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Decision-making in cross-border e-commerce supply chains and coordination under revenue sharing and deferred payment contracts

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A B S T R A C T

Deferred payment and revenue-sharing contracts are significantly important for promoting the collaboration and the management of retail export supply chains for cross-border e-commerce. This research addresses the real-world challenges faced by managers in this domain by using a joint optimization model to investigate the best ordering and pricing tactics within cross-border e-commerce retail export supply chains, particularly taking into account export tax rebates and import tariffs. Our findings reveal that while revenue-sharing contracts and deferred payment mechanisms can significantly enhance supply chain profitability, their effectiveness is contingent on variables such as export rebate rates, tariffs, and tariff transfer factors. The practical implications of this study suggest that business administrators should carefully assess these factors when designing contracts to ensure robust supply chain coordination. When traditional contract mechanisms fail, hybrid approaches combining revenue-sharing and deferred payment can offer superior outcomes, thus providing a strategic advantage in volatile markets. These insights are crucial for managers seeking to navigate the complexities of international trade and optimize their supply chain performance.

1. Introduction

Cross-border e-commerce retail export, as a novel approach of international trade, helps diversify and broaden export channels, reducing the impact of trade barriers, better meeting the end consumer demand, and facilitating the enhancement of industrial structure. Meanwhile, the growing complexity and severity of international situations and international trade disputes make cross-border e-commerce retail exports face increasing uncertainty. Cost control has become an important way to improve export competitiveness, the core of which is pricing and inventory optimization management. In the cross-border e-commerce export supply chain, logistics management is usually the responsibility of a third party, while the two core decisions of pricing and inventory are jointly the responsibility of domestic manufacturers and foreign retailers. The wholesale price of domestic manufacturers and foreign market demand directly affect the retail price decision of foreign retailers (Niu et al., 2022). Pricing decisions and supply and demand structure determine inventory management, and the two influence and interact with each other. As an important means to adjust demand fluctuation and price fluctuation, inventory affects the adjustment of retail price and direct selling price. Decisions in inventory management are often handled separately, which can lead to deviations from optimal decisions, resulting in overall welfare losses. Therefore, the combination of pricing and inventory decision-making can optimize the overall performance and effectively resolve the "reverse interest" phenomenon among supply chain members. Inventory coordination is especially difficult given the unpredictability of customer demand. (Cao & Zuo 2015). Compared with e-commerce in China, the unique feature of cross-border e-commerce export is that it needs to consider the impact of tariffs. For example the experience of Shandong province's export-driven enterprises illustrates the importance of efficient tax rebate processes in maintaining a competitive edge in international markets. In February 2023, the Qingdao Area of the China (Shandong) Pilot Free Trade Zone implemented a new initiative to expedite export tax rebates.

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This initiative was aimed at reducing the time required for enterprises to receive their tax refunds, thereby improving their cash flow and financial stability. Fluctuations in tariffs not only can force Numerous manufacturers to revise their production schedules, but also when the country of origin increases tariffs, manufacturers are compelled to target markets with lower tariff rates (Wang et al., 2021). Cross-border e-commerce is vulnerable to export tax rebate policies. Policy changes can impact the profitability and competitiveness of exporters' foreign firms. Manufacturers should assess the tariff impact, focusing on import and export tariffs as well as the impact of tax rebate policies.

In the case of fierce market competition and product homogeneity, sellers not only provide commercial credit to retailers, but also promote the sales of final products through certain rebate incentives (Zhan et al., 2019). Revenue-sharing contracts (RSC) are contracts that define how profits and losses are shared among supply chain participants. (Bart et al., 2021), and Revenue-sharing contracts have gained significant popularity nowadays. The leading party can effectively coordinate the cross-border e-commerce retail export supply chain and sustain the stability of the partnership by designing revenue-sharing contracts that fairly allocate excess earnings, compensating the follower for any profit losses (Zhai et al., 2020). However, rising uncertainty in the international economic landscape can reduce foreign demand, causing a decline in the profits of foreign retailers and intensifying competition within the supply chain. In a related study, Tang et al. (2021) explored the optimization of credit terms in a dual-channel supply chain and discovered that when customers favor retailer channels more or are less sensitive to price, the manufacturer gains a larger share of profits and has greater leverage in negotiations. Deferred payment, as a form of internal credit financing, offers a strategic advantage in supply chains by alleviating financial constraints faced by foreign downstream enterprises. This payment method allows retailers to expand their product orders by deferring payment for goods to a later date, thus enabling them to overcome cash flow limitations. Typically, retailers are required to pay for goods upon receipt, which limits their order volume based on their available funds. To encourage purchasing despite these financial constraints, suppliers often provide deferred payment terms, which allow retailers to settle payments within a specified period. This arrangement benefits both parties. Retailers can increase their inventory, improving product availability and boosting sales, while suppliers benefit from higher sales volumes to retailers. However, deferred payment also introduces a degree of risk, as retailers may face the possibility of being unable to repay their debts (Boulaksil & van Wijk, 2018). The profitability of firms is positively correlated with payment delays, which are in turn influenced by factors such as the difference in capital costs between buyers and suppliers, as well as the price elasticity of demand and inventory deterioration rates (Seifert et al., 2017). Consequently, suppliers must carefully weigh the risks of inventory management and potential credit defaults when deciding whether to offer deferred payment terms.

For enterprises, being able to effectively manage pricing and inventory in the cross-border e-commerce supply chain can not only enhance competitiveness, but also directly affect their market share and profitability. For example, small manufacturers entering international markets through cross-border e-commerce platforms are able to achieve lower market entry costs and higher profit margins. However, due to the constant changes in tariff policies and international trade disputes, these enterprises face many challenges, such as cost control and inventory optimization become particularly critical. Deferred payment has become an effective strategy for cross-border e-commerce to deal with capital liquidity problems. Especially when funds are tight, deferred payment can relieve the financial pressure of retailers, while also promoting the stable operation of the supply chain. For example, the revenue-sharing contract between manufacturers and retailers not only maintains the stability of supply chain cooperation but also enhances market competitiveness by reasonably allocating excess returns. In addition, the fluctuation of tariff and export tax rebate policies of importing countries directly affects the profit margin and market strategy of enterprises. These practical needs have driven the study on the optimization of cross-border e-commerce retail export supply chain to help enterprises remain competitive and sustainable in the complex and changeable market environment.

Many studies in the existing research focus on price management and inventory control in cross-border supply chains, but little studies reveal the interaction mechanism of price management and inventory control in cross-border e-commerce supply chains, and the impact of their integration and optimization on the overall performance of the supply chain. Also, they give little attention paid to the joint impact of deferred payment on pricing decisions and inventory management. To address these research gaps, this study proposes the following research questions.

(1) How do deferred payment and revenue-sharing contracts facilitate collaboration within the cross-border e-commerce retail export supply chain?
(2) What is the coordination effect when the two contracts are mixed?
(3) How will export tax rebates and import tariffs affect the coordination mechanism?

This paper addresses the identified challenges by employing a two-stage Stackelberg game model, which focuses on a cross-border e-commerce supply chain featuring a manufacturer and a retailer. The model incorporates revenue-sharing and deferred payment contracts, alongside the influence of tariff rebates and inventory considerations. It seeks to determine the optimal strategies for both the individual entities and the overall supply chain. The key contributions of this study are outlined below:

(1) Include inventory optimization in pricing decisions.
(2) In cross-border e-commerce, we consider import tariffs, export tax rebates and tariff transfer factors, which are crucial for cross-border e-commerce enterprises to enter new markets and improve competitiveness.

(3) We consider the application of revenue sharing contract and deferred payment in the cross-border e-commerce supply chain, and consider the mixed use of the two contracts, which is relatively common in real life, but few scholars have studied the hybrid contract.
(4) Revenue-sharing contracts, deferred payments, and their combination each offer distinct advantages for the supply chain, depending on the situation. When used separately, both revenue sharing and deferred payments provide benefits to the supply chain. However, when applied together in a mixed contract, the overall supply chain benefit surpasses the benefits of using either method alone, at any given time.

The structure of this paper is as follows: Section 2 offers a concise review of the relevant literature. Section 3 outlines the model assumptions and notation. Section 4 addresses the coordination of cross-border export supply chains. Section 5 provides an analysis of the algorithm. Lastly, Section 6 concludes with key findings and proposes potential avenues for future research.

2. Literature review

The literature related to our work can be divided into: pricing and inventory optimization problems, import and export tariffs, revenue sharing as well as deferred payment. A brief review of the relevant literature in each of these areas is provided below:

As cross-border e-commerce continues to expand and its share in international trade increases, there has been growing attention from scholars on the pricing and inventory decisions within cross-border supply chains. Bhattacharjee and Sen (2023) emphasized the importance of accounting for inventory overhang risk when making pricing decisions. Similarly, Zhang et al. (2024) highlighted that poor inventory management can lead to stock-outs or overstocking, which in turn can impact pricing strategies. Thus, inventory decisions should be integrated with pricing decisions to optimize overall supply chain performance. Inventory management plays a crucial role in determining the success of supply chains. For example, when the e-tailer's market share is significant and the profit-sharing rate is low, the e-tailer tends to favor bulk ordering. Conversely, in other scenarios, both e-tailers and manufacturers lean towards a drop-off policy. In cases where channel substitutability is low and demand fluctuations are high, adopting a de-stocking policy benefits both manufacturers and e-tailers (Qiu et al., 2021). Maiorova and Balashova (2023) show that the widespread use of digital technologies makes tasks like inventory management challenging and hampers the development of effective warehouse inventory strategies and policies using unsupported methods. Song et al. (2024) showed that the commodity inventory decision depends on the commodity demand, which is closely related to the pricing decision. It can be shown that in the cross-border supply chain, pricing and inventory interact, and integrating them into a decision-making center can effectively optimize supply chain efficiency, while domestic and foreign scholars have little research on pricing and inventory in the cross-border supply chain.

Scholars have explored the impact of international financial variables, such as tariffs and exchange rates, on cross-border supply chain pricing. Cao and Zuo (2015) developed four pricing models for the secondary export supply chain and found that higher tariff barriers hindered cooperation within the supply chain. Chen et al. (2021) examined how exchange rate fluctuations affect the optimal pricing decisions in cross-border dual-channel supply chains and discovered that the impact on profitability depends on the costs associated with online channels. Slopek (2018) concluded that tariffs led to higher prices within the cross-border export supply chain, ultimately reducing profits for all members and decreasing social welfare. Chen et al. (2019) further highlighted that changes in tariffs influence the pricing decisions of supply chain members, with the effect being linked to the consumer price sensitivity coefficient. The above literature shows that tariffs are one of the factors that cannot be ignored when studying cross-border export supply chains. Cooperation between upstream and downstream enterprises can effectively deal with the problems caused by tariff barriers (Cao & Zuo, 2015). Gou et al. (2016) found that import and export barriers seriously affect the export strategies of suppliers and the willingness of supply chain members to take inventory risks when considering the external market.

Among various supply chain coordination mechanisms, studies by Arani et al. (2016) and Bart et al. (2021) identified revenue-sharing contracts as the most widely used approach for aligning the interests of supply chain members and the preferred option for many principals. Hou et al. (2017) and Hu et al. (2016) analyzed the coordination and performance of three-layer supply chains under different conditions, concluding that revenue-sharing contracts could achieve Pareto improvements in supply chain coordination under certain scenarios. Ji et al. (2020), examining production decisions under cap-and-trade regulations, found that government over-allocation of carbon quotas could reduce manufacturers' profits under both wholesale price and revenue-sharing contracts. Furthermore, under low-cost conditions, wholesale price contracts resulted in lower social welfare compared to revenue-sharing contracts. Wu et al. (2024) investigated revenue-sharing contracts for loss-averse, capital-constrained retailers, discovering that such retailers had higher revenue-sharing ratios and greater expected utility than neutral retailers. Bart et al. (2021) also reviewed the literature on revenue-sharing contracts, noting their applicability to various types of products and their potential to enhance coordination. However, these contracts require effective monitoring mechanisms to ensure accurate sales information exchange.

Vendor-allowed deferred payment has the potential to significantly reduce the retailer's holding costs, serving as compensation in competitive environments and an alternative to price discounts. Research by Kaushik (2023) and Sundararajan et al. (2021) highlights that extended trade credit terms can enhance total profits but adversely affect the supplier's working capital, thus impacting the efficiency of the entire supply chain. Huang et al. (2022) introduced a multi-period model to explore how deferred payment affects the collaborative cash-to-cash (CC2C) cycle and shareholder value added (SVA) under certain conditions. Mahata et al. (2019) examined inventory dynamics for deteriorating items under price inflation with deferred payment, while Soni (2013) developed a model linking demand rate with both price and inventory level, incorporating deferred payment. Sepehri et al. (2021) integrated pricing and inventory management for deteriorating items under optimal deferred payment periods and selling prices. Although prior research has explored revenue-sharing and deferred payment contracts for supply chain coordination, few studies address the influence of external markets. Motlagh and Nasiri (2023) analyzed static and dynamic pricing strategies with discounts and revenue-sharing contracts to maximize profitability, but their work does not account for import and export tariffs in cross-border supply chains.

In summary, while scholars have explored aspects of price management and inventory control in cross-border supply chains, they have not yet clarified the interaction mechanisms between price management and inventory control within cross-border e-commerce supply chains, nor have they examined the effects of their integration and optimization on overall supply chain performance. Furthermore, existing studies on cross-border supply chains have only briefly addressed the influence of tariffs, lacking a systematic analysis of how tariffs impact participants' strategic decisions and the optimization pathways of supply chains. Additionally, current research has primarily focused on the effects of deferred payment on inventory management, with minimal attention to its combined influence on pricing decisions and inventory management. In the context of post-pandemic economic uncertainty, deferred payment, as an internal financing mechanism in cross-border e-commerce supply chains, when paired with revenue-sharing contracts, can enable domestic manufacturers to secure more foreign orders, align strategies among supply chain participants, and stabilize the cross-border e-commerce supply chain. This paper, therefore, investigates the joint impact of revenue-sharing and deferred payment contracts on cross-border e-commerce export supply chains, particularly emphasizing the role of import tariffs in shaping participant strategies and system performance. By addressing these topics, the study aims to contribute to the literature on cross-border e-commerce export supply chains and offer managerial insights and decision-making guidance for member enterprises. A comparative summary of this paper and related literature is presented in Table 1.

