficial to the system. Sofiana et al. [I.[9]] considered the quality investment and supply chain profit sharing under the rework policy, established an optimization model for quality improvement, and determined the best quality improvement strategy for the two products considering product sharing. Li et al. [I.[10]] divided customer needs into two categories: quality-sensitive and quality-insensitive for different types of customer needs, and studied the Stackelberg non-cooperative coordination game problem between suppliers and manufacturers under product quality, price and lead time competition.

In the study of cultural differences, Hofstede [I.[12]] measures the cultural differences of different countries, which provides a framework for the hypothetical development of cross-cultural organization research. Subsequently, many scholars used Hofstede's cultural dimension theory to measure the cultural differences of different countries. Based on the modified gravity model, Chen et al. [I.[13]] concluded that there is a negative correlation between cultural distance and China's export trade flow. Yang et al. [I.[14]] applied the threshold effect test method to conclude that there is an inverted U-shaped relationship between cultural distance and the performance of Chinese OFDI companies. Alofan et al. [I.[15]] explored the influence of cultural distance on management innovation decisions of multinational companies through fuzzy sets. Qi and Yang [I.[16]] used panel data of OFDI in 40 countries from 2003 to 2010, and introduced cross-term variables for overall testing. The results showed that geographical distance and cultural distance were in a negative relationship with OFDI.

It can be seen that few scholars consider the influence of cultural differences on the quality decision of the supply chain. This paper considers the important influence of cultural differences on the quality decision of the supply

chain along the "Belt and Road", and studies the optimal decision-making problem of the quality of the supply chain along the "Belt and Road" under the influence of cultural differences.

III. Model Description

The study includes the optimal quality decision problem of the two-level cross-border supply chain S along the "Belt and Road" consisting of a manufacturer M and a retailer R. The research is influenced by cultural differences between China and countries along the "Belt and Road". The manufacturer M improves the quality of products through certain production efforts, and the retailer R purchases products from the manufacturer M and overcome cultural differences to sell products across countries.

Drawing on the literature of Sampath and Rahman I.[17] and using the cultural distance variable φ to measure the cultural differences between China and the countries along the "Belt and Road", it can be seen that cultural differences may have both positive and negative effects on the supply chain. Assuming that both the retailer R and the manufacturer M are risk-neutral, the product market demand d is affected by the retail price p, product quality level ϕ, and cultural distance φ, that is, d decreases as the retail price of the product increases, increases as the quality improvement level increases, and decreases as the cultural distance increases. According to literature I.[18], it is assumed that the functional relationship of d is $d = a - bp + \lambda\phi - \delta(\varphi - \gamma)$, where a is the basic market demand, b is the elasticity coefficient of market demand to price, λ is the elasticity coefficient of market demand to product quality level, δ is the elasticity coefficient of market demand to cultural distance, and γ is the critical value when the positive effect of cultural distance on the supply chain S is equal to the negative effect. Suppose c is the production cost per product of the manufacturer M, and w is the wholesale cost per product of the retailer R. Without loss of generality, this article does not consider the issue of the unit price of logistics services. It is assumed that market demand can be met.

The manufacturer M decides the degree of effort to produce the product and then determines the quality level of the product, and the retailer R sets the retail price of the product according to the expected profit. According to Peng et al. I.[19], it can be seen that the quality improvement cost of manufacturer M is $\alpha\phi^2/2$ and according to the research of Beugelsdijk et al. I.[20], this paper uses $\beta(\varphi-\gamma)^2/2$ to represent the inverted U-shaped nonlinear relationship, which represents the cultural distance to the retailer R cost impact, where β represents the sensitivity coefficient of the retailer R cost to cultural distance. Without loss of generality, this paper does not consider inventory and out-of-stock costs.

