

Research Article

A Multinational Green Supply Chain Model Suffered to Import Tariff

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This paper considers a multinational green supply chain (MGSC), composed of a manufacturer and a foreign retailer affected by import tariff. The main theme of this paper is to explore supply chain decisions and coordination contract. Four decision models were investigated: (1) the centralized decision supply chain model (model CS), (2) the decentralized decision supply chain model (model DS), (3) the R&D cost sharing contract model (model RD) with the retailer sharing a portion of green R&D cost, and (4) the quantity discount-cost sharing contract model (model QD), which combined a quantity discount contract with a cost sharing contract. The equilibrium decisions of these models were derived. The R&D cost sharing contract was found to improve greenness and performance of the supply chain but cannot reach the optimal performance compared to the centralized decision model. While the quantity discount-cost sharing contract can achieve a perfect coordination of MGSC. Furthermore, import tariff has an adverse effect on the performance of MGSC. The increase in tariff shrinks the threshold of the highest wholesale price and quantity discount coefficient offered by the manufacturer, which will hamper the cooperation of supply chain. However, the enhancement of consumers' green preference is conducive to encourage the retailer to participate in cooperation and smoothen the adverse effects of tariff fluctuation. In the same model, the adverse effect of tariff on product greenness and the retail price does not change with the increase in its value. However, the adverse effect on the green performance price ratio and the profits from all parties in the supply chain are slow.

1. Introduction

The continuous improvement of consumers' awareness on green environmental protection and the acceleration of globalization are promoting the rapid development of green trade [1, 2]. On the grounds of environmental pollution, product food safety, and health problems, meanwhile, many countries have raised the requirements for environmental, safety, and health access to products entering the domestic market [3]. Based on these factors, some enterprises begin to join the practice of MGSC and regard green technology as an effective means to enhance product differentiation and quality, as the international market of products is expanded and the competitiveness and international image of enterprises are enhanced [4–6]. To develop clean technologies for the green production, different from traditional

multinational supply chain, the manufacturer is required to invest additional costs. As a result, the production pressure of the manufacturer is increased. In this case, it is quite necessary for the supply chain members to actively cooperate in R&D of green technologies, thereby making the operating costs reduced and the profit structure optimized