Table 1
The distinctions between this paper and the most relevant literature

Paper	Inventory management	Import and export tariffs	Revenue sharing	Deferred payment
Bhattacharjee and Sen (2023)	√	/	/	/
Zhang et al. (2024)	√	/	/	/
Qiu et al. (2021)	√	/	/	/
Maiorova and Balashova (2023)	√	/	/	/
Song et al. (2024)	√	/	/	/
Cao and Zuo (2015)	/	√	/	/
Chen et al. (2021)	/	√	/	/
Slopek (2018)	/	√	/	/
Chen et al. (2019)	/	√	/	/
Gou et al. (2016)	/	√	/	/
Arani et al. (2016)	/	/	√	/
Bart et al. (2021)	/	/	√	/
Hou et al. (2017)	/	/	√	/
Hu et al. (2016)	/	/	√	/
Ji et al. (2020)	/	/	√	/
Wu et al. (2024)	/	/	√	/
Kaushik(2023)	√	/	/	√
Sundararajan et al. (2021)	√	/	/	√
Huang et al. (2022)	/	/	/	√
Mahata et al. (2019)	√	/	/	√
Soni (2013)	√	/	/	√
Sepehri et al. (2021)	√	/	/	√
Motlagh and Nasiri (2023)	/	/	√	√
This paper	√	√	√	√

2. Notation and Model Assumptions

2.1 Model description

Fig. 1 shows the description of the model. Chinese president has repeatedly pointed out the need to tap the growth potential of export trade, in the environment of unprotected demand and severe epidemics, foreign exports are more difficult, and the economic development in other countries is more challenging, the study of the export supply chain can provide domestic and foreign enterprises with a certain degree of decision-making insights to alleviate the development of export enterprises, and dedicate a part of China’s power to promote the growth of international trade and the world economic development. Therefore, this paper constructs a two-tier cross-border e-commerce export supply chain consisting of a Chinese manufacturer and a foreign retailer, decides on member pricing and ordering quantity under the condition of considering export tax rebates and import tariffs, and will consider revenue-sharing and deferred payment to synergize the supply chain. The revenue-sharing contract allows the retailer to obtain a lower wholesale price from the manufacturer, reducing part of the purchasing cost, and in return, it will give the manufacturer a portion of its sales revenue. Deferred payment contracts can incentivize retailers' desire to purchase and thus increase the order quantity, which is an important promotional tool (Mahata et al., 2019). For retailers with limited funds, deferred payment can help them to work capital, and for retailers without limited funds, deferred payment can enable them to obtain additional investment returns. However, the deferred payment strategy poses some risk to the manufacturer, i.e., when it comes to the deferred payment time period, the retailer may default on the contract due to financial constraints.

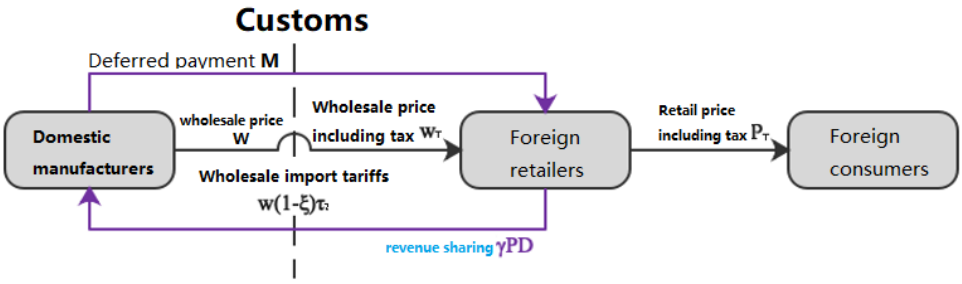

Fig. 1. Description of the model

2.2 Description of symbols

d: base demand
D: market demand
α: consumer price sensitivity coefficient
β: rate of impact of inventory on demand
I(t): inventory quantity over time
b: safety stock level
T: ordering cycle
u: deferred payment time horizon
τ_1: export tax rebate rate
τ_2: wholesale import tariff rate
w_T: wholesale price including tax
P_T: retail price including tax
c: unit production cost
k: unit inventory cost
P: retail price
ξ: tariff transfer factor
γ: revenue sharing factor
a:the retailer's default factor
δ:the deferred payment factor
F(u): default risk rate of
w: wholesale price
Q: foreign retailer's order quantity

Denoted by right superscript d under decentralized decision making, right superscript r under revenue sharing covenants, right superscript f under deferred payment covenants, and right superscript m under hybrid covenants.

2.3 Model assumptions

(1) Consider the export tariff policy practiced by China and the general adoption of this industrial policy of imposing import tariffs by all countries (Cao & Zuo, 2015). Assume the refund of VAT paid by Chinese manufacturers at the ad valorem rate τ_1 ($0<\tau_1<1/2$) in China. Based on the practice of levating import duties on an AD valorem basis in overseas countries, assume that the AD valorem rate of the wholesale import tariff of the importing country is $\tau_2(0 < \tau_2 < \frac{1}{2})$, the foreign retailer transfers part of it to the consumer, and the transfer factor is $\xi(0 < \xi < 1)$, that is, the wholesale tax inclusive price paid by the foreign retailer is $w_T = w[1 + (1 - \xi)\tau_2]$, and the tax inclusive retail price decided by the foreign retailer is $P_T = P + w\tau_2\xi$. The tariff factor ξ is endogenous, and the tariff transfer factor is determined by the retailer. In this paper, the wholesale price including tax paid by foreign retailers w_T=w[1+(1-ξ) τ_2], the retail price including tax decided by foreign retailers P_T=P+wτ_2; In this paper, the retailer decides ξ in advance and divides the tariff into two parts, one part transfers to the wholesale price and the other to the retail price, so the ξ in w_T+P_T cancelling each other out.

(2) In this scenario, the manufacturer, possessing unlimited production capacity, does not need to consider inventory costs.

Conversely, the retailer, seeking to maximize profits, disregards the possibility of stockouts and maintains a safety stock denoted as “b”. This setup indicates a supply chain dynamic where the retailer’s focus is on securing a certain level of inventory to meet demand, while the manufacturer is able to meet any level of demand without incurring additional inventory costs.

(3) Market demand is influenced not only by price but also by inventory levels (Pando et al., 2021). In addition, deferred payment is used as a promotional tool to attract new buyers and stimulate consumption. Jaggi et al. (2008) were the first to develop an optimal trade credit model for sellers, assuming that the deferred payment period positively impacts demand. In practice, the effect of the credit period on demand can be represented in three ways: linear, polynomial, and exponential. To ensure generality, this paper assumes that demand is an exponential function of the credit period. In summary, it assumes that market demand (Lou & Wang, 2013) $D = de^{\delta u} - \alpha P_T + \beta I(t)$, where δ is a positive constant. This function illustrates that market demand is influenced by a base level of demand, further modified by the impact of deferred payments. Additionally, it is inversely affected by price and influenced by inventory levels. Inventory level will affect the retailer's marketing strategy, if the inventory level is too high, it will take some promotional activities, thereby increasing market demand. This relationship highlights the complex interplay between these factors in shaping market demand.

(4) The longer the credit period granted to the retailer, the higher the default risk borne by the manufacturer (Singh et al., 2010). In practice, there are linear, polynomial or exponential ways to express the relationship between the deferred payment time period u and the default risk rate. In reference (Lou & Wang, 2013), assuming a default risk rate of $F(u) = 1 - e^{-au}$ without loss of generality, where $a \in (0,1)$ measures the retailer’s default factor. In the proposed scenario, the retailer is assumed to be a small or medium-sized enterprise (SME). In the event of a default, the retailer’s liquidation or restructuring is not considered. Therefore, there is a designated probability, represented as $F(u)$, that the retailer may fail to make the necessary payment. Correspondingly, this implies that the manufacturer faces an equal probability $F(u)$ of incurring financial losses. This assumption highlights the inherent risk factors in dealings with SMEs, especially in scenarios involving deferred payments.

Assume that both Chinese manufacturers and foreign retailers are risk-neutral rational agents.

Benchmark modeling of cross-border export supply chain systems:

Under the assumption that the inventory function of the foreign retailer can be derived, it is noted that throughout the ordering cycle (0 to T), the foreign retailer's inventory changes in response to market demand. Consequently, the retailer's inventory function must satisfy the differential equation shown in Eq. (1).

$$\frac{dI(t)}{dt} = -D[P_T, I(t), u], 0 \le t \le T \tag{1}$$

and the above equation satisfies the boundary conditions of $I(0) = Q + b$ and $I(T) = b$. By substituting the above equation, we can get the following Eq. (2).

$$I(t) = \left(b + \frac{de^{\delta u} - \alpha P_T}{\beta}\right) e^{\beta(T-t)} - \frac{de^{\delta u} - \alpha P_T}{\beta}, 0 \le t \le T \tag{2}$$

Therefore, the expression for the order quantity is given by Eq. (3).

$$Q = I(0) - b = \left(b + \frac{de^{\delta u} - \alpha P_T}{\beta}\right)\left(e^{\beta T} - 1\right) \tag{3}$$

Thus, the retailer’s inventory level during an ordering cycle (0 to T) can be expressed by Eq. (4).

$$I = \int_0^T I(t)dt = \Phi_1 b + (\Phi_1 - T)\frac{de^{\delta u} - \alpha P_T}{\beta} \tag{4}$$

where $\Phi_1 = \frac{e^{\beta T} - 1}{\beta}$. This section we will discuss the decentralized decision-making model without revenue sharing or deferred payment, establishing a benchmark for the supply chain coordination problem. Here, the deferred payment period is zero, so the market demand function is: $D = d - \alpha P_T + \beta I(t)$. In a decentralized decision-making model, the Chinese manufacturer establishes the wholesale price to maximize their own profit, while the foreign retailer sets both the retail price and order quantity to optimize its own objectives. This study assumes a hierarchical structure in which the Chinese manufacturer, as the leader in a Stackelberg game, makes the first move in setting the wholesale price. This study adopts a hierarchical structure where the Chinese manufacturer, acting as the leader in a Stackelberg game, sets the wholesale price first. The foreign retailer, following this decision, then determines the retail price, considering the manufacturer's choice. In this framework, the profit function for the Chinese manufacturer is represented by Eq. (5).

$$\Pi_1^d = wQ + \tau_1 cQ - cQ \tag{5}$$

The profit function of a foreign retailer can be expressed by Eq. (6).

$$\Pi_2^d = P_T D - wQ - (1-\xi)\tau_2 wQ - kI \tag{6}$$

In this paper, we use the inverse method to solve the problem and obtain Theorem 1 as follows.

Theorem 1: In a decentralized cross-border export supply chain system, the optimal equilibrium outcomes for both Chinese manufacturers and foreign retailers are described by Eq. (7).

$$\begin{cases} w^{d^*} = \dfrac{\Phi_3^d - \Phi_4^d}{2\Phi_2^d} + \dfrac{1}{2}(1-\tau_1)c \\ P^{d^*} = \Phi_4^d + (\Phi_2^d - \tau_2\xi)\left[\dfrac{\Phi_3^d - \Phi_4^d}{2\Phi_2^d} + \dfrac{1}{2}(1-\tau_1)c\right] \\ Q^{d^*} = \dfrac{1}{2}\alpha\Phi_1[\Phi_3^d - \Phi_4^d - \Phi_2^d(1-\tau_1)c] \end{cases} \tag{7}$$

where $\Phi_2^d = \frac{1+\tau_2(1-\xi)}{2}$, $\Phi_3^d = \frac{d+\beta b}{\alpha}$, $\Phi_4^d = \frac{1}{2}\left[\Phi_3^d + \frac{k(\Phi_1 - \mathrm{T})}{\beta\Phi_1}\right]$.

Theorem 1 demonstrates that in a decentralized decision-making framework, the manufacturer's profit function is concave with respect to the wholesale price, while the retailer's profit function exhibits concavity in relation to the retail price. This property allows both supply chain participants to identify the optimal pricing and ordering strategies that maximize their individual profits. As the leader in this setup, the Chinese manufacturer's chosen wholesale price directly impacts the retailer's decisions regarding pricing and inventory management. If the wholesale price imposes excessive financial pressure on the retailer, the retailer may attempt to negotiate a reduction in the purchase cost. To maintain a long-term partnership and ensure supply chain stability, the manufacturer may engage in negotiations or establish a contract that fosters a mutually beneficial solution.

Corollary 1: Within a decentralized cross-border export supply chain system, variations in the export tax rebate rate influence the decision-making processes and profitability of supply chain participants in the following manner:

(1) An escalation in the export tax rebate rate results in a reduction of both wholesale and retail prices, concurrently leading to an increase in order quantities.

(2) Rising export tax rebate rates lead to enhanced profitability for both the manufacturer and the retailer.

Corollary 1 reveals that:

(1) A higher rate of export tax rebates significantly lowers the manufacturer's expenses, encouraging them to lower the wholesale price to stimulate demand and generate additional revenue. This reduction in wholesale price also lowers the retailer's procurement costs, allowing them to decrease the retail price and increase order volume to maximize profits.

(2) Increasing the export tax rebate rate results in lower production costs for Chinese manufacturers and reduced procurement costs for foreign retailers, ultimately increasing profits for both. This indicates that the export tax rebate policy can effectively mitigate trade barriers, promote exports, and enhance the international competitiveness of domestic products.