This paper refers to Tian and Yan I.[21] on the measurement method of cultural distance, and uses the KS index method to calculate the national cultural distance. The formula is as follows:

$$CD_{oc} = \frac{1}{6}\sum_{n=1}^{6}\left(I_{ni} - I_{nc}\right)^2 / V_n \quad (1)$$

CD_{oc} in the formula represents the size of the cultural differences. The calculation refers to the cultural differences algorithm of Kogut&Singh (1988), I_{ni} represents the score of the n-th dimension of country i, and I_{nc} represents the score in the n-th dimension of China(excluding Hong Kong, Macau and Taiwan). V_n represents the variance of the scores of the n-th dimension of the countries along the "Belt and Road" in the

study.

Scores of six dimensions and cultural distance of countries along the “Belt and Road are as Table 1:

Table 1 Scores of six dimensions and cultural distance of countries along the “Belt and Road”

Countries	*PDI*	*IDV*	*MAS*	*UAI*	*LTO*	*IVR*	cultural distance
China	80	20	66	30	87	24	0.0000
Vietnam	70	20	40	30	57	35	0.6644
Thailand	64	20	34	64	32	45	2.0357
Malaysia	100	26	50	36	41	57	1.5169
Singapore	74	20	48	8	72	46	0.6831
Indonesia	78	14	46	48	62	38	0.6023
Philippines	94	32	64	44	27	42	1.3539
India	77	48	56	40	51	26	0.9281
Pakistan	55	14	50	70	50	0	1.6885
Bengal	80	20	55	60	47	20	0.7893
Bhutan	94	52	32	28	0	0	3.5534
Nepal	65	30	40	40	0	0	2.7699
Sri Lanka	80	35	10	45	45	0	2.4938
Turkey	66	37	45	85	46	49	2.3544
Iran	58	41	43	59	14	40	2.5557
Israel	13	54	47	81	38	0	4.8926
UAE	90	25	50	80	0	0	3.3164
Egypt	70	25	45	80	7	4	3.0063
Syria	80	35	52	60	30	0	1.7159
Kuwait	90	25	40	80	0	0	3.5152
Lebanon	75	40	65	50	14	25	1.7579
Jordan	70	30	45	65	16	43	2.2373
Iraq	95	30	70	85	25	17	2.2495
Saudi Arabia	95	25	60	80	36	52	2.1422
Russia	93	39	36	95	81	20	2.2606
Poland	68	60	64	93	38	29	3.1443
Czech Republic	57	58	57	74	70	29	2.0048
Slovakia	100	52	100	51	77	28	1.5947
Hungary	46	80	88	82	58	31	4.3237
Slovenia	71	27	19	88	49	48	3.0126
Croatia	73	33	40	80	58	33	1.6009
Romania	90	30	42	90	52	20	1.9817
Bulgaria	70	30	40	85	69	16	1.6261
Serbia	86	25	43	92	52	28	1.9672
Estonia	40	60	30	60	82	16	2.7710
Lithuania	42	60	19	65	82	16	3.2456
Latvia	44	70	9	63	69	13	4.3173
Albania	90	20	80	70	61	15	0.9258
Ukraine	92	25	27	95	86	14	2.3638

Data source: Hofstede official website. The PDI, IDV, MAS, UAI, LTO and IVR in the table refer to the six cultural dimensions of Power Distance, Individualism versus Collectivism, Masculinity versus Femininity, Uncertainty versus Avoidance, Long-term versus Short-term and Indulgence versus Restraint .

IV. Model Building

4.1 Research on Optimal Decision of Supply Chain Without Considering Cultural Distance and Quality Improvement

4.1.1 Research on Optimal Decision of Decentralized Supply Chain

In the case of decentralized decision-making, the profit functions of the retailer, the manufacturer and the supply chain are expressed as follows:

$$\prod_R = (p-w)(a-bp) \quad (2)$$

$$\prod_M = (w-c)(a-bp) \quad (3)$$

$$\prod_T = (p-c)(a-bp) \quad (4)$$

Using Stackelberg reverse induction method to solve, let $\frac{\partial \prod_R}{\partial p} = 0$, we can get $p = \frac{a+bw}{2b}$, and substitute it into (3). let $\frac{\partial \prod_M}{\partial w} = 0$, we can get the optimal wholesale price $w_D^* = \frac{a+bc}{2b}$, the optimal retail price $p_D^* = \frac{3a+bc}{4b}$, the optimal retailer profit $\prod_{DR}^* = \frac{(a-bc)^2}{16b}$, the optimal manufacturer profit $\prod_{DM}^* = \frac{(a-bc)^2}{8b}$, the optimal supply chain profit $\prod_{DS}^* = \frac{(a-bc)^2}{4b}$, and the optimal demand $d_D^* = \frac{a-bc}{4}$ under decentralized decision.

4.1.2 Research on Optimal Decision of Centralized Supply Chain

Let $\frac{\partial \prod_T}{\partial p} = 0$, we can get the optimal retail price $p_C^* = \frac{a+bc}{2b}$, the optimal supply chain profit $\prod_{CS}^* = \frac{(a-bc)^2}{4b}$, and the optimal demand $d_C^* = \frac{a-bc}{2}$ under centralized decision.

4.2 Research on Optimal Decision of Supply Chain Considering Cultural Distance

4.2.1 Research on Optimal Decision of Decentralized Supply Chain

The order of decision is: in the first stage, the manufacturer determines the wholesale price of the product with the goal of maximizing its profit; in the second stage, the retailer determines the retail price and cultural distance of the product. The profit functions of the retailer, the manufacturer and the supply chain are expressed as follows:

$$\prod_R = (p-w)[a-bp-\delta(\varphi-\gamma)]-\beta(\varphi-\gamma)^2/2 \quad (5)$$

$$\prod_M = (w-c)[a-bp-\delta(\varphi-\gamma)] \quad (6)$$

$$\prod_S = (p-c)[a-bp-\delta(\varphi-\gamma)]-\beta(\varphi-\gamma)^2/2 \quad (7)$$

The Hessian matrix of $\prod_R$ with respect to p and φ is $H = \begin{pmatrix} -2b & -\delta \\ -\delta & -\beta \end{pmatrix}$. It is easy to know that when $2b\beta - \delta^2 > 0$, the Hessian matrix of $\prod_R$ with respect to p and φ is negative definite. Let $\frac{\partial \prod_R}{\partial p} = 0$,

$\frac{\partial \Pi_R}{\partial \varphi}=0$, we can get the optimal wholesale price $w_D^*=\frac{a+bc}{2b}$, the optimal retail price $p_D^*=\frac{b\beta(3a+bc)-\delta^2(a+bc)}{2b(2b\beta-\delta^2)}$, the optimal cultural distance $\varphi_D^*=\gamma-\frac{\delta(a-bc)}{2(2b\beta-\delta^2)}$, and the optimal demand $d_D^*=\frac{b\beta(a-bc)}{2(2b\beta-\delta^2)}$ under the decentralized decision. The optimal profit of the retailer, the manufacturer and the supply chain under the decentralized decision are: $\prod_{DR}^*=\frac{\beta(a-bc)^2}{8(2b\beta-\delta^2)}$, $\prod_{DM}^*=\frac{\beta(a-bc)^2}{4(2b\beta-\delta^2)}$, $\prod_{DS}^*=\frac{3\beta(a-bc)^2}{8(2b\beta-\delta^2)}$.

4.2.2 Research on Optimal Decision of Centralized Supply Chain

The Hessian matrix of Π_S about p and φ is $H=\begin{pmatrix}-2b & -\delta\\ -\delta & -\beta\end{pmatrix}$. It is easy to know that if β satisfies $2b\beta-\delta^2>0$, and then the Hessian matrix of Π_S about p and φ is negative definite. Let $\frac{\partial \Pi_S}{\partial p}=0$, $\frac{\partial \Pi_S}{\partial \varphi}=0$, we can get the optimal retail price $p_C^*=\frac{\beta(a+bc)-c\delta^2}{2b\beta-\delta^2}$, the optimal cultural distance $\varphi_C^*=\gamma-\frac{\delta(a-bc)}{2b\beta-\delta^2}$, the optimal supply chain profit $\prod_{CS}^*=\frac{\beta(a-bc)^2}{2(2b\beta-\delta^2)}$ and the optimal demand $d_C^*=\frac{b\beta(a-bc)}{2b\beta-\delta^2}$ under centralized decision.

