Research on Pricing Decision and Coordination in Cross-Border Supply Chain

Yanna-Bao, Fuchang-LI*

School of Economics and Management
Yunnan Normal University
Kunming, P.R.China
** Corresponding author: 2095614551@qq.com*

ABSTRACT
In the context of the rapid development of cross-border trade and the gradual popularization of the mobile Internet, the development of cross-border supply chains has become more complex, and the needs of consumers have become more diverse. This paper analyzes the supply chain dominated by foreign retailers by establishing decentralized decision-making, centralized decision-making, and revenue-sharing decision-making models, trying to explain the impact of logistics service levels on the overall or partial profits of cross-border supply chains. The results show that the overall profit of the supply chain under the decentralized decision-making model is lower than the total profit under the centralized decision-making and revenue-sharing decision-making models; under the guarantee of the revenue-sharing contract, the profits of each node enterprise in the cross-border supply chain can be maximized .

Keywords: *cross-border supply chain; logistics service level; stackelberg game; revenue sharing*

1.INTRODUCTION

With the upgrading of domestic and foreign consumer markets and changes in consumer attitudes, the idea of "buying and selling the world" is deeply rooted in the hearts of the people, and the development of cross-border trade has become more and more prosperous. Driven by global trends, my country's cross-border trade and cross-border e-commerce platforms have developed rapidly. According to my country's customs statistics as of July 2021, my country's total import and export value was 21.34 trillion yuan, a year-on-year increase of 24.5%, of which exports were 1.166 billion yuan, a year-on-year increase of 23.5%; imports were 9.68 trillion yuan, a year-on-year increase of 24.4%. Cross-border trade has derived a cross-border supply chain, which involves domestic manufacturers, foreign retailers, third-party cross-border logistics companies, foreign consumers and other subjects from upstream to downstream. The level of expectations continues to rise, and it is difficult for a single enterprise to play various roles in the cross-border supply chain alone. This paper constructs a cross-border supply chain consisting of domestic manufacturers, third-party cross-border logistics enterprises, and foreign retailers, and attempts to use the decision-making model of decentralization, concentration, and revenue sharing to explain the impact of factors such as logistics level on the overall revenue of the supply chain, so as to strengthen the enterprise The emphasis on logistics services in the cross-border supply chain will promote the further development of my country's cross-border supply chain.

2.RELEVANT LITERATURE REVIEWS

Combined with the current development of cross-border trade, the research related to cross-border supply chain covers a wide range. In the existing literature, the research on supply chain mostly focuses on pricing strategy, contract coordination, inventory sharing effect and so on. Combined with the research points of this paper, the literature on pricing strategy and contract coordination will be described here. First, in terms of pricing strategy, Lei Jin (2013) adopted the idea of dynamic pricing strategy to analyze and solve the problem of channel conflict, and came to the conclusion that dynamic pricing will bring greater benefits. Hongfang Song (2018) proposed in the review of dynamic pricing research that the relationship between price, inventory and demand should be fully considered in the process of supply chain management, and suggested that decision-making should be made in a dynamic environment. Pavithra et al. (2019) proposed an

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omni-channel pricing solution to achieve independent pricing for retailers and coordinate cross-channel coordination of prices. The omni-channel pricing method is a comprehensive pricing method that enables retailers to maintain a certain market share while being competitive. Lingqiao Fu (2020) analyzed the impact of the imposition of tariffs on the pricing strategy of the supply chain, and showed that the impact of tariffs on the supply chain is proportional to the tariff rate. Manufacturers share higher tariff costs than distributors, and retailers share the lowest ratio. Rafael (2019) improved product pricing methods by establishing a demand selection model to avoid price spillovers. Secondly, in terms of contract synergy, Zhiping Du (2020) took the cross-border e-commerce supply chain as the research object, and introduced a reward coefficient, so as to build a reward mechanism based on the growth of supply chain members improvement of business level, and apply the "The Revenue Sharing + Quantity Discount" combined contract model discusses the coordinated operation of the cross-border e-commerce supply chain. Yongwei Zhou (2020) set up bonded warehouses for retailers in the free trade zone, bonded the imported goods, and then sold them through online channels. He further used the stackelberg game model to analyze the expected profits, and achieved coordination by establishing a revenue sharing contract.

This paper discusses the coordinated operation of the cross-border supply chain based on the revenue-sharing contract model, and takes the cross-border supply chain of domestic manufacturers, third-party cross-border logistics enterprises, and foreign retailers as the research objects, and concludes that the cooperation under the revenue-sharing contract is more conducive to The stable operation of the supply chain can maximize the protection of the interests of enterprises at each node in the supply chain.