Corollary 2: Within a decentralized cross-border export supply chain system, variations in wholesale import tariff rates influence both the decision-making processes and profitability of supply chain participants: (1) Wholesale prices decrease as the wholesale import tariff rate increases; When satisfying $\xi\Phi_3^d < \frac{\xi k(\Phi_1 - \mathrm{T})}{\beta\Phi_1} + 2{\Phi_2^d}^2 c(1-\tau_1)(1-3\xi)$, retail prices are positively correlated with wholesale import tariff rates. When satisfying $\xi\Phi_3^d > \frac{\xi k(\Phi_1 - \mathrm{T})}{\beta\Phi_1} + 2{\Phi_2^d}^2 c(1-\tau_1)(1-3\xi)$. The selling price is negatively related to the wholesale import tariff rate; the order quantity decreases with the increase of the wholesale import tariff rate. (2) The profits of all supply chain members also decline with rising wholesale import tariff rates.

Corollary 2 demonstrates that: (1) As wholesale import tariffs are partially absorbed by retailers, an increase in these tariffs leads manufacturers to lower wholesale prices to minimize the impact on retailers' purchasing behavior. Retailers' pricing adjustments in response to rising wholesale import tariffs depend on factors such as cost structure and the tariff transfer rate. If inventory costs are high or the tariff transfer rate is low, retailers tend to increase retail prices to compensate for their losses. On the other hand, if inventory costs are relatively low or a larger share of the tariffs is passed on to consumers, retailers may opt to decrease retail prices to ease the burden on consumers and encourage consumption. Regardless of the strategy, however, an increase in wholesale import tariffs raises retailers' costs, prompting them to reduce order quantities to avoid excess inventory and high holding costs. (2) An increase in the wholesale import tariff rate raises overall supply chain costs, resulting in a decline in profits for all members of the supply chain. This suggests that tariffs exacerbate trade barriers between countries, potentially hindering international trade and obstructing economic globalization.

Corollary 3: Within a decentralized cross-border export supply chain structure, the tariff transfer factor impacts the decision-making and profitability of supply chain stakeholders in the following manner: (1) As the tariff transfer factor escalates, wholesale prices increase, retail prices decline, and order quantities grow; (2) As the tariff transfer factor increases, profits for both manufacturers and retailers also rise.

Corollary 3 indicates that: (1) When the retailer increases the tariff transfer factor, consumers bear a larger share of the tariffs, which leads to a higher optimal wholesale price from the manufacturer under conditions of symmetric information. However, if the retailer chooses not to disclose the tariff transfer factor, the manufacturer may offer a lower wholesale price, and could then infer the retailer's tariff transfer strategy through alternative channels to set the optimal price. Thus, the tariff transfer factor plays a crucial role in the decision-making process. When the retailer raises this factor, they typically reduce the retail price to mitigate the consumer's cost burden, resulting in a lower price inclusive of taxes, which boosts demand and, consequently, increases the order quantity. (2) As the tariff transfer factor increases, the manufacturer benefits from higher wholesale prices, while the retailer's profit also rises due to a greater margin between the tax-inclusive retail and wholesale prices. In a decentralized decision-making framework, a higher tariff transfer factor correlates with greater profits for both members of the supply chain, reinforcing the observation that tariffs are ultimately borne by consumers.

3. Cross-Border Export Supply Chain Coordination

3.1 Supply chain coordination based on revenue sharing contracts

A wealth of research has shown that revenue-sharing contracts effectively coordinate supply chains through mutual profit transfer, and in cross-border supply chains, manufacturers often voluntarily enter into such contracts with downstream enterprises due to the instability of demand. This section will consider using it to coordinate cross-border export supply chain systems to improve performance, whereby the retailer receives a lower wholesale price from the manufacturer in return for a percentage of the sales revenue (with a ratio of γ and $0 < \gamma < 1/2$) to the manufacturer. At this point, the profit function of the Chinese manufacturer is expressed by Eq. (8).

$$\Pi_1^r = wQ + \tau_1 cQ + \gamma P_T D - cQ \tag{8}$$

The profit function of the foreign retailer is expressed by Eq. (9).

$$\Pi_2^r = (1-\gamma)P_T D - wQ - (1-\xi)\tau_2 wQ - kI \tag{9}$$

When a revenue-sharing contract is used to coordinate a cross-border export supply chain system, a manufacturer-dominated Stackelberg game is employed between a Chinese manufacturer and a foreign retailer. In this setup, the Chinese manufacturer determines the wholesale price, while the foreign retailer makes decisions regarding the retail price and order quantity, each aiming to optimize their respective gains. The optimal strategies for both parties can be derived through backward induction, as presented in Theorem 2.

Theorem 2: In the coordination of the revenue-sharing contract, the equilibrium pricing and ordering volumes of the Chinese manufacturer and the foreign retailer are represented by the following Eq. (10).

$$\begin{cases} w^{r*}(\gamma) = \dfrac{\Phi_3^r - \Phi_4^r}{2\Phi_2^r} + \dfrac{c(1-\tau_1) - \gamma\Phi_4^r}{2(1+\gamma\Phi_2^r)} \\ P^{r*}(\gamma) = \Phi_4^r + (\Phi_2^r - \tau_2\xi)\left[\dfrac{\Phi_3^r - \Phi_4^r}{2\Phi_2^r} + \dfrac{c(1-\tau_1) - \gamma\Phi_4^r}{2(1+\gamma\Phi_2^r)}\right] \\ Q^{r*}(\gamma) = \dfrac{1}{2}\alpha\Phi_1\left[\Phi_3^r - \Phi_4^r - \dfrac{c(1-\tau_1)\Phi_2^r - \gamma\Phi_2^r\Phi_4^r}{1+\gamma\Phi_2^r}\right] \end{cases} \tag{10}$$

where $\Phi_2^r = \frac{1+\tau_2(1-\xi)}{2(1-\gamma)}$, $\Phi_3^r = \frac{d+\beta b}{\alpha}$, $\Phi_4^r = \frac{1}{2}\left[\Phi_3^r - \frac{k(\Phi_1 - T)}{(\gamma-1)\beta\Phi_1}\right]$. The result of Theorem 2 indicates that in the cross-border export supply chain system with a revenue sharing contract, the pricing and ordering decisions of the supply chain members are all functions of the revenue sharing factor γ. When γ=0, the outcomes align with those of decentralized decision-making, meaning that the revenue sharing contract has no effect on the supply chain equilibrium decisions.

Corollary 4: In the cross-border export supply chain system considering RSC, revenue sharing can realize supply chain coordination when the revenue sharing factor r satisfies the following condition $\frac{\partial Q^{r^*}}{\partial \gamma}\left[c(\tau_1-1)-\Phi_3^r+\Phi_4^r+w^{r^*}[\Phi_2^r-\tau_2(1-\xi)]+\frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}\right]<\tau_2(1-\xi)Q^{r^*}\frac{\partial w^{r^*}}{\partial \gamma}$.

Corollary 4 shows that the revenue-sharing contract, which is one of the commonly used contracts for supply chain coordination, redistributes profits among supply chain members, but coordination of cross-border export supply chains can only be achieved under specific conditions and the coordination effect is affected by export tax rebate rates, wholesale import tariff rates and tariff transfer factors.

Corollary 5: In a cross-border export supply chain system that considers revenue sharing, the effects of the revenue sharing factor on the decision making of supply chain members are: (1) Wholesale price decreases as the revenue sharing factor increases; Retail price is positively correlated with the revenue sharing factor when $Q^{r^*}\left[\frac{1}{2}\Phi_3^r-\Phi_4^r-(1-\gamma)\Phi_2^r\frac{\partial w^{r^*}}{\partial \gamma}\right]$ is satisfied and negatively correlated with the revenue sharing factor when $(1-\Phi_2^r-\gamma\Phi_2^{r2})\Phi_4^r+\Phi_2^r c(1-\tau_1)(1+\gamma\Phi_2^r-\Phi_2^r)-\frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2}<2(1-\gamma)(1+\gamma\Phi_2^r)^2\frac{\partial w^{r^*}}{\partial \gamma}\tau_2\xi$ is satisfied; When $(1-\Phi_2^r-\gamma\Phi_2^{r2})\Phi_4^r+\Phi_2^r c(1-\tau_1)(1+\gamma\Phi_2^r-\Phi_2^r)<\frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2}$ is satisfied, subscription is positively correlated with the revenue sharing factor and when $(1-\Phi_2^r-\gamma\Phi_2^{r2})\Phi_4^r+\Phi_2^r c(1-\tau_1)(1+\gamma\Phi_2^r-\Phi_2^r)>\frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2}$ is satisfied, subscription is negatively correlated with the revenue sharing factor. (2) Manufacturer profit is positively correlated with the revenue-sharing factor when $Q^{r^*}\left[\frac{2(1-\gamma)\Phi_2^r-1}{4\Phi_2^r(1-\gamma)}\Phi_3^r+\frac{\gamma(1+\Phi_2^r)\Phi_4^r}{2(1-\gamma)(1+\gamma\Phi_2^r)}\right]>-[w^{r^*}(1+\gamma\Phi_2^r)+\gamma\Phi_4^r-c(1-\tau_1)]\frac{\partial Q^{r^*}}{\partial \gamma}$ is satisfied and negatively correlated with the revenue sharing factor when $Q^{r^*}\left[\frac{2(1-\gamma)\Phi_2^r-1}{4\Phi_2^r(1-\gamma)}\Phi_3^r+\frac{\gamma(1+\Phi_2^r)\Phi_4^r}{2(1-\gamma)(1+\gamma\Phi_2^r)}\right]<-[w^{r^*}(1+\gamma\Phi_2^r)+\gamma\Phi_4^r-c(1-\tau_1)]\frac{\partial Q^{r^*}}{\partial \gamma}$ is satisfied; Retailer profit is positively correlated with the revenue sharing factor when $Q^{r^*}\left[\frac{1}{2}\Phi_3^r-\Phi_4^r-(1-\gamma)\Phi_2^r\frac{\partial w^{r^*}}{\partial \gamma}\right]>\frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}\frac{\partial Q^{r^*}}{\partial \gamma}$ is satisfied and negatively correlated with the revenue sharing factor when $Q^{r^*}\left[\frac{1}{2}\Phi_3^r-\Phi_4^r-(1-\gamma)\Phi_2^r\frac{\partial w^{r^*}}{\partial \gamma}\right]<\frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}\frac{\partial Q^{r^*}}{\partial \gamma}$ is satisfied.

Corollary 5 shows that (1) the revenue-sharing contract is based on lowering the wholesale price, so as the revenue-sharing factor increases, the higher the shared benefit to the manufacturer, and in order to more effectively compensate for the retailer's losses and prevent supply chain decoupling, the manufacturer will continue to lower the wholesale price. (2) The effects of revenue sharing factors on retail prices and orders and members' profits are related to inventory costs, manufacturers' production costs, export rebate rates, wholesale import tariff rates and tariff transfer factors. That is, under certain conditions, members' profits will increase with the increase of the revenue-sharing factor, so in reality, members need to rationally game the revenue-sharing factor according to the existing conditions to maximize their own profits. It can also be seen from the proof that when the condition of negative correlation between retail price and revenue sharing factor is met, the order quantity is positively correlated with revenue sharing factor, and the manufacturer prefers a larger revenue sharing factor in this case.

3.2 Supply chain coordination based on deferred payment contracts

Deferred payment contracts influence demand by affecting the ordering decisions of supply chain members, ultimately improving supply chain performance through intra-supply chain financing and stimulating purchasing desires. The outbreak and continuation of the COVID-19 epidemic reinforced the practical necessity for supply chain members to enter into deferred payment contracts. In this section, we consider coordinating the cross-border export supply chain system using a deferred payment contract, where the manufacturer wholesales goods to the retailer and grants a period of time to defer payment, thereby incentivizing the retailer's purchasing behavior. However, this arrangement also introduces credit risk for the manufacturer, as the retailer's default could lead to financial losses. The profit function of the Chinese manufacturer in this context is expressed in Eq. (11).

$$\Pi_1^f=[1-F(u)]wQ+\tau_1 cQ-cQ \tag{11}$$

The profit function of the foreign retailer is given by Eq. (12).

$$\Pi_2^f=P_T D-[1-F(u)]wQ-(1-\xi)\tau_2 wQ-kI \tag{12}$$

When the cross-border export supply chain system is coordinated through a deferred payment contract, a manufacturer-dominated Stackelberg game is played between the Chinese manufacturer and the foreign retailer. In this setup, the manufacturer sets the wholesale price, while the retailer makes decisions to optimize their own returns. The optimal strategies for both parties are derived using backward induction, as outlined in Theorem 3.

Theorem 3: The equilibrium pricing and ordering volumes of the Chinese manufacturer and the foreign retailer under the coordination of deferred payment are expressed by Eq. (13).

$$\begin{cases} w^{f^*}(u) = \dfrac{\Phi_3^f - \Phi_4^f}{2\,\Phi_2^f} + \dfrac{1}{2} e^{au} c(1-\tau_1) \\ P^{f^*}(u) = \Phi_4^f + \left(\Phi_2^f - \tau_2 \xi\right)\left[\dfrac{\Phi_3^f - \Phi_4^f}{2\,\Phi_2^f} + \dfrac{1}{2} e^{au} c(1-\tau_1)\right] \\ Q^{f^*}(u) = \dfrac{1}{2}\alpha\Phi_1\left[\Phi_3^f - \Phi_4^f - e^{au}c(1-\tau_1)\Phi_2^f\right] \end{cases} \tag{13}$$

where $\Phi_2^f = \frac{e^{-au}+\tau_2(1-\xi)}{2}$, $\Phi_3^f = \frac{de^{\delta u}+\beta b}{\alpha}$, $\Phi_4^f = \frac{1}{2}\left[\Phi_3^f + \frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}\right]$.