4.3 Research on Optimal Decision of Supply Chain Considering Both Cultural Distance and Quality Improvement

4.3.1 Research on Optimal Decision of Decentralized Supply Chain

The profit functions of the retailer, the manufacturer and the supply chain are expressed as follows:

$$\Pi_R=(p-w)[a-bp+\lambda\phi-\delta(\varphi-\gamma)]-\beta(\varphi-\gamma)^2/2 \quad (8)$$

$$\Pi_M=(w-c)[a-bp+\lambda\phi-\delta(\varphi-\gamma)]-\alpha\phi^2/2 \quad (9)$$

$$\Pi_S=(p-c)[a-bp+\lambda\phi-\delta(\varphi-\gamma)]-\alpha\phi^2/2-\beta(\varphi-\gamma)^2/2 \quad (10)$$

The Hessian matrix of Π_R with respect to p and φ is $H=\begin{pmatrix}-2b & -\delta\\ -\delta & -\beta\end{pmatrix}$. It is easy to know that when $2b\beta-\delta^2>0$, and then the Hessian matrix of Π_R with respect to p and φ is negative definite. The Hessian

matrix of Π_M with respect to ϕ and w is $H=\begin{pmatrix} -\alpha & \dfrac{b\beta\lambda}{2b\beta-\delta^2} \\ \dfrac{b\beta\lambda}{2b\beta-\delta^2} & \dfrac{-2b^2\beta}{2b\beta-\delta^2} \end{pmatrix}$. It is easy to know that if α and β satisfy $2\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2>0$, and then the Hessian matrix of Π_M with respect to ϕ and w is negative definite. Let $\frac{\partial\Pi_R}{\partial p}=0$, $\frac{\partial\Pi_R}{\partial\varphi}=0$, we can get the optimal quality improvement level $\phi_D^*=\frac{\beta\lambda\left(a-bc\right)}{2\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2}$, the optimal wholesale price $w_D^*=\frac{\alpha\left(a+bc\right)\left(2b\beta-\delta^2\right)-bc\beta\lambda^2}{2\alpha b\left(2b\beta-\delta^2\right)-b\beta\lambda^2}$, the optimal retail price $p_D^*=\frac{\alpha\left(a+bc\right)\left(b\beta-\delta^2\right)+b\beta\left(2\alpha a-c\lambda^2\right)}{2\alpha b\left(2b\beta-\delta^2\right)-b\beta\lambda^2}$, the optimal cultural distance $\varphi_D^*=\gamma-\frac{\alpha\delta\left(a-bc\right)}{2\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2}$ and the optimal demand $d_D^*=\frac{\alpha b\beta\left(a-bc\right)}{2\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2}$ under decentralized decision. The optimal profit of the retailer, the manufacturer and the supply chain under decentralized decision are:

$$\Pi_{DR}^*=\frac{\alpha^2\beta\left(a-bc\right)^2\left(2b\beta-\delta^2\right)}{2\left[2\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2\right]^2},\qquad \Pi_{DM}^*=\frac{\alpha\beta\left(a-bc\right)^2}{2\left[2\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2\right]},$$

$$\Pi_{DS}^*=\frac{\alpha\beta\left(a-bc\right)^2\left[3\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2\right]}{2\left[2\alpha\left(2b\beta-\delta^2\right)-\beta\lambda^2\right]^2}.$$