3.Problem Description and Model Building

The cross-border supply chain involved in this paper is mainly composed of a domestic manufacturer, a third-party cross-border logistics enterprise, a foreign retailer and consumers, and domestic manufacturers are dominant. The relevant symbols and main parameters involved in the model construction of the cross-border supply chain pricing strategy and coordination decision-making are shown in Table 1.

Table 1 Description of symbols and main parameters

Symbol /parameter	Definition	Explanation Symbol/Parameter	Definition Explanation
s	Domestic manufacturer	P_l	Unit-logistics service price
r	oreign retailer	P_r	Foreign retailer unit-product selling price
l	Third-party cross-border logistics companies	q	Sales volume of foreign retailers
c_s	Production cost per unit of product by domestic manufacturer	c_r	Unit sales cost of foreign retailer
w_s	Wholesale price per unit of product	f	Decentralized decision making
l_l	Third-party cross-border logistics enterprise logistics service level	j	Centralized decision-making
c_l	unit logistics service cost	C	revenue sharing decision
β_l	Logistics service cost coefficient	γ_1	Consumer sensitivity to commodity prices
C (l_l)	Quadratic function of logistics service level	γ_2	Sensitivity coefficient of consumers to logistics service level
μ_l	evenue-sharing contract parameters	μ_s	Revenue-sharing contract parameters

	provided by foreign retailers to domestic manufacturers		provided by foreign retailers to domestic manufacturers
Q	Market size		

According to Table 1, the production cost per unit product of domestic manufacturers is c_s, and the wholesale price per unit product is w_s; the logistics service level of third-party cross-border logistics enterprises is l_l, the unit logistics service cost is c_l, and the unit logistics service price is P_l; The foreign retailer's unit product sales price is P_r, the sales volume is q, and the unit sales cost is c_r, and it is assumed that $P_r>P_s+P_l+c_r>c_s+c_l+c_r$, $P_s>c_s$, $P_l>c_l$. The relevant assumptions for the model are as follows:

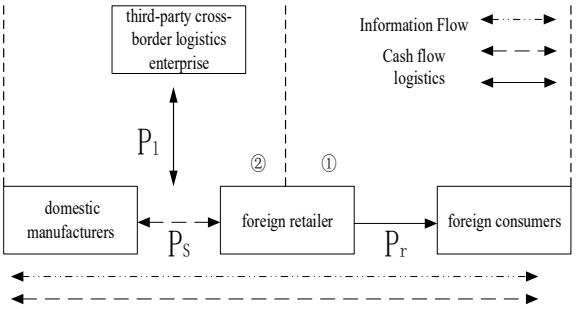
Hypothesis 1: At this time, the wholesale price w_s of the domestic manufacturer's unit product is already optimal; then the domestic manufacturer's profit $\prod_s{}^f$ has been the optimal function;

Hypothesis 2: Market demand is negatively correlated with commodity prices, and market demand is positively correlated with logistics service levels. Market demand is a linear function of product price and logistics services. The logistics service is determined by the capability level l_l of the third-party cross-border logistics enterprise, and the market demand is: D=Q$-\gamma_1 p_r+\gamma_2 l_l$, where Q is the size of market, $\gamma_1$and $\gamma_2$are the prices of commodities, Sensitivity coefficient of logistics service level, and γ_i >0;

Hypothesis 3: The higher the service level of third-party cross-border logistics enterprises, the higher the cost of logistics services. Referring to the research of Xiao et al. (2008) and Zhiping Du (2020), the cost increase C(l_l) brought by the improvement of logistics service level by third-party logistics is a quadratic function of logistics service level l_l, then C (l_l)=$\frac{\beta_l l_l^2}{2}$, where β_l is the logistics service cost coefficient, and β_l>0;

3.1. Coordinated decision-making model of cross-border e-commerce supply chain under decentralized decision-making

In a cross-border supply chain dominated by foreign retailers, foreign retailers first determine the sales price P_r of the product, while domestic manufacturers, as followers, determine the wholesale price w_s of products based on the decisions of foreign retailers, third-party logistics services The enterprise decides its logistics service price P_l and logistics service level l_l, which constitutes a stackelberg game model. The game sequence diagram under decentralized decision-making is shown in Figure 1.