The result of theorem 3 shows that the deferred payment contract influences the price decision and order decision of Chinese manufacturers and foreign retailers by setting an appropriate deferred payment time period u, thus coordinating the cross-border export supply chain. When u = 0, the result is consistent with decentralized decision making, and deferred payment contracts do not have any effect on supply chain equilibrium decision making.

Corollary 6: In a cross-border export supply chain system considering deferred payment contracts, deferred payment enables supply chain coordination when the deferred payment factor u satisfies the following condition $\left[\frac{\Phi_2^f+e^{-au}}{4\alpha\Phi_2^f}\delta de^{\delta u} + \frac{ac(1-\tau_1)}{4}\right]Q^{f^*} + \frac{\alpha\Phi_1}{4}\left[e^{-au}w^{f^*} + c(\tau_1-1)\right]\left[\frac{\delta de^{\delta u}}{\alpha} - ac(1-\tau_1)\tau_2(1-\xi)\right] + \frac{\alpha k(\Phi_1-\mathrm{T})}{4\beta}ac(1-\tau_1)\tau_2(1-\xi) > \tau_2(1-\xi)\frac{ae^{-au}}{4{\Phi_2^f}^2}(\Phi_3^f - \Phi_4^f)Q^{f^*} + \frac{k(\Phi_1-\mathrm{T})}{\beta}\delta de^{\delta u}$.

Corollary 6 shows that deferred payment can coordinate the cross-border export supply chain system under specific conditions. From the proof, it can be seen that its coordination effect is affected by various aspects such as export tax rebate rate, import tariff rate and tariff transfer factor.

Corollary 7: In a cross-border export supply chain system that considers deferred payment, the effects of deferred payment time period on supply chain members' decisions as well as on profits are: (1) Wholesale price is positively related to deferred payment time period; When $\frac{3\delta de^{\delta u}}{4\alpha} + \frac{a}{4}c(1-\tau_1)\left(2e^{au}\Phi_2^f - 1\right) > \frac{\partial w^{f^*}}{\partial u}\tau_2\xi$ is satisfied, retail price is positively related to deferred payment time period and when $\frac{3\delta de^{\delta u}}{4\alpha} + \frac{a}{4}c(1-\tau_1)\left(2e^{au}\Phi_2^f - 1\right) < \frac{\partial w^{f^*}}{\partial u}\tau_2\xi$ is satisfied, retail price is negatively related to deferred payment time period; The ordering volume increases with the extension of the deferred payment time horizon. (2) Manufacturer's profit is positively related to deferred payment time period when $\frac{\delta de^{\delta u}}{2\alpha\Phi_2^f} > aw + \frac{\partial w^{f^*}}{\partial u}$ is satisfied and negatively related to deferred payment time period when $\frac{\delta de^{\delta u}}{2\alpha\Phi_2^f} < aw + \frac{\partial w^{f^*}}{\partial u}$ is satisfied; Retailer profit is positively related to deferred payment time period when $\left(\Phi_3^f - 2w^{f^*}\Phi_2^f\right)\frac{\partial Q^{f^*}}{\partial u} > \alpha\Phi_1\left(\Phi_4^f - \frac{1}{2}\Phi_3^f\right)\left(\frac{\partial P^{f^*}}{\partial u} + \frac{\partial w^{f^*}}{\partial u}\tau_2\xi\right)$ is satisfied and negatively related to deferred payment time period when $\left(\Phi_3^f - 2w^{f^*}\Phi_2^f\right)\frac{\partial Q^{f^*}}{\partial u} < \alpha\Phi_1\left(\Phi_4^f - \frac{1}{2}\Phi_3^f\right)\left(\frac{\partial P^{f^*}}{\partial u} + \frac{\partial w^{f^*}}{\partial u}\tau_2\xi\right)$ is satisfied.

Corollary 7 demonstrates that when the time limit for deferred payment is extended, the manufacturer increases the wholesale price to offset the loss of investment cost due to delayed payments. This extension of the payment period results in a positive increase in demand, which encourages the retailer to raise the order quantity. Consequently, the higher wholesale price leads to an increase in the retail price. However, if the order quantity increase is substantial, it can reduce sales volume and raise inventory costs. Retailers may face more losses than gains in such cases, meaning the change in retail price depends on the specific situation. Additionally, the extension of the deferred payment period can cause the profits of both supply chain members to either increase or decrease, depending on factors such as inventory costs, production costs, export tax rebate rates, wholesale import tariff rates, the tariff transfer factor, and the retailer's default risk. As a result, manufacturers and retailers should carefully consider all these factors when negotiating the terms of the deferred payment period.

Corollary 8: In a cross-border export supply chain system considering deferred payment, the effects of the retailer's default factor on the supply chain equilibrium decision and members' profits are (1) Wholesale price increases as the retailer's default factor increases; Retail price is positively correlated with the retailer default factor when $\left[e^{au}\left(\Phi_2^f-\tau_2\xi\right)-\frac{1}{2}\right]c(1-\tau_1)>\frac{\tau_2\xi e^{-au}\left(\Phi_3^f-\Phi_4^f\right)}{2\Phi_2^{f^2}}$ is satisfied and negatively correlated with the retailer default factor when $\left[e^{au}\left(\Phi_2^f-\tau_2\xi\right)-\frac{1}{2}\right]c(1-\tau_1)<\frac{\tau_2\xi e^{-au}\left(\Phi_3^f-\Phi_4^f\right)}{2\Phi_2^{f^2}}$ is satisfied; ordering decreases as the retailer default factor increases. (2) All supply chain members' profits decrease with the increase of the retailer's default factor.

Corollary 8 shows that (1) when the retailer's default factor is larger, the manufacturer bears more credit risk and naturally decides on a higher wholesale price. As higher wholesale prices put greater sales pressure on retailers, they reduced orders due to concerns about inventory accumulation. As for the retail price decision, higher wholesale prices lead to higher retail prices, but since higher prices lead to lower sales and possibly inventory buildup, retail price setting is also related to other factors. (2) When the retailer's creditworthiness is lower, the manufacturer's profit decreases due to the greater risk and the decrease in the retailer's order quantity, and the retailer's profit decreases due to the increase in the wholesale price. Therefore, Chinese manufacturers should fully understand the trade credit of foreign retailers before signing the deferred payment contract, and foreign retailers should try to maintain their good trade credit in order to obtain more profits.

Corollary 9: In a cross-border export supply chain system that considers deferred payment, the effect of the deferred payment factor affecting demand on the equilibrium decision of the supply chain and the profitability of its members: (1) The wholesale price increases with the increase of the deferred payment factor affecting demand; When $3\Phi_2^f>\tau_2\xi$ is satisfied, retail price is positively correlated with the deferred payment factor affecting demand, and when $3\Phi_2^f<\tau_2\xi$ is satisfied, retail price is negatively correlated with the deferred payment factor affecting demand; ordering quantity increases with the increase in the deferred payment factor affecting demand. (2) Manufacturers' profits increase with the increase in the deferral factor affecting demand; retailers' profits are positively correlated with the deferral factor affecting demand when $2\Phi_3^f>3\Phi_4^f+w^{f^*}\Phi_2^f$ is satisfied, and negatively correlated with the deferral factor affecting demand when $2\Phi_3^f<3\Phi_4^f+w^{f^*}\Phi_2^f$ is satisfied.

Corollary 9 illustrates that, under the same deferred payment time horizon, a larger deferred payment factor affecting demand leads to higher market demand, which in turn causes the retailer to increase the order quantity. To capitalize on this, the manufacturer raises the wholesale price to secure greater profits. The change in retail price, however, is influenced by factors such as the retailer's default risk, wholesale import tariffs, and the tariff transfer factor. Additionally, when the deferred payment factor impacting demand is larger, the manufacturer's profit increases due to higher wholesale prices and larger order quantities. The retail price, however, remains variable, meaning the retailer's profit will depend on the specific circumstances. Therefore, before entering into a deferred payment contract, both the manufacturer and retailer should carefully estimate the factors influencing market demand to develop a more appropriate decision-making strategy.

3.3 Supply chain coordination based on hybrid contracts

This section examines the combined effect of revenue-sharing and deferred payment contracts on supply chain profits. Revenue-sharing contracts impact profits primarily through pricing decisions, while deferred payment contracts influence them by affecting order quantities. A hybrid contract is introduced, incorporating both mechanisms: retailers share a proportion γ of their sales revenue with manufacturers and also benefit from a credit period for deferred payment on wholesale accounts. The key question addressed is whether these two mechanisms offset or accumulate their effects on supply chain profits. Under the hybrid contract coordination mechanism, the manufacturer first announces the parameters of the contract. If the retailer accepts the terms, both parties proceed to determine the wholesale price and retail price, guided by the principle of profit maximization. The profit function for the Chinese manufacturer under this coordination framework is expressed in Eq. (14).

$$\Pi_1^m=[1-F(u)]wQ+\tau_1cQ+\gamma P_TD-cQ \tag{14}$$

The above equation represents the manufacturer's profit = sales revenue after taking into account the risk of default + export tax rebates + revenue sharing - production costs.

The profit function of the foreign retailer is given by Eq. (15).

$$\Pi_2^m=(1-\gamma)P_TD-[1-F(u)]wQ-(1-\xi)\tau_2wQ-kI \tag{15}$$

The above equation indicates that retailer's profit = sales revenue after revenue sharing - purchasing cost after taking into account the risk of default - import duty amount - inventory cost.

Theorem 4: In the coordination of the hybrid contract, the equilibrium pricing and ordering volume of the Chinese manufacturer and the foreign retailer are expressed by Eq. (16).

$$\begin{cases} w^{m*}(\gamma,u) = \dfrac{\Phi_3^m - \Phi_4^m}{2\Phi_2^m} + \dfrac{c(1-\tau_1) - \gamma\Phi_4^m}{2(\gamma\Phi_2^m + e^{-au})} \\ P^{m*}(\gamma,u) = \Phi_4^m + (\Phi_2^m - \tau_2\xi)\left[\dfrac{\Phi_3^m - \Phi_4^m}{2\Phi_2^m} + \dfrac{c(1-\tau_1) - \gamma\Phi_4^m}{2(\gamma\Phi_2^m + e^{-au})}\right] \\ Q^{m*}(\gamma,u) = \dfrac{1}{2}\alpha\Phi_1\left[\Phi_3^m - \Phi_4^m - \dfrac{\Phi_2^m}{\gamma\Phi_2^m + e^{-au}}[c(1-\tau_1) - \gamma\Phi_4^m]\right] \end{cases} \tag{16}$$

where $\Phi_2^m = \frac{e^{-au}+\tau_2(1-\xi)}{2(1-\gamma)}$, $\Phi_3^m = \frac{de^{\delta u}+\beta b}{\alpha}$, $\Phi_4^m = \frac{1}{2}\left[\Phi_3^m - \frac{k(\Phi_1 - T)}{(\gamma-1)\beta\Phi_1}\right]$.

The result of Theorem 4 shows that the hybrid contract coordinates the cross-border export supply chain system by determining the appropriate revenue-sharing factor γ and deferred payment time, which in turn influence the pricing and ordering decisions of the Chinese manufacturer and the foreign retailer. When u = 0 and γ = 0, the outcomes align with decentralized decision-making, meaning that the hybrid contract does not affect the supply chain equilibrium decisions. Since the inference under the hybrid contract is consistent with the results obtained from previous inferences, further elaboration on this point is unnecessary.

4. Algorithm Analysis

In this section, the cross-border export supply chain system based on hybrid contract explores the effects of export tax rebate rate, import tariff rate and tariff transfer factor on the equilibrium decision of the supply chain as well as the profits of the supply chain members through numerical arithmetic examples, and explores the coordinating effects of RSC, DPC and hybrid contract on the supply chain. Based on the actual export situation of Chimi Information Technology Co., Ltd. which develops and sells intelligent industrial robots in Hefei, Anhui Province, the parameters are set as follows according to the conditions that the theoretical results are valid, taking into account the relevant parameters of the previous inventory studies. $\alpha = 3.5, \beta = 1.2, T = 0.25$ years, $k = \$6$ /unite*per year, $c = \$10/\text{per}, d = 1000, b = 300, a = 0.125, \delta = 0.35, \xi \in [0,1]$, $\tau_1 \in [0,\frac{1}{2}], \tau_2 \in [0,\frac{1}{2}]$.

4.1 An analysis of the effect of export tax rebate rates, import tariffs and tariff shift factors on supply chain coordination

In cross-border export supply chain, tax rate is a non-negligible factor affecting supply chain equilibrium. Figs. 2-4 consider the effects of different tax rebate rates, import tariff rates and tariff transfer factors on the profits of supply chain members under different contracts, respectively. Where, referring to previous literature, the revenue sharing factor γ = 0.15 and the deferred payment time horizon u = 0.25 years. According to the relevant regulations of China's export tax rebate policy, the export tax rebate rate of most commodities is between (0, 50%), and according to the multinational tariff regulations, it is known that the import tariff rate of most commodities is generally less than 50%, therefore, the export tax rebate rate τ_1 and the wholesale import tariff rate τ_2 are taken as three different values of 0, 0.3, and 0.5, respectively, the tariff transfer factor ξ is taken as 0.2, 0.4, 0.6, 0.8 , 1, and the other parameters are shown above.