4.3.2 Research on Optimal Decision of Centralized Supply Chain

In this case, the Hessian matrix of Π_S with respect to p, ϕ, and φ is $H=\begin{pmatrix} -2b & \lambda & -\delta \\ \lambda & -\alpha & 0 \\ -\delta & 0 & -\beta \end{pmatrix}$. It is easy to know that if α and β satisfy $2b\alpha-\lambda^2>0$ and $2b\alpha\beta-\alpha\delta^2-\beta\lambda^2>0$, and then the Hessian matrix of Π_S with respect to p, ϕ, and φ is negative definite. Let $\frac{\partial\Pi_S}{\partial p}=0$, $\frac{\partial\Pi_S}{\partial\phi}=0$, $\frac{\partial\Pi_S}{\partial\varphi}=0$, we can get the optimal retail price $p_C^*=\frac{\alpha\beta\left(a+bc\right)-c\left(\alpha\delta^2+\beta\lambda^2\right)}{2b\alpha\beta-\alpha\delta^2-\beta\lambda^2}$, the optimal quality improvement level $\phi_C^*=\frac{\lambda\beta\left(a-bc\right)}{2b\alpha\beta-\alpha\delta^2-\beta\lambda^2}$, the optimal cultural distance $\varphi_C^*=\gamma-\frac{\alpha\delta\left(a-bc\right)}{2b\alpha\beta-\alpha\delta^2-\beta\lambda^2}$, the optimal supply chain profit $\Pi_{CS}^*=\frac{\alpha\beta\left(a-bc\right)^2}{2\left(2b\alpha\beta-\alpha\delta^2-\beta\lambda^2\right)}$ and the optimal demand $d_C^*=\frac{b\alpha\beta\left(a-bc\right)}{2b\alpha\beta-\alpha\delta^2-\beta\lambda^2}$ under centralized decision.

V. Example Analysis

5.1 Numerical Setting and Example Analysis

Suppose the basic demand of a product market is $a=60$, the manufacturer's unit production cost is c=8, and $b=6$, $\lambda=3$, $\delta=2$, $\alpha=2$, $\beta=3$, $\gamma=2.5$ [22]. The market demand functions in the above three situations are $d=60-6p$, $d=60-6p-2(\varphi-2.5)$, and $d=60-6p+3\phi-2(\varphi-2.5)$, respectively. The cost of quality improvement by the manufacturer and the cost of the retailer caused by cultural distance are $c(\phi)=\phi^2$ and $c(\varphi)=1.5(\varphi-2.5)^2$, respectively. Therefore, the variables and profit values of the three situations under centralized decision and decentralized decision can be obtained.

Table 2 The optimal variables and profit values of three situations under centralized decision

Different situations	p	d	ϕ	φ	Π_T
Without considering cultural distance and quality improvement	9	6	——	——	6
Considering cultural distance	9.125	6.75	——	1.75	6.75
Considering cultural distance and quality improvement	9.9459	11.6757	2.9189	1.2027	11.6757

Table 3 The optimal variables and profit values of the three situations under decentralized decision

Different situations	p	d	w	ϕ	φ	Π_R	Π_M	Π_T
Without considering cultural distance and quality improvement	9.5	3	9	——	——	1.5	3	4.5
Considering cultural distance	9.5625	3.375	9	——	2.125	1.6875	3.375	5.0625
Considering cultural distance and quality improvement	9.9802	4.2772	9.2673	1.0693	2.0248	2.7103	4.2772	6.9874

It can be seen from Table 2 and Table 3 Whether it is a centralized decision or a decentralized decision, the retail price, demand, and supply chain profit under the optimal decision while considering cultural distance and quality improvement are the largest. The retail price, demand, and supply chain profit under considering cultural distance are the second, and the retail price, demand, and the retail price, demand, and supply chain profit are the smallest without considering the cultural distance and quality improvement. In addition, under decentralized decision-making, the profit of the retailer and the manufacturer that consider cultural distance and quality improvement are also the largest.