Note: ① is the first stage game, foreign retailers set the unit product sales price P_r; ② is the second stage game, domestic manufacturers follow foreign retailers to set the unit product wholesale price w_s, and the third logistics service enterprise sets the unit logistics service Price P_l and logistics service level l_l

Figure 1 The sequence diagram of the stackelberg game under decentralized decision making

According to the above assumptions, the overall profit functions of foreign retailers, domestic manufacturers, third-party logistics platforms and cross-border supply chains are respectively$\prod_r{}^f$、$\prod_s{}^f$、$\prod_l{}^f$和$\prod^f$:

$$\prod_r{}^f=(P_r-w_s-P_l-c_r)*D=(P_r-w_s-P_l-c_r)*(Q-\gamma_1 p_r+\gamma_2 l_l) \quad (1)$$

$$\prod_s{}^f=(w_s-c_s)*D=(w_s-c_s)*(Q-\gamma_1 p_r+\gamma_2 l_l) \quad (2)$$

$$\prod_l{}^f=(P_l-c_l)*D-C(l_l)=(P_l-c_l)*(Q-\gamma_1 p_r+\gamma_2 l_l)-\frac{\beta_l l_l^2}{2} \quad (3)$$

$$\prod^f=\prod_r{}^f+\prod_s{}^f+\prod_l{}^f \quad (4)$$

Assuming that w_s and P_l are fixed values, according to the stackelberg game, the derivation calculation is carried out by the reverse induction method.

First, find the first derivative of $\prod_l{}^f$with respect to l_l from formula (3), and obtain the optimal logistics service level l_l^{f*} as:

$$l_l^{f*}=\frac{(P_l-c_l)*\gamma_2}{\beta_l} \quad (5)$$

Secondly, find the first derivative of $\prod_r{}^f$ with respect to P_r from formula (1), and bring the optimal logistics service level into formula (5) to obtain the optimal unit product sales price P_r^{f*} for:

$$P_r^{f*}=\frac{\gamma_2{}^2(P_l-c_l)+Q\beta_l}{2\gamma_1\beta_l} \quad (6)$$

Finally, the optimal service level l_l^{f*}in equation (5) and the optimal unit product sales price P_r^{f*} in equation

(6) are brought into equation (1) (3) to get the foreign retail sales The overall optimal profit functions of merchants, third-party logistics platforms, and cross-border supply chains are:

$$\prod_r^{f*}=\left(\frac{\gamma_2^{\,2}(P_l-c_l)+Q\beta_l}{2\gamma_1\beta_l}-w_s-P_l-c_r\right)*\left(Q-\frac{3\gamma_2^{\,2}(P_l-c_l)+Q\beta_l}{2\beta_l}\right) \quad (7)$$

$$\prod_s^{f}=(w_s-c_s)*D=(w_s-c_s)*(Q-\gamma_1 p_r+\gamma_2 l_l) \quad (2)$$

$$\prod_l^{f*}=\frac{3\gamma_2^{\,2}(P_l-c_l)-4\gamma_2^{\,2}(P_l-c_l)^{\,2}+Q\beta_l}{2\beta_l} \quad (8)$$

$$\prod_f^{f*}=\prod_r^{f*}+\prod_s^{f}+\prod_f^{f*} \quad (9)$$

3.2.Coordinated decision-making model in cross-border e-commerce supply chain under centralized decision-making

In the case of centralized decision-making, there is complete trust among foreign retailers, domestic manufacturers, and third-party cross-border logistics companies, and information is transparent in the cross-border supply chain, which can achieve true sharing. The node enterprises are not considering maximizing their own profits, but foreign retailers, domestic manufacturers, and third-party cross-border logistics companies negotiate together to maximize the entire process of the cross-border supply chain. The schematic diagram of decision-making in the cross-border supply chain under centralized decision-making is shown in Figure 2.

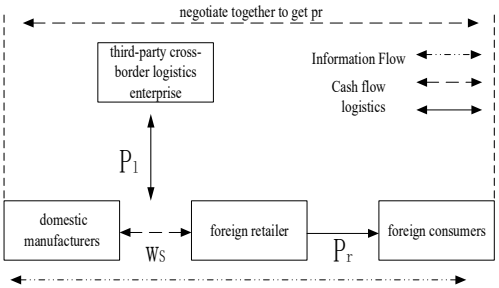


Figure 2 Schematic diagram of centralized decision-making

According to the above model assumptions, it can be concluded that the optimal overall profit function after the three-party negotiation of the cross-border supply chain is:

$$\prod_j^{j*}=(P_r-c_s-c_r-c_l)*D-C(l_l)=(P_r-c_s-c_r-c_l)*(Q-\gamma_1 p_r+\gamma_2 l_l)-\frac{\beta_l l_l^{\,2}}{2} \quad (10)$$