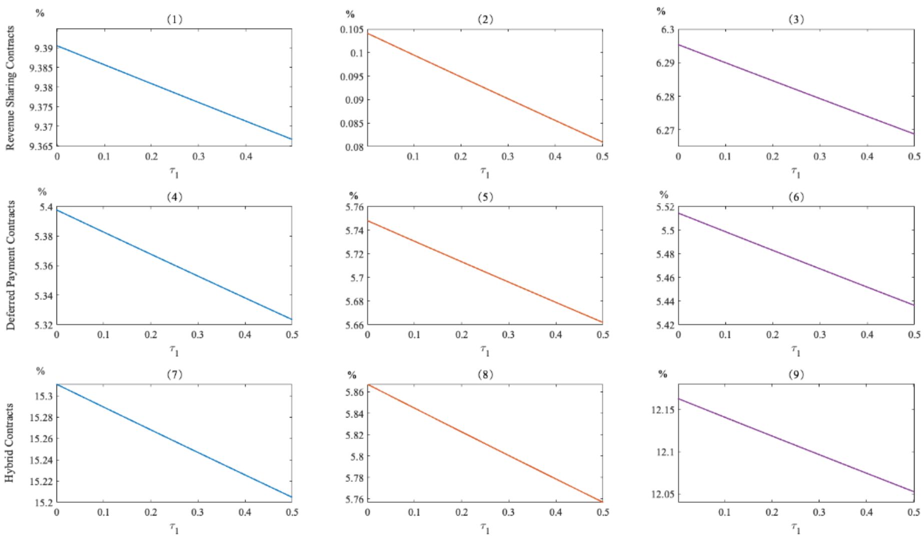

Fig. 2. Impact of export tax rebate rate on the effect of contractual coordination supply chain

Vertically, Figs. 2-4 (1), (4), and (7) represent the changes in manufacturer's profit, (2), (5), and (8) represent the changes in retailer's profit, and (3), (6), and (9) represent the changes in total supply chain profit. Horizontally, Fig.s 2-4, (1), (2), and (3) represent the changes in the profits and total profits of each member of the supply chain under the revenue-sharing contract, (4), (5), and (6) represent the changes in the profits and total profits of the members of the supply chain under the deferred payment contract, and (7), (8), and (9) represent the changes in the profits and total profits of the members of the supply chain under the hybrid contract. Profits under the hybrid contract. Comparing the profits of supply chain members under the three types of contracts with the decentralized decision can be found.

(1) As the export tax rebate rate increases, the ability of the three contract types to boost the profits of supply chain members and enhance overall profitability diminishes. The findings indicate that while all three contracts can improve the profits of supply chain members compared to decentralized decision-making, their coordination effects become less pronounced as the export tax rebate rate rises. From a broader perspective, the export tax rebate policy contributes to the growth of cross-border enterprises and mitigates the negative impact of tariff barriers. This underscores the importance for China to maintain the export tax rebate policy in order to achieve a high level of economic openness. Regarding future actions, when the export tax rebate rate is low, all three contract types—revenue-sharing, deferred payment, and hybrid contracts—can increase the profits of supply chain members, thus supporting the stability of the supply chain.

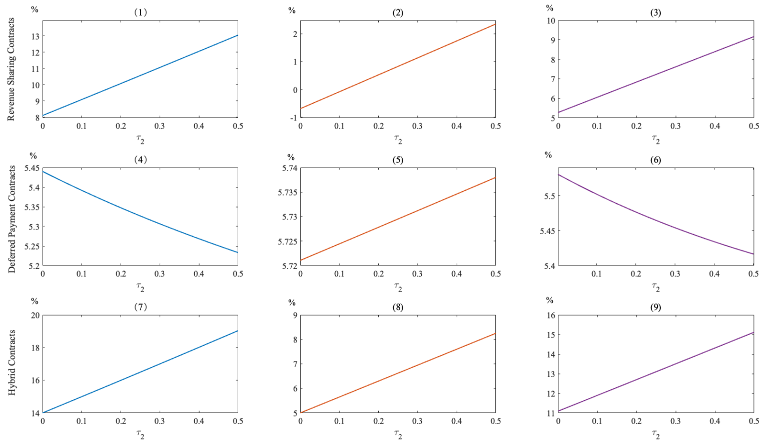

Fig. 3. Impact of Wholesale Import Tariff Rates on the Effectiveness of Contractual Coordination Supply Chains

(2) As the wholesale import tariff increases, the effect of the three covenants on improving retailer profits gradually increases, and the effect of the revenue-sharing covenant and the hybrid covenant on improving manufacturer and total profits gradually increases, but the effect of the deferred-payment covenant on improving manufacturer and total profits decreases. According to the results, higher wholesale import tariffs reduce the profits of supply chain members under decentralized decision-making. The negative effects of these rising tariffs can be mitigated by using revenue-sharing or hybrid contracts. However, the deferred payment factor has a more pronounced negative effect on manufacturers' profits, which diminishes the ability of the deferred payment contract to improve manufacturers' profitability. When tariff barriers between countries increase, Chinese manufacturers and foreign retailers are more likely to enter into revenue-sharing contracts or hybrid contracts to form cooperation to cope with the negative effects of tariffs. Meanwhile, when wholesale import tariffs are zero or low, revenue-sharing contracts do not improve retailers' profits but rather reduce them. When tariff barriers between countries are low, deferred payment contracts and hybrid contracts can improve supply chain members' and total profits.

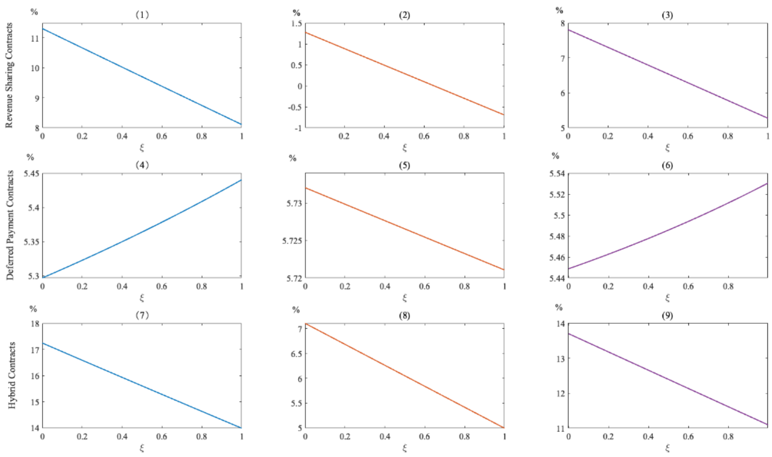

Fig. 4. Impact of tariff shifting factors on the effectiveness of contractual coordination of supply chains

(3) As the tariff transfer factor increases, the effectiveness of the three contracts in boosting the retailer's profit gradually diminishes. Among these, the hybrid contract shows the greatest reduction in its ability to improve the retailer's profit, while the revenue-sharing and hybrid contracts also experience a narrowing effect on the improvement of both manufacturer and total profit. In contrast, the deferred payment contract results in a gradual expansion of the manufacturer's and overall supply chain profit. The findings reveal that as a greater share of tariffs is transferred to consumers, the coordination effects of the revenue-sharing and hybrid contracts become less pronounced. However, due to the influence of the deferred payment factor, the increase in manufacturer and total profit under deferred payment conditions exceeds that under decentralized decision-making, leading to a stronger coordination effect of the deferred payment contract on both the manufacturer and the entire supply chain. Notably, as shown in Corollary 3, a higher tariff transfer factor corresponds to higher profits for supply chain members under decentralized decision-making, which aligns with the understanding that consumers ultimately bear the cost of tariffs. However, as illustrated in (2) of Figure 4, when a revenue-sharing contract is implemented, the retailer's profit declines relative to decentralized decision-making as the tariff transfer factor increases. Therefore, the retailer must carefully evaluate the optimal tariff transfer factor, as it is not always advantageous for consumers to bear a larger portion of the tariff. In conclusion, when entering into contracts, supply chain members must thoughtfully determine the tariff transfer factor to maximize overall benefits.

4.2 The effect of revenue sharing factor and deferred payment time horizon on supply chain equilibrium and profitability

In the cross-border export supply chain system with hybrid contracts, the revenue sharing factor $\gamma \in [0, \frac{1}{2}]$, the deferred payment time horizon $u \in [0, 0.3]$, and other parameters are as described above. Fig. 5 illustrates how the revenue-sharing factor and the deferred payment time horizon influence the supply chain equilibrium decision. Under the hybrid contract, the wholesale and retail prices show a negative correlation with the revenue-sharing factor, while the order quantity exhibits a positive correlation with this factor. This aligns with the findings of (Cao & Zuo, 2015) under the revenue-sharing contract, suggesting that the introduction of the deferred payment contract does not alter the relationship between the revenue-sharing factor and the equilibrium decision but rather modifies the correlation coefficient. Furthermore, the wholesale price, retail price, and order quantity all demonstrate a positive correlation with the deferred payment period. This is consistent with the result derived under the deferred payment contract, indicating that the addition of the revenue-sharing contract does not change the relationship between the deferred payment period and the equilibrium decision, but it affects the magnitude of the correlation coefficient.

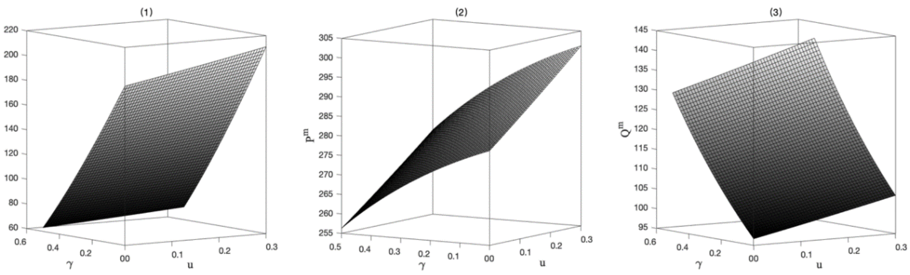

Fig. 5. Impact of hybrid contracts on supply chain equilibrium decisions

Fig. 6 illustrates how the revenue-sharing factor and the deferred payment period influence the profit of supply chain. As the revenue-sharing factor increases, the profit of manufacturer rises, while the retailer's profit first increases and then decreases. However, the total profit of the supply chain rises overall, suggesting that the implementation of a revenue-sharing contract (RSC) can improve coordination within the supply chain. The optimal level of the revenue-sharing factor is influenced by the bargaining power of both the manufacturer and the retailer, as well as their strategic choices. Although the RSC leads to a higher total supply chain profit, this increase is primarily driven by the manufacturer's gain, with the retailer's profit declining. This indicates that, in certain situations, the RSC might weaken the overall stability of the supply chain. To address this, transfer payments could be introduced to compensate the retailer, ensuring their participation and fostering a mutually beneficial arrangement. Additionally, extending the deferred payment period boosts profits for both the manufacturer and the retailer, as well as the total supply chain profit. In this scenario, the deferred payment contract (DPC) also supports supply chain coordination, resulting in a win-win outcome for both parties.

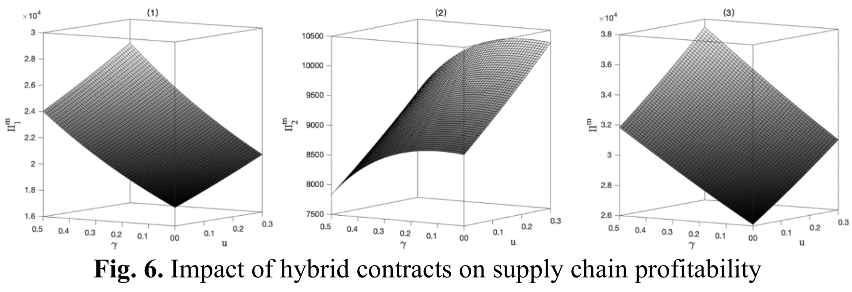

Fig. 6. Impact of hybrid contracts on supply chain profitability

4.3 The role of the compacts in supply chain coordination

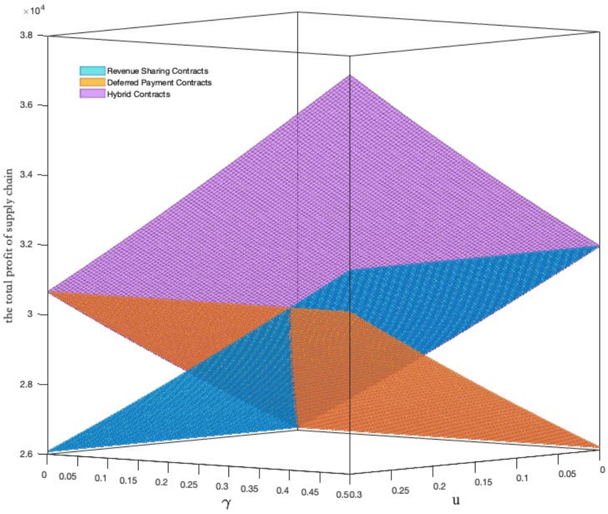

Fig. 7. The role of the compacts in supply chain coordination

Fig. 7 illustrates the total profit of the supply chain under each type of contract. It shows that, under certain conditions, the total supply chain profit under the revenue-sharing contract (RSC) may exceed the total profit under the deferred payment contract (DPC), and vice versa. However, in both cases, the total profit is lower than that under the hybrid contract. This suggests that, in specific scenarios, the hybrid contract is more effective in coordinating the cross-border export supply chain. When either the revenue-sharing or deferred payment contract is insufficient on its own, supply chain members may consider adopting the alternative contract to better coordinate the system. Moreover, when either the RSC or DPC can successfully coordinate the supply chain, manufacturers and retailers might explore combining both contracts into a hybrid agreement to maximize profits.