5.2 The Influence of Cultural Distance on Variable value and Profit Value in Different Situations

5.2.1 Decentralized Supply Chain Quality Decision Analysis

It can be seen from Figures 1 and 2: under decentralized decision-making, only considering cultural distance and considering cultural distance and quality improvement, cultural distance is inversely proportional to retail price and demand, and when cultural distance exceeds a certain value, them will be less than the retail price and demand without considering the cultural distance and quality improvement. The retail price and demand in the case of considering both are greater than the retail price and demand in the case of considering cultural distance, respectively.

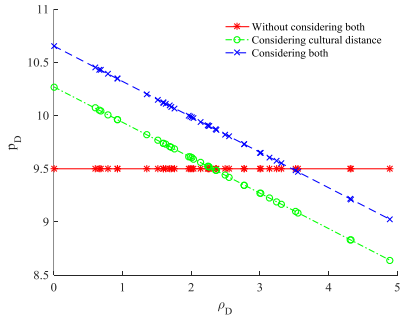

Fig 1 The influence of cultural distance on the retail price under decentralized decision

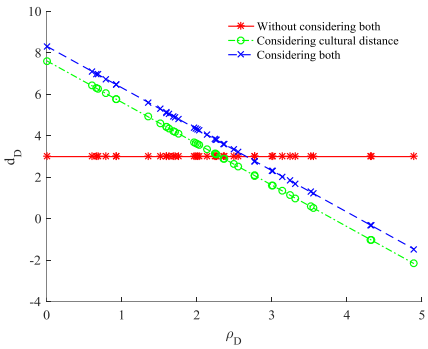

Fig 2 The influence of cultural distance on the demand under decentralized decision

It can be seen from Figures 3, 4 and 5: under decentralized decision-making, only considering cultural distance and considering cultural distance and quality improvement, the profit of the manufacturer is inversely proportional to the cultural distance and the profit of the retailer and the supply chain increases first and then decreases as the cultural distance increases. The profit of the retailer considering both is greater than the profit of the retailer considering only cultural distance. When the cultural distance is not very large, the profit of the manufacturer and the supply chain considering both are greater than the profit of the manufacturer and the supply chain considering only cultural distance.

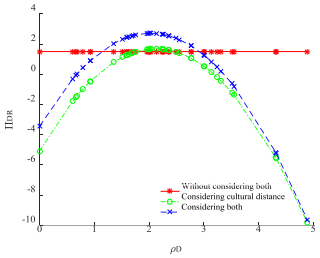

Fig 3 The influence of cultural distance on the retailer profit under decentralized decision

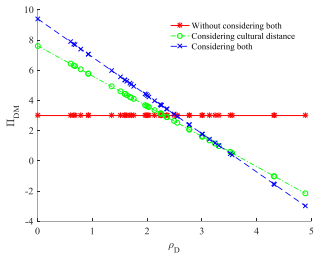

Fig 4 The influence of cultural distance on the manufacturer profit under decentralized decision

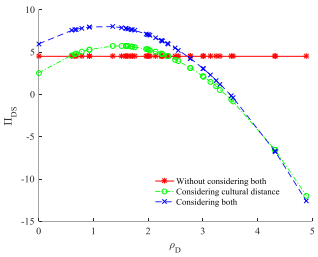

Fig 5 The influence of cultural distance on the supply chain profit under decentralized decision

5.2.2 Centralized Supply Chain Decision Analysis

Through Figure 6, Figure 7 and Figure 8, it is found that when centralized decision-making only considers cultural distance and considers cultural distance and quality improvement, cultural distance is inversely proportional to the retail price and demand, and when cultural distance exceeds a certain value, them will less than the retail price and demand without considering both. As the cultural distance increases, the profit of the supply chain increases first and then decreases. When the cultural distance is within a certain range, the profit of the supply chain under considering both is the largest, the profit of the supply chain under considering only cultural distance is the second, and the profit of the supply chain without considering both is the smallest. But when the cultural distance is not within this range, there will be other situations.