Similarly, the first-order derivatives of l_l and P_r are calculated for formula (10) respectively, and the optimal logistics level l_l^{j*} and the optimal product sales price P_r^{j*} are obtained as follows:

$$l_l^{j*}=\frac{(P_r-c_s-c_r-c_l)*\gamma_2}{2\beta_l} \quad (11)$$

$$P_r^{j*}=\frac{3\gamma_2^{\,2}c_s+3\gamma_2^{\,2}c_r+\gamma_2^{\,2}c_l}{8\beta_l\gamma_1-3\gamma_2^{\,2}} \quad (12)$$

Finally, the optimal logistics level l_l^{j*} and the optimal product sales price P_r^{j*} are put into formula (10), and it can be obtained that the overall profit of the cross-border supply chain is optimal at this time:

$$\prod_j^{j*}=\prod_j^{j*}(l_l^{j*},\ P_r^{j*}) \quad (13)$$

3.3. Coordinated decision-making model in cross-border e-commerce supply chain under revenue sharing contract

The revenue sharing contract can effectively reduce the price competition among enterprises in the cross-border supply chain, and can further coordinate the contradictions between enterprises at each node. Under the coordination of revenue sharing contracts, foreign retailers must not only take into account the maximization of their own interests, but also the related interests of domestic manufacturers and third-party cross-border logistics companies. The profit of income distribution is jointly negotiated by foreign retailers, third-party cross-border logistics companies, and domestic manufacturers, which maximizes the coordination of cross-border supply chains.

Under the coordination of revenue sharing, foreign retailers, the leader of the cross-border supply chain, will reach certain contracts with domestic manufacturers and third-party cross-border logistics companies. Domestic manufacturers will continue to supply domestic retailers, and both parties negotiate μ_s, $\mu_s>0$ is the contract parameter for revenue sharing, and its revenue sharing amount $\alpha_s=\gamma_1 w_s\mu_s$; secondly, due to the high-quality logistics service level will promote market demand the increase of the quantity is $\gamma_2 l_l$, while the foreign retailers provide μ_l, $\mu_l>0$ revenue sharing contract parameters to encourage the services of third-party cross-border logistics enterprises, the revenue sharing amount $\alpha_l=\gamma_2 l_l P_l\mu_l$. The expected profit function of foreign retailers, domestic manufacturers and third-party cross-border logistics enterprises under the revenue sharing contract is as follows:

$$\prod_r^{c*}=[(P_r-w_s-P_l)*D-c_r]*D-\alpha_s-\alpha_l=[(P_r-w_s-P_l)*(Q-\gamma_1 p_r+\gamma_2 l_l)-c_r]*(Q-\gamma_1 p_r+\gamma_2 l_l)-\gamma_1 w_s\mu_s-\gamma_2 l_l P_l\mu_l \quad (14)$$

$$\prod_s^{c*}=(w_s-c_s)*D+\alpha_s=(w_s-c_s)*(Q-\gamma_1 p_r+\gamma_2 l_l)+\gamma_1 w_s\mu_s \quad (15)$$

$$\prod_l^{c*} = (P_l - c_l) * D - C(l_l) + \alpha_l = (P_l - c_l) * (Q - \gamma_1 p_r + \gamma_2 l_l) - \frac{\beta_l l_l^2}{2} + \gamma_2 l_l P_l \mu_l \quad (16)$$

Combining formulas (14) and (16) to obtain the first derivative of P_r and l_l respectively, the optimal logistics level l_l^{c*} and the optimal product sales price P_r^{c*} are obtained as follows:

$$l_l^{c*} = \frac{\gamma_2 (P_l - c_l - P_l \mu_l)}{2\beta_l} \quad (17)$$

$$P_r^{c*} = \frac{4\beta_l Q_1 - \gamma_2^2 (P_l - c_l - P_l \mu_l)}{4\beta_l \gamma_1} \quad (18)$$

Substituting l_l^{c*} and P_r^{c*} into equations (14) (15) (16), the optimal profit and the maximum profit of the cross-border supply chain under the revenue sharing contract.