5. Conclusion

Amid China's continued commitment to high levels of international openness and the ongoing presence of trade disputes, export tax rebates and import tariffs have emerged as key factors influencing pricing and inventory decisions in the country's cross-border e-commerce export supply chain. This paper develops a joint optimization model to examine the optimal pricing and ordering strategies for cross-border e-commerce retail export supply chains, focusing on the impact of export tax rebates, import tariffs, and tariff transfer factors. The study also investigates how these factors affect supply chain equilibrium, decision-making, and profitability. Additionally, it explores optimal pricing and ordering strategies under different contractual arrangements, including revenue-sharing, deferred-payment, and hybrid contracts, and evaluates their effects on supply chain coordination. The findings reveal several key insights: (1) While revenue-sharing contracts can facilitate supply chain coordination, their effectiveness is influenced by factors such as export tax rebate rates, tariffs, and tariff transfer factors. Although the revenue-sharing factor may lower wholesale prices, its impact on retail prices, order volumes, and overall supply chain profit is complex and context-dependent. (2) Deferred-payment mechanisms can also coordinate cross-border export supply chains, but their effectiveness is constrained by similar factors, including export tax rebates and tariffs. The duration of the deferred payment period can influence supply chain profits due to changes in inventory and investment costs. (3) As the retailer's default risk increases, manufacturers may raise wholesale prices to offset the associated credit risk. However, this increase could lead to a decrease in retailer order volumes, ultimately reducing overall supply chain profits. Retail prices should be adjusted to account for wholesale prices and other market conditions to prevent inventory accumulation caused by declining sales. (4) Higher export tax rebate rates diminish the coordination effect of all three contracts on the supply chain. Additionally, as the tariff transfer factor increases, the scope of all three contracts' ability to enhance retailer profits gradually narrows, with the hybrid contract showing the largest reduction in effectiveness. However, the deferred-payment contract's ability to boost manufacturer and total supply chain profits expands. Export tax rebates, import tariffs, and tariff transfer factors significantly affect both profit distribution and the coordination effectiveness of supply chain contracts. (5) When one type of contract fails to achieve the desired coordination, supply chain members can consider using an alternative contract or a combination of contracts to optimize results, such as combining revenue-sharing and deferred-payment contracts for higher profits. Several management insights can be drawn: (1) Different contract types (such as revenue-sharing and deferred-payment contracts) have varying effects on supply chain coordination. Companies should tailor their contract choices to the specific market environment and policy conditions (such as export rebate rates and tariffs) to maximize overall supply chain efficiency. (2) As the retailer's default risk increases, manufacturers must adjust wholesale prices strategically to balance credit risks and fluctuations in demand. Pricing strategies should also consider market competition and customer creditworthiness to optimize both sales volume and profitability. (3) External policies, such as export tax rebates and tariffs, significantly affect profit distribution and contract coordination within the supply chain. Both researchers and managers should closely monitor policy changes and adapt supply chain management strategies accordingly. (4) When a single contract type proves ineffective, combining multiple contract forms, such as hybrid contracts, may improve supply chain coordination and increase profits for all parties involved. It is essential to evaluate the synergies of various contract combinations when making strategic decisions.

Future research could further extend this study. This paper focuses solely on the equilibrium decision-making of a single-channel supply chain and does not address the complexities of dual-channel systems, such as those combining online and offline channels. Future investigations could explore joint optimization and coordination of pricing and inventory management in dual-channel cross-border export supply chains, with a particular focus on resolving conflicts of interest among supply chain members.

Data Availability Statement

The data used to support the findings of this study are available from the corresponding author upon request.

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Appendix

Theorem 1

Proof: Eq. (6) for the retail price P: $\frac{\partial \Pi_2^d}{\partial P} = (d+\beta b)\Phi_1 - 2\alpha\Phi_1(P+\tau_2 w\xi) + \alpha w\Phi_1 - \alpha\Phi_1 w\tau_2(\xi-1) + \frac{\alpha k}{\beta}(\Phi_1 - \mathrm{T})$; $\frac{\partial^2 \Pi_2^d}{\partial P^2} = -2\alpha\Phi_1 < 0$.

Under decentralized decision making $\partial\Pi_2^d/\partial\mathrm{P} = 0$: $P^d(w) = \Phi_4^d + w(\Phi_2^d - \tau_2\xi)$, $Q^d(w) = \alpha\Phi_1(\Phi_3^d - \Phi_4^d - w\Phi_2^d)$.
$\frac{\partial \Pi_1^d}{\partial w} = \alpha\Phi_1[\Phi_3^d - \Phi_4^d + c\Phi_2^d(1-\tau_1)] - 2\alpha w\Phi_1\Phi_2^d$; $\frac{\partial^2 \Pi_1^d}{\partial w^2} = -\alpha\Phi_1[1+\tau_2(1-\xi)] < 0$.
Let $\frac{\partial \Pi_1^d}{\partial w} = 0$ to get the optimal wholesale price $w^{d^*} = \frac{\Phi_3^d - \Phi_4^d}{2\Phi_2^d} + \frac{1}{2}(1-\tau_1)c$.
$P^{d^*} = \Phi_4^d + (\Phi_2^d - \tau_2\xi)\left[\frac{\Phi_3^d - \Phi_4^d}{2\Phi_2^d} + \frac{1}{2}(1-\tau_1)c\right]$, $Q^{d^*} = \frac{1}{2}\alpha\Phi_1[\Phi_3^d - \Phi_4^d - \Phi_2^d(1-\tau_1)c]$. At this time, the maximum profit of Chinese manufacturers is: $\Pi_1^{d^*} = \alpha\Phi_1\left[\frac{\Phi_4^d}{2\Phi_2^d} + \frac{1}{2}c(\tau_1 - 1)\right]\left[\Phi_3^d - \frac{3}{2}\Phi_4^d + \frac{\Phi_2^d}{2}c(\tau_1-1)\right]$. The maximum profit for a foreign retailer is: $\Pi_2^{d^*} = \alpha\Phi_1[\Phi_3^d + c(\tau_1-1)]\left[\Phi_4^d - \frac{1}{2}\Phi_3^d + \frac{1}{2}\Phi_2^d c(\tau_1-1)\right] - \frac{k}{\beta}\left\{\beta\Phi_1 b + (\Phi_1 - \mathrm{T})\left[\frac{1}{2}\alpha\Phi_2^d c(\tau_1-1) + d - \frac{1}{2}\alpha\Phi_3^d\right]\right\}$.

Corollary 1
Proof: (1) $\frac{\partial w^{d^*}}{\partial \tau_1} = -\frac{c}{2} < 0$; $\frac{\partial P^{d^*}}{\partial \tau_1} = \frac{c}{2}(\tau_2\xi - \Phi_2^d) < 0$; $\frac{\partial Q^{d^*}}{\partial \tau_1} = \frac{c}{2}\alpha\Phi_1\Phi_2^d > 0$. (2) $\frac{\partial \Pi_1^{d^*}}{\partial \tau_1} = \left(\frac{\partial w^{d^*}}{\partial \tau_1} + c\right)Q^{d^*} + [w + (\tau_1 - 1)c]\frac{\partial Q^{d^*}}{\partial \tau_1} = \frac{c}{2}Q^{d^*} + [w + (\tau_1-1)c]\frac{\partial Q^{d^*}}{\partial \tau_1} > 0$; $\frac{\partial \Pi_2^{d^*}}{\partial \tau_1} = \frac{c}{2}\alpha\Phi_1[\Phi_3^d - \Phi_4^d - \Phi_2^d c(1-\tau_1)] > 0$.

Corollary 2

Proof: (1) $\frac{\partial w^{d^*}}{\partial \tau_2} = -\frac{1-\xi}{4\Phi_2^{d^2}}(\Phi_3^d - \Phi_4^d) < 0$; $\frac{\partial P^{d^*}}{\partial \tau_2} = \frac{1}{4\Phi_2^{d^2}}\left[\Phi_2^{d^2} c(1-\tau_1)(1-3\xi) + \frac{\xi k(\Phi_1 - \mathrm{T})}{2\beta\Phi_1} - \frac{\xi}{2}\Phi_3^d\right]$, when $\xi\Phi_3^d < \frac{\xi k(\Phi_1-\mathrm{T})}{\beta\Phi_1} + 2\Phi_2^{d^2} c(1-\tau_1)(1-3\xi)$, $\frac{\partial P^{d^*}}{\partial \tau_2} > 0$, when $\xi\Phi_3^d > \frac{\xi k(\Phi_1-\mathrm{T})}{\beta\Phi_1} + 2\Phi_2^{d^2} c(1-\tau_1)(1-3\xi)$, $\frac{\partial P^{d^*}}{\partial \tau_2} < 0$; $\frac{\partial Q^{d^*}}{\partial \tau_2} = -\frac{1-\xi}{4}\alpha\Phi_1 c(1-\tau_1) < 0$. (2) $\frac{\partial \Pi_1^{d^*}}{\partial \tau_2} = \frac{\partial w^{d^*}}{\partial \tau_2} Q^{d^*} + [w + (\tau_1 - 1)c]\frac{\partial Q^{d^*}}{\partial \tau_2} < 0$, $\frac{\partial \Pi_2^{d}}{\partial \tau_2} = 2(\Phi_3^d - \Phi_4^d - w\Phi_2^d)\frac{\partial Q^{d^*}}{\partial \tau_2} < 0$.

Corollary 3

Proof: (1) $\frac{\partial w^{d^*}}{\partial \xi} = \frac{\tau_2}{4\Phi_2^{d^2}}(\Phi_3^d - \Phi_4^d) > 0$; $\frac{\partial P^{d^*}}{\partial \xi} = \frac{\tau_2(\Phi_3^d - \Phi_4^d)}{4\Phi_2^{d^2}}(\Phi_2^d - \tau_2\xi - 3) - \frac{3\tau_2}{4}c(1-\tau_1) < 0$; $\frac{\partial Q^{d^*}}{\partial \xi} = \frac{\alpha\Phi_1\tau_2}{4}(1-\tau_1)c > 0$. (2) $\frac{\partial \Pi_1^{d^*}}{\partial \xi} = \frac{\partial w^{d^*}}{\partial \xi} Q^{d^*} + w\frac{\partial Q^{d^*}}{\partial \xi} > 0$; $\frac{\partial \Pi_2^{d^*}}{\partial \xi} = 2(\Phi_3^d - \Phi_4^d - w\Phi_2^d)\frac{\partial Q^{d^*}}{\partial \xi} > 0$.

Theorem 2

Proof: $\frac{\partial \Pi_2^r}{\partial P} = 2\Phi_1\alpha(P + \tau_2 w\xi)(\gamma - 1) - \Phi_1(\gamma - 1)(d + \beta b) + \frac{\alpha k(\Phi_1 - \mathrm{T})}{\beta} + 2(1-\gamma)\Phi_1\alpha w\Phi_2$; $\frac{\partial^2 \Pi_2^r}{\partial P^2} = 2\Phi_1\alpha(\gamma - 1) < 0$.
Under RSC coordination, $\frac{\partial \Pi_2^r}{\partial P} = 0$ $P^r(w) = \Phi_4^r + w(\Phi_2^r - \tau_2\xi)$ $Q^r(w) = \alpha\Phi_1(\Phi_3^r - \Phi_4^r - w\Phi_2^r)$.
Eq. (8) $\frac{\partial \Pi_1^r}{\partial w} = \left\{\alpha\Phi_1\Phi_3^r + \frac{\alpha k(\Phi_1 - \mathrm{T})}{(\gamma-1)\beta\Phi_1} + 2\Phi_1\alpha w\Phi_2^r\right\}\frac{1-\gamma\tau_2(\xi-1)}{2(1-\gamma)} - \Phi_2^r\Phi_1[\alpha w + \alpha c(\tau_1 - 1) + \Phi_1(d + \beta b)]$; $\frac{\partial^2 \Pi_1^r}{\partial w^2} = -2\alpha\Phi_1\Phi_2^r(1 + \gamma\Phi_2^r) < 0$.

$\frac{\partial \Pi_1^r}{\partial w} = 0$ $w^{r*}(\gamma) = \frac{\Phi_3^r - \Phi_4^r}{2\Phi_2^r} + \frac{c(1-\tau_1) - \gamma\Phi_4^r}{2(1+\gamma\Phi_2^r)}$ $P^{r*}(\gamma) = \Phi_4^r + (\Phi_2^r - \tau_2\xi)\left[\frac{\Phi_3^r - \Phi_4^r}{2\Phi_2^r} + \frac{c(1-\tau_1) - \gamma\Phi_4^r}{2(1+\gamma\Phi_2^r)}\right]$; $Q^{r*}(\gamma) = \frac{1}{2}\alpha\Phi_1\left[\Phi_3^r - \Phi_4^r - \frac{c(1-\tau_1)\Phi_2^r - \gamma\Phi_2^r\Phi_4^r}{1+\gamma\Phi_2^r}\right]$ $\Pi_1^{r*} = \frac{1}{4}\alpha\Phi_1\left[\Phi_3^r - \Phi_4^r - \frac{c(1-\tau_1)\Phi_2^r - \gamma\Phi_2^r\Phi_4^r}{1+\gamma\Phi_2^r}\right]\left[\gamma\Phi_4^r + c(\tau_1 - 1) + \frac{(\Phi_3^r - \Phi_4^r)(1+\gamma\Phi_2^r)}{\Phi_2^r}\right]$. $\Pi_2^{r*} = \frac{1-\gamma}{2}\alpha\Phi_1\left[\Phi_3^r - \Phi_4^r - \frac{c(1-\tau_1)\Phi_2^r - \gamma\Phi_2^r\Phi_4^r}{1+\gamma\Phi_2^r}\right]\left[\Phi_4^r - \frac{1}{2}(\Phi_3^r - \Phi_4^r) - \frac{\Phi_2^r[c(1-\tau_1) - \gamma\Phi_4^r]}{2(1+\gamma\Phi_2^r)}\right] - \frac{k}{\beta}\left\{\beta\Phi_1 b + (\Phi_1 - \mathrm{T})\left[d - \alpha\left[\frac{\Phi_3^r + \Phi_4^r}{2} - \frac{\Phi_2^r[c(1-\tau_1) - \gamma\Phi_4^r]}{2(1+\gamma\Phi_2^r)}\right]\right]\right\}$.