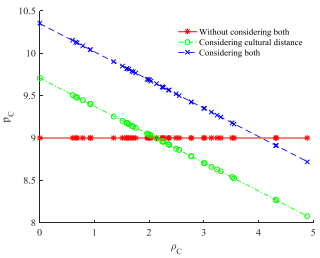

Fig 6 The influence of cultural distance on the retail price under centralized decision

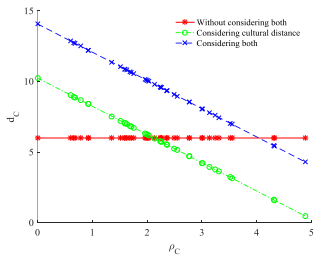

Fig 7 The influence of cultural distance on the demand under centralized decision

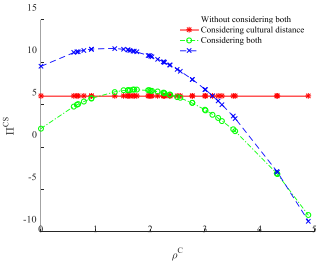

Fig 8 The influence of cultural distance on the supply chain profit under centralized decision

5.2.3 Comparison of Centralized Decision and Decentralized Decision

From Figure 9, Figure 10 and Figure 11, we can know that when only considering the cultural distance, the retail price under centralized decision is less than the retail price under decentralized decision, and the demand under centralized decision is greater than the demand under decentralized decision. When the cultural distance is not very small, the profit of the supply chain under centralized decision is greater than the profit of the supply chain under decentralized decision.

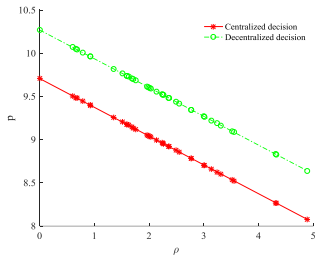

Fig 9 The influence of cultural distance on the retail price under considering cultural distance

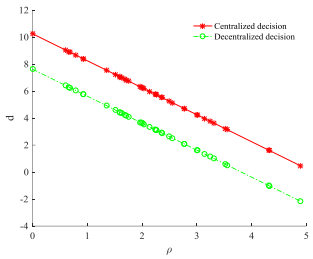

Fig 10 The influence of cultural distance on the demand under considering cultural distance

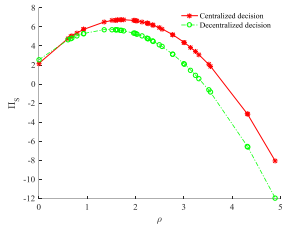

Fig 11 The influence of cultural distance on the supply chain profit under considering cultural distance

As can be seen from Figures 12, 13, 14 and 15, considering the cultural distance and quality improvement, the retail price under centralized decision is less than the retail price under decentralized decision, while the demand, quality improvement level and the supply chain profit under centralized decision are greater than the demand, quality improvement level and the supply chain profit under decentralized decision-making, respectively, and the cultural distance is directly proportional to the quality improvement level.

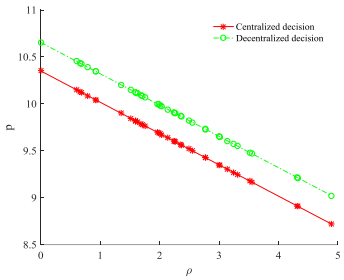

Fig 12 The influence of cultural distance on the retail price under considering both

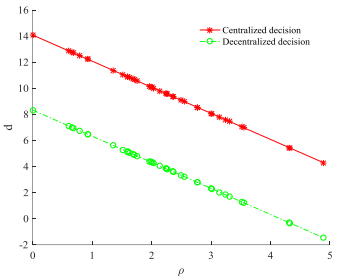

Fig 13 The influence of cultural distance on the demand under considering both

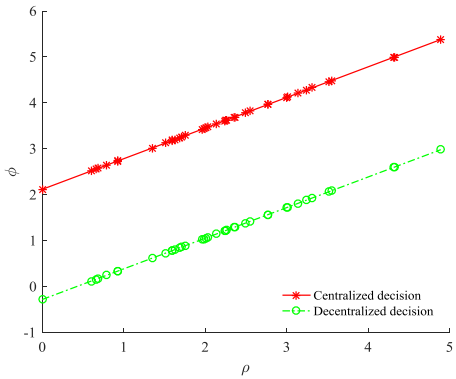

Fig 14 The influence of cultural distance on the quality improvement level under considering both