Under the revenue-sharing contract model, supply chain coordination can be achieved only when the optimal decision under centralized decision-making is equal to the optimal decision under decentralized decision-making, that is, when $l_l^{c*} = l_l^{f*}$, When the equation (17) and (5) are combined together, the equation (19) is obtained as follows:

$$\frac{\gamma_2 (P_l - c_l - P_l \mu_l)}{2\beta_l} = \frac{(P_l - c_l) * \gamma_2}{\beta_l} \quad (19)$$

Equation (19) is obtained to obtain the revenue sharing contract parameter μ_l,

$$\mu_l = \frac{(\gamma_2 c_l - P_l)}{P_l} \quad (20)$$

When the revenue sharing contract parameters meet the above requirements, the cross-border supply chain can achieve coordination. The coordination of the revenue sharing contract can not only increase the overall revenue of the supply chain compared with decentralized decision-making, but also realize a situation in which domestic manufacturers, foreign retailers, and third-party cross-border logistics companies can all benefit. The unification is conducive to strengthening the cooperation among the nodes

4. Example Analysis

In order to more intuitively reflect the effectiveness of the above decision-making strategies, the actual numerical values are now used for analysis, and the numerical selection satisfies the objective conditions. Numerical assumptions are shown in Table 2.

Table 2 Parameter assumption value information table

No.	Symbol/parameter	Definition	Description Value
1	P_l	unit logistics service price	40
2	w_s	unit product wholesale price	60
3	c_r	Foreign retailer unit cost of goods sold	16
4	c_s	Production cost per unit product of domestic manufacturer	24
5	c_l	Cost of logistics services per unit	12
6	β_l	Logistics service cost factor	30
7	γ_1	Consumer sensitivity to commodity prices	8
8	γ_2	Sensitivity coefficient of consumers to logistics service level	4
9	Q	Market size	2400

Taking the values in Table 2 into decentralized decision-making, centralized decision-making, and revenue-sharing decision-making, the relevant pricing and information needs of foreign retailers, domestic manufacturers, and third-party cross-border logistics companies can be obtained as shown in Table 3.

Table 3 Analysis table of numerical calculation results

Decision-making method		Decentralized decision-making	Centralized decision-making	Revenue sharing decision
Unit product sales price	Symbol	P_r^{f*}	P_r^{j*}	P_r^{c*}
	Numerical value	150.93	112.82	123.42
Symbol Numerical value	Symbol	l_l^{f*}	l_l^{j*}	l_l^{c*}
	Numerical value	3.73	4.05	5.26
Maximum profit of	Symbol	$\prod_s^f$	------	$\prod_s^{c*}$

domestic manufacturers	Numerical value	42399.36	------	50433.09
Maximum revenue of third-party cross-border logistics enterprises	Symbol	$\prod_l^{f*}$	------	$\prod_l^{c*}$
	Numerical value	30885.03		38919.76
Maximum profit of foreign retailers	Symbol	$\prod_r^{f*}$	------	$\prod_r^{c*}$
	Numerical value	83379.21	-----	91413.94
The overall maximum profit of the cross-border supply chain	Symbol	$\prod_f^{f*}$	$\prod_j^{j*}$	$\prod_c^{c*}$
	Numerical value	156663.60	180767.80	180767.80

It can be seen from the coordination analysis results that the overall benefits of the supply chain under centralized decision-making and coordinated decision-making are better than those under decentralized decision-making. The revenue sharing strategy plays an effective role in regulating the overall supply chain, so that the overall revenue of the cross-border supply chain can reach the level of centralized decision-making, and it is beneficial to all participants in the supply chain.

5.CONCLUSION

Combining the impact of logistics services on cross-border supply chains, this paper builds a supply chain model consisting of domestic manufacturers, foreign retailers, and third-party cross-border logistics companies, and studies the impact of logistics service levels on supply chain pricing decisions and profits. The results show that the overall benefits obtained under centralized decision-making and revenue-sharing decision-making are greater than the benefits of decentralized decision-making; under the decision-making of revenue-sharing model, domestic retailers sign relevant contracts with third-party cross-border logistics companies and domestic manufacturers to ensure high-quality products. The high-quality logistics service level provides overseas consumers with high-quality logistics service experience, which effectively protects the interests of cooperative members and enables the cross-border supply chain to operate stably for a long time.

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About the Author

Yanna Bao (1995-), female, Han, from Qujing City, Yunnan Province, is a postgraduate student at the School of Economics and Management of Yunnan Normal University, her research direction is e-commerce, logistics and supply chain management.

Fuchang Li (1981-), male, Han, from Lechang City, Guangdong Province, Ph.D., professor of the School of Economics and Management of Yunnan Normal University, doctoral supervisor, research direction: logistics and supply chain management, financial engineering and risk management.

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