Corollary 4

Proof: the increment of total supply chain profit after considering RSC is: $\Delta\Pi^r = \Pi_1^{r*} + \Pi_2^{r*} - \Pi_1^{d*} - \Pi_2^{d*}$, when $r = 0$, $\Delta\Pi^r = 0$, when $r \neq 0$. Take the increment $\Delta\Pi^r$ as its derivative, then $\frac{\partial \Delta\Pi^r}{\partial \gamma} = \frac{\partial Q^{r^*}}{\partial \gamma}\left[c(\tau_1 - 1) - \Phi_3^r + \Phi_4^r + w^{r*}[\Phi_2^r - \tau_2(1-\xi)] + \frac{k(\Phi_1 - \mathrm{T})}{\beta\Phi_1}\right] - \tau_2(1-\xi)Q^{r*}\frac{\partial w^{r^*}}{\partial \gamma}$,when $\frac{\partial Q^{r^*}}{\partial \gamma}\left[c(\tau_1 - 1) - \Phi_3^r + \Phi_4^r + w^{r*}[\Phi_2^r - \tau_2(1-\xi)] + \frac{k(\Phi_1 - \mathrm{T})}{\beta\Phi_1}\right] > \tau_2(1-\xi)Q^{r*}\frac{\partial w^{r^*}}{\partial \gamma}$, $\frac{\partial \Delta\Pi^r}{\partial \gamma} < 0$. At this point when $r > 0$, $\Delta\Pi^r < 0$,; when $\frac{\partial Q^{r^*}}{\partial \gamma}\left[c(\tau_1 - 1) - \Phi_3^r + \Phi_4^r + w^{r*}[\Phi_2^r - \tau_2(1-\xi)] + \frac{k(\Phi_1 - \mathrm{T})}{\beta\Phi_1}\right] < \tau_2(1-\xi)Q^{r*}\frac{\partial w^{r^*}}{\partial \gamma}$, $\frac{\partial \Delta\Pi^r}{\partial \gamma} > 0$. At this point $r > 0$, $\Delta\Pi^r > 0$,

Corollary 5

Proof: (1) $\frac{\partial w^{r^*}}{\partial \gamma} = -\frac{(1+\gamma+\gamma\Phi_2^r)\Phi_4^r + \Phi_2^r c(1-\tau_1)}{2(1-\gamma)(1+\gamma\Phi_2^r)^2} - \frac{\Phi_3^r}{4\Phi_2^r(1-\gamma)(1+\gamma\Phi_2^r)} < 0$; $\frac{\partial P^{r^*}}{\partial \gamma} = \frac{\partial \Phi_4^r}{\partial \gamma} + \frac{\partial w^{r^*}}{\partial \gamma}(\Phi_2^r - \tau_2\xi) + w^{r*}\frac{\partial \Phi_2^r}{\partial \gamma} = \frac{1}{2(1-\gamma)(1+\gamma\Phi_2^r)^2}\left[(1 - \Phi_2^r - \gamma\Phi_2^{r^2})\Phi_4^r + \Phi_2^r c(1-\tau_1)(1 + \gamma\Phi_2^r - \Phi_2^r) - \frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2}\right]\frac{\partial w^{r^*}}{\partial \gamma}\tau_2\xi$, when $(1 - \Phi_2^r - \gamma\Phi_2^{r^2})\Phi_4^r + \Phi_2^r c(1-\tau_1)(1 + \gamma\Phi_2^r - \Phi_2^r) - \frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2} > 2(1-\gamma)(1+\gamma\Phi_2^r)^2\frac{\partial w^{r^*}}{\partial \gamma}\tau_2\xi$, $\frac{\partial P^{r^*}}{\partial \gamma} > 0$, when $(1 - \Phi_2^r - \gamma\Phi_2^{r^2})\Phi_4^r + \Phi_2^r c(1-\tau_1)(1 + \gamma\Phi_2^r - \Phi_2^r) - \frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2} < 2(1-\gamma)(1+\gamma\Phi_2^r)^2\frac{\partial w^{r^*}}{\partial \gamma}\tau_2\xi$, $\frac{\partial P^{r^*}}{\partial \gamma} < 0$; $\frac{\partial Q^{r^*}}{\partial \gamma} = -\alpha\Phi_1\left[\frac{\partial \Phi_4^r}{\partial \gamma} + \frac{\partial w^{r^*}}{\partial \gamma}\Phi_2^r + w^{r*}\frac{\partial \Phi_2^r}{\partial \gamma}\right] = \frac{-\alpha\Phi_1}{2(1-\gamma)(1+\gamma\Phi_2^r)^2}\left[(1 - \Phi_2^r - \gamma\Phi_2^{r^2})\Phi_4^r + \Phi_2^r c(1-\tau_1)(1 + \gamma\Phi_2^r - \Phi_2^r) - \frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2}\right]$, when $(1 - \Phi_2^r - \gamma\Phi_2^{r^2})\Phi_4^r + \Phi_2^r c(1-\tau_1)(1 + \gamma\Phi_2^r - \Phi_2^r) < \frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2}$, $\frac{\partial Q^{r^*}}{\partial \gamma} > 0$, when $(1 - \Phi_2^r - \gamma\Phi_2^{r^2})\Phi_4^r + \Phi_2^r c(1-\tau_1)(1 + \gamma\Phi_2^r - \Phi_2^r) > \frac{(1+\gamma\Phi_2^r)\Phi_3^r}{2}$, $\frac{\partial Q^{r^*}}{\partial \gamma} < 0$. (2) $\frac{\partial \Pi_1^{r^*}}{\partial \gamma} = \alpha\Phi_1(\Phi_3^r - \Phi_4^r - w\Phi_2^r)\left[\frac{\partial w^{r^*}}{\partial \gamma}(1 + \gamma\Phi_2^r) + \frac{\Phi_2^r w^{r^*}}{1-\gamma} + \Phi_4^r + \frac{\gamma\left(\Phi_4^r - \frac{1}{2}\Phi_3^r\right)}{1-\gamma}\right] + [w^{r*}(1 + \gamma\Phi_2^r) + \gamma\Phi_4^r - c(1-\tau_1)]\frac{\partial Q^{r^*}}{\partial \gamma} = Q^{r*}\left[\frac{2(1-\gamma)\Phi_2^r - 1}{4\Phi_2^r(1-\gamma)}\Phi_3^r + \frac{\gamma(1+\Phi_2^r)\Phi_4^r}{2(1-\gamma)(1+\gamma\Phi_2^r)}\right] + [w^{r*}(1 + \gamma\Phi_2^r) + \gamma\Phi_4^r - c(1-\tau_1)]\frac{\partial Q^{r^*}}{\partial \gamma}$, $when^*\left[\frac{2(1-\gamma)\Phi_2^r - 1}{4\Phi_2^r(1-\gamma)}\Phi_3^r + \frac{\gamma(1+\Phi_2^r)\Phi_4^r}{2(1-\gamma)(1+\gamma\Phi_2^r)}\right] > -[w^{r*}(1 + \gamma\Phi_2^r) + \gamma\Phi_4^r - c(1-\tau_1)]\frac{\partial Q^{r^*}}{\partial \gamma}$, $\frac{\partial \Pi_1^{r^*}}{\partial \gamma} > 0$, when

$Q^{r*}\left[\frac{2(1-\gamma)\Phi_2^r-1}{4\Phi_2^r(1-\gamma)}\Phi_3^r+\frac{\gamma(1+\Phi_2^r)\Phi_4^r}{2(1-\gamma)(1+\gamma\Phi_2^r)}\right]<-[w^{r*}(1+\gamma\Phi_2^r)+\gamma\Phi_4^r-c(1-\tau_1)]\frac{\partial Q^{r*}}{\partial\gamma}$, $\frac{\partial\Pi_1^{r*}}{\partial\gamma}<0$; $\frac{\partial\Pi_2^{r*}}{\partial\gamma}=Q^{r*}\left[\frac{1}{2}\Phi_3^r-\Phi_4^r-(1-\gamma)\Phi_2^r\frac{\partial w^{r*}}{\partial\gamma}\right]-\frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}\frac{\partial Q^{r*}}{\partial\gamma}$, when $Q^{r*}\left[\frac{1}{2}\Phi_3^r-\Phi_4^r-(1-\gamma)\Phi_2^r\frac{\partial w^{r*}}{\partial\gamma}\right]>\frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}\frac{\partial Q^{r*}}{\partial\gamma}$, $\frac{\partial\Pi_2^{r*}}{\partial\gamma}>0$, when $Q^{r*}\left[\frac{1}{2}\Phi_3^r-\Phi_4^r-(1-\gamma)\Phi_2^r\frac{\partial w^{r*}}{\partial\gamma}\right]<\frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}\frac{\partial Q^{r*}}{\partial\gamma}$, $\frac{\partial\Pi_2^{r*}}{\partial\gamma}<0$.

Theorem 3

Proof: $\frac{\partial\Pi_2^f}{\partial P}=\alpha\Phi_1\Phi_3^f-2\Phi_1\alpha(P+\tau_2w\xi)+\Phi_1\alpha we^{-au}+\frac{\alpha k(\Phi_1-\mathrm{T})}{\beta}-\Phi_1\alpha\tau_2w(\xi-1)$; $\frac{\partial^2\Pi_2^f}{\partial P^2}=-2\Phi_1\alpha<0$.

Under the coordination of the DPC

$\frac{\partial\Pi_2^f}{\partial P}=0$

$P^f(w)=\Phi_4^f+w(\Phi_2^f-\tau_2\xi)$,

$Q^f(w)=\alpha\Phi_1(\Phi_3^f-\Phi_4^f-w\Phi_2^f)$.

$\frac{\partial\Pi_1^f}{\partial w}=\frac{1}{2}e^{-au}\alpha\Phi_1\left[\Phi_3^f-\frac{k(\Phi_1-\mathrm{T})}{\beta\Phi_1}-4w\Phi_2^f\right]+\alpha\Phi_1\Phi_2^fc(\tau_1-1)$; $\frac{\partial^2\Pi_1^f}{\partial w^2}=-2e^{-au}\alpha\Phi_1\Phi_2^f<0$.

Let $\frac{\partial\Pi_1^f}{\partial w}=0$ to obtain the optimal wholesale price $w^{f*}(u)=\frac{\Phi_3^f-\Phi_4^f}{2\Phi_2^f}+\frac{1}{2}e^{au}c(1-\tau_1)$ in the presence of a deferred payment contract.

$P^{f*}(u)=\Phi_4^f+(\Phi_2^f-\tau_2\xi)\left[\frac{\Phi_3^f-\Phi_4^f}{2\Phi_2^f}+\frac{1}{2}e^{au}c(1-\tau_1)\right]$; $Q^{f*}(u)=\frac{1}{2}\alpha\Phi_1[\Phi_3^f-\Phi_4^f-e^{au}c(1-\tau_1)\Phi_2^f]$. At this time, the maximum profit of Chinese manufacturers is: $\Pi_1^{f*}=\frac{1}{4}\alpha\Phi_1\left[\frac{e^{-au}(\Phi_3^f-\Phi_4^f)}{\Phi_2^f}+c(\tau_1-1)\right][\Phi_3^f-\Phi_4^f+e^{au}c(\tau_1-1)\Phi_2^f]$. *The maximum profit for a foreign retailer is:* $\Pi_2^{f*}=\frac{\alpha\Phi_1}{2}[\Phi_3^f-\Phi_4^f-e^{au}c(1-\tau_1)\Phi_2^f]\left[\Phi_4^f+\left(\frac{e^{au}}{2}-1\right)[e^{-au}(\Phi_3^f-\Phi_4^f)-c(\tau_1-1)\Phi_2^f]\right]-\frac{k}{\beta}\left\{\beta\Phi_1b+(\Phi_1-\mathrm{T})\left[de^{\delta u}-\frac{\alpha}{2}[\Phi_3^f+\Phi_4^f+e^{au}c(1-\tau_1)\Phi_2^f]\right]\right\}$.