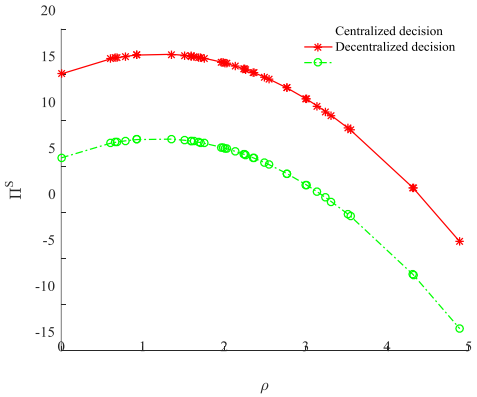

Fig 15 The influence of cultural distance on the supply chain profit under considering both

VI. Conclusion

With the spread of new coronaviruses around the world and the proposition of the “Belt and Road” major strategy, the importance of cultural differences and quality improvement in the supply chain along the “Belt and Road” has become increasingly prominent. In order to reduce supply chain losses, maintain supply chain credibility, and improve the core competitiveness of the supply chain along the route, and considering the impact of cultural differences and quality improvement on the supply chain along the route is problem that decision makers must pay attention to. In the context of the global epidemic situation and the “Belt and Road” policy, this paper separately constructs the centralized supply chain and decentralized supply chain in three situations to compare and analyze the optimal decisions under centralized and decentralized decision.

The results of the study show that cultural distance is inversely proportional to the retail price and demand, and cultural distance is directly proportional to the level of quality improvement. No matter whether it is centralized decision or decentralized decision, the retail price, demand and supply chain profit under the optimal decision taking into account both cultural distance and quality improvement are the largest. Under centralized decision-making, as the cultural distance increases, the profit of the supply chain increases first and then decreases. When the cultural distance is small, the profit of the supply chain under considering both is the largest, the profit of the supply chain under considering cultural distance is the second, and the supply chain profit is the smallest without considering both. Under decentralized decision-making, the profit of the manufacturer is inversely proportional to the cultural distance. The profit of the retailer and supply chain increases first and then decreases as the cultural distance increases. In the case of considering only cultural distance, the retail price under centralized decision-making is smaller than that under decentralized decision-making, and the demand under centralized decision-making is greater than that under decentralized decision-making. When the cultural distance is not very small, the profit of the supply chain under centralized decision is greater than the profit of the supply chain under decentralized decision. Under considering cultural distance and quality improvement, the retail price under centralized decision is less than the retail price under decentralized decision, while the demand, quality improvement level and the supply chain profit under centralized decision are greater than those under decentralized decision.

This paper uses cultural distance to measure the cultural differences of countries along the “Belt and Road”, but cultural differences are a very complex influencing factor. It is not accurate enough to use only one variable to measure cultural differences. Supply chain quality decision-making research based on multi-variable measurement of cultural differences is also a very important and valuable issue, which will be the focus of our next research. In addition, this paper only constructs the centralized and decentralized supply chain in three situations to perform comparative analysis on optimal decision-making. It does not use other contracts such as revenue sharing contracts, repurchase contracts or comprehensive contracts to coordinate, and uses repurchase contracts or comprehensive contracts. Contract coordination supply chain is also a problem worthy of study. There is no use of revenue sharing contracts, repurchase contracts, comprehensive contracts and other contracts to coordinate. Coordinating the supply chain with repurchase contracts or comprehensive contracts is also a problem worthy of study

Acknowledgements

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