Corollary 6

Proof: after considering the deferred payment covenant, the supply chain increment is: $\Delta\Pi^f=\Pi_1^{f*}+\Pi_2^{f*}-\Pi_1^{d*}-\Pi_2^{d*}$. When u = 0, $\Delta\Pi^f=0$, and when u ≠ 0, the increment $\Delta\Pi^f$ is derived from it, then $\frac{\partial\Delta\Pi^f}{\partial u}=\left[\frac{\Phi_2^f+e^{-au}}{4\alpha\Phi_2^f}\delta de^{\delta u}+\frac{ac(1-\tau_1)}{4}\right]Q^{f*}+\frac{\alpha\Phi_1}{4}[e^{-au}w^{f*}+c(\tau_1-1)]\left[\frac{\delta de^{\delta u}}{\alpha}-ac(1-\tau_1)\tau_2(1-\xi)\right]+\frac{\alpha k(\Phi_1-\mathrm{T})}{4\beta}ac(1-\tau_1)\tau_2(1-\xi)-\tau_2(1-\xi)\frac{ae^{-au}}{4\Phi_2^{f2}}(\Phi_3^f-\Phi_4^f)Q^{f*}-\frac{k(\Phi_1-\mathrm{T})}{\beta}\delta de^{\delta u}$. When $\left[\frac{\Phi_2^f+e^{-au}}{4\alpha\Phi_2^f}\delta de^{\delta u}+\frac{ac(1-\tau_1)}{4}\right]Q^{f*}+\frac{\alpha\Phi_1}{4}[e^{-au}w^{f*}+c(\tau_1-1)]\left[\frac{\delta de^{\delta u}}{\alpha}-ac(1-\tau_1)\tau_2(1-\xi)\right]+\frac{\alpha k(\Phi_1-\mathrm{T})}{4\beta}ac(1-\tau_1)\tau_2(1-\xi)>\tau_2(1-\xi)\frac{ae^{-au}}{4\Phi_2^{f2}}(\Phi_3^f-\Phi_4^f)Q^{f*}+\frac{k(\Phi_1-\mathrm{T})}{\beta}\delta de^{\delta u}$, $\frac{\partial\Delta\Pi^f}{\partial u}>0$. At this point when u > 0, $\Delta\Pi^f>0$, the deferred payment contract enables supply chain coordination; when $\left[\frac{\Phi_2^f+e^{-au}}{4\alpha\Phi_2^f}\delta de^{\delta u}+\frac{ac(1-\tau_1)}{4}\right]Q^{f*}+\frac{\alpha\Phi_1}{4}[e^{-au}w^{f*}+c(\tau_1-1)]\left[\frac{\delta de^{\delta u}}{\alpha}-ac(1-\tau_1)\tau_2(1-\xi)\right]+\frac{\alpha k(\Phi_1-\mathrm{T})}{4\beta}ac(1-\tau_1)\tau_2(1-\xi)<\tau_2(1-\xi)\frac{ae^{-au}}{4\Phi_2^{f2}}(\Phi_3^f-\Phi_4^f)Q^{f*}+\frac{k(\Phi_1-\mathrm{T})}{\beta}\delta de^{\delta u}$, $\frac{\partial\Delta\Pi^f}{\partial u}<0$. when u > 0, $\Delta\Pi^f<0$,

Corollary 7

Proof: (1) $\frac{\partial w^{f*}}{\partial u}=\frac{\delta de^{\delta u}}{4\alpha\Phi_2^f}+\frac{ae^{-au}}{4\Phi_2^{f2}}(\Phi_3^f-\Phi_4^f)+\frac{a}{2}e^{au}c(1-\tau_1)>0$; $\frac{\partial P^{f*}}{\partial u}=\frac{\delta de^{\delta u}}{2\alpha}+\frac{\partial w^{f*}}{\partial u}(\Phi_2^f-\tau_2\xi)-\frac{ae^{-au}}{2}w^{f*}=\frac{3\delta de^{\delta u}}{4\alpha}+\frac{a}{4}c(1-\tau_1)(2e^{au}\Phi_2^f-1)-\frac{\partial w^{f*}}{\partial u}\tau_2\xi$, when $\frac{3\delta de^{\delta u}}{4\alpha}+\frac{a}{4}c(1-\tau_1)(2e^{au}\Phi_2^f-1)>\frac{\partial w^{f*}}{\partial u}\tau_2\xi$, $\frac{\partial P^{f*}}{\partial u}>0$, when $\frac{3\delta de^{\delta u}}{4\alpha}+\frac{a}{4}c(1-\tau_1)(2e^{au}\Phi_2^f-1)<\frac{\partial w^{f*}}{\partial u}\tau_2\xi$, $\frac{\partial P^{f*}}{\partial u}<0$, $\frac{\partial Q^{f*}}{\partial u}=\alpha\Phi_1\left[\frac{\partial\Phi_3^f}{\partial u}-\frac{\partial\Phi_4^f}{\partial u}-\frac{\partial w^{f*}}{\partial u}\Phi_2^f-w^{f*}\frac{\partial\Phi_2^f}{\partial u}\right]=\frac{\alpha\Phi_1}{4}\left[\frac{\delta de^{\delta u}}{\alpha}-ac(1-\tau_1)\tau_2(1-\xi)\right]>0$. (2) $\frac{\partial\Pi_1^{f*}}{\partial u}=\frac{\alpha\Phi_1}{2}[e^{-au}(\Phi_3^f-\Phi_4^f)-\Phi_2^fc(1-\tau_1)]\left[-aw-\frac{\partial w^{f*}}{\partial u}+\frac{\delta de^{\delta u}}{2\alpha\Phi_2^f}\right]$, when $\frac{\delta de^{\delta u}}{2\alpha\Phi_2^f}>aw+\frac{\partial w^{f*}}{\partial u}$, $\frac{\partial\Pi_1^{f*}}{\partial u}>0$, when $\frac{\delta de^{\delta u}}{2\alpha\Phi_2^f}<aw+\frac{\partial w^{f*}}{\partial u}$, $\frac{\partial\Pi_1^{f*}}{\partial u}<0$; $\frac{\partial\Pi_2^{f*}}{\partial u}=\left(\frac{\partial\Phi_4^f}{\partial u}-\frac{\partial w^{f*}}{\partial u}\Phi_2^f-w^{f*}\frac{\partial\Phi_2^f}{\partial u}\right)Q^{f*}+(\Phi_4^f-w\Phi_2^f)\frac{\partial Q^{f*}}{\partial u}-$

$\alpha\Phi_1\left(\Phi_4^f-\frac{1}{2}\Phi_3^f\right)\left(\frac{\partial P^{f^*}}{\partial u}+\frac{\partial w^{f^*}}{\partial u}\tau_2\xi\right)=\left(\Phi_3^f-2w^{f^*}\Phi_2^f\right)\frac{\partial Q^{f^*}}{\partial u}-\alpha\Phi_1\left(\Phi_4^f-\frac{1}{2}\Phi_3^f\right)\left(\frac{\partial P^{f^*}}{\partial u}+\frac{\partial w^{f^*}}{\partial u}\tau_2\xi\right)$, when $\left(\Phi_3^f-2w^{f^*}\Phi_2^f\right)\frac{\partial Q^{f^*}}{\partial u}>\alpha\Phi_1\left(\Phi_4^f-\frac{1}{2}\Phi_3^f\right)\left(\frac{\partial P^{f^*}}{\partial u}+\frac{\partial w^{f^*}}{\partial u}\tau_2\xi\right),\frac{\partial \Pi_2^{f^*}}{\partial u}>0$, when $\left(\Phi_3^f-2w^{f^*}\Phi_2^f\right)\frac{\partial Q^{f^*}}{\partial u}<\alpha\Phi_1\left(\Phi_4^f-\frac{1}{2}\Phi_3^f\right)\left(\frac{\partial P^{f^*}}{\partial u}+\frac{\partial w^{f^*}}{\partial u}\tau_2\xi\right),\frac{\partial \Pi_2^{f^*}}{\partial u}<0$.

Corollary 8

Proof: (1) $\frac{\partial w^{f^*}}{\partial a}=\frac{ue^{-au}\left(\Phi_3^f-\Phi_4^f\right)}{4\Phi_2^{f^2}}+\frac{ue^{au}c(1-\tau_1)}{2}>0$; $\frac{\partial P^{f^*}}{\partial a}=\frac{u}{2}\left[-\frac{\tau_2\xi e^{-au}\left(\Phi_3^f-\Phi_4^f\right)}{2\Phi_2^{f^2}}+\left[e^{au}\left(\Phi_2^f-\tau_2\xi\right)-\frac{1}{2}\right]c(1-\tau_1)\right]$, when $\left[e^{au}\left(\Phi_2^f-\tau_2\xi\right)-\frac{1}{2}\right]c(1-\tau_1)>\frac{\tau_2\xi e^{-au}\left(\Phi_3^f-\Phi_4^f\right)}{2\Phi_2^{f^2}},\frac{\partial P^{f^*}}{\partial a}>0$, when $\left[e^{au}\left(\Phi_2^f-\tau_2\xi\right)-\frac{1}{2}\right]c(1-\tau_1)<\frac{\tau_2\xi e^{-au}\left(\Phi_3^f-\Phi_4^f\right)}{2\Phi_2^{f^2}},\frac{\partial P^{f^*}}{\partial a}<0$; $\frac{\partial Q^{f^*}}{\partial a}=-\frac{\alpha\Phi_1 ue^{au}c(1-\tau_1)\tau_2(1-\xi)}{4}<0$. (2) $\frac{\partial \Pi_1^{f^*}}{\partial a}=\frac{ue^{-au}\left(\Phi_3^f-\Phi_4^f\right)}{4\Phi_2^{f^2}}\tau_2(1-\xi)Q^{f^*}+\left[e^{-au}w^{f^*}-(1-\tau_1)c\right]\frac{\partial Q^{f^*}}{\partial a}<0$; $\frac{\partial \Pi_2^{f^*}}{\partial a}=2\left(\Phi_3^f-\Phi_4^f-w^{f^*}\Phi_2^f\right)\frac{\partial Q^{f^*}}{\partial a}<0$.

Corollary 9

Proof: (1) $\frac{\partial w^{f^*}}{\partial \delta}=\frac{ude^{\delta u}}{4\Phi_2^f\alpha}>0$; $\frac{\partial P^{f^*}}{\partial \delta}=\frac{ude^{\delta u}}{4\alpha\Phi_2^f}\left(3\Phi_2^f-\tau_2\xi\right)$, when $3\Phi_2^f>\tau_2\xi,\frac{\partial P^{f^*}}{\partial \delta}>0$, when $3\Phi_2^f<\tau_2\xi,\frac{\partial P^{f^*}}{\partial \delta}<0$; $\frac{\partial Q^{f^*}}{\partial \delta}=\frac{ude^{\delta u}\Phi_1}{4}>0$. (2) $\frac{\partial \Pi_1^{f^*}}{\partial \delta}=e^{-au}Q^{f^*}\frac{\partial w^{f^*}}{\partial \delta}+\left[e^{-au}w^{f^*}-(1-\tau_1)c\right]\frac{\partial Q^{f^*}}{\partial \delta}>0$; $\frac{\partial \Pi_2^{f^*}}{\partial \delta}=\frac{ude^{\delta u}\Phi_1}{2}\left(2\Phi_3^f-3\Phi_4^f-w^{f^*}\Phi_2^f\right)$, when $2\Phi_3^f>3\Phi_4^f+w^{f^*}\Phi_2^f,\frac{\partial \Pi_2^{f^*}}{\partial \delta}>0$, when $2\Phi_3^f<3\Phi_4^f+w^{f^*}\Phi_2^f,\frac{\partial \Pi_2^{f^*}}{\partial \delta}<0$.

Theorem 4

Proof: $\frac{\partial \Pi_2^m}{\partial P}=\alpha\Phi_1\Phi_3^f(1-\gamma)-2\Phi_1\alpha(1-\gamma)(P+\tau_2 w\xi)-\Phi_1\alpha\tau_2 w(\xi-1)+\frac{\alpha k(\Phi_1-\mathrm{T})}{\beta}+\Phi_1\alpha we^{-au}$; $\frac{\partial^2 \Pi_2^m}{\partial P^2}=-2\Phi_1\alpha(1-\gamma)<0$.

Let $\frac{\partial \Pi_2^m}{\partial P}=0$

$P^m(w)=\Phi_4^m+w(\Phi_2^m-\tau_2\xi)$,
$Q^m(w)=\alpha\Phi_1[\Phi_3^m-\Phi_4^m-w\Phi_2^m]$.
$\frac{\partial \Pi_1^m}{\partial w}=(\gamma\tau_2\xi+e^{-au})\alpha\Phi_1\Phi_3^m-\alpha\Phi_1(P+\tau_2 w\xi)(2\gamma\tau_2\xi+e^{-au})-\alpha\Phi_1\tau_2 w\xi e^{-au}+\alpha\Phi_1\tau_2\xi c(\tau_1-1)$; $\frac{\partial^2 \Pi_1^m}{\partial w^2}=-2\alpha\Phi_1\tau_2\xi(\gamma\tau_2\xi+e^{-au})<0$.
Let $\frac{\partial \Pi_1^m}{\partial w}=0$
$w^{m^*}(\gamma,u)=\frac{\Phi_3^m-\Phi_4^m}{2\Phi_2^m}+\frac{c(1-\tau_1)-\gamma\Phi_4^m}{2(\gamma\Phi_2^m+e^{-au})}$.
$P^{m^*}(\gamma,u)=\Phi_4^m+(\Phi_2^m-\tau_2\xi)\left[\frac{\Phi_3^m-\Phi_4^m}{2\Phi_2^m}+\frac{c(1-\tau_1)-\gamma\Phi_4^m}{2(\gamma\Phi_2^m+e^{-au})}\right]$; $Q^{m^*}(\gamma,u)=\frac{1}{2}\alpha\Phi_1\left[\Phi_3^m-\Phi_4^m-\frac{\Phi_2^m}{\gamma\Phi_2^m+e^{-au}}[c(1-\tau_1)-\gamma\Phi_4^m]\right]$. At this time, the maximum profit of Chinese manufacturers is: $\Pi_1^{m^*}=\frac{1}{4}\alpha\Phi_1\left[\Phi_3^m-\Phi_4^m-\frac{\Phi_2^m}{\gamma\Phi_2^m+e^{-au}}[c(1-\tau_1)-\gamma\Phi_4^m]\right]\left[\frac{(\gamma\Phi_2^m+e^{-au})(\Phi_3^m-\Phi_4^m)}{\Phi_2^m}-c(1-\tau_1)+\gamma\Phi_4^m\right]$. The maximum profit for a foreign retailer is: $\Pi_2^{m^*}=\frac{1}{4}\alpha\Phi_1(1-\gamma)\left[3\Phi_4^m-\Phi_3^m-\frac{c(1-\tau_1)-\gamma\Phi_4^m}{\gamma\Phi_2^m+e^{-au}}\right]\left[\Phi_3^m-\Phi_4^m-\frac{\Phi_2^m}{\gamma\Phi_2^m+e^{-au}}[c(1-\tau_1)-\gamma\Phi_4^m]\right]-k\Phi_1 b-\frac{k(\Phi_1-\mathrm{T})}{\beta}\left[de^{\delta u}-\frac{\alpha}{2}\left[\frac{\Phi_3^m+\Phi_4^m}{\Phi_2^m}+\frac{c(1-\tau_1)-\gamma\Phi_4^m}{\gamma\Phi_2^m+e^{-au}}\right]\right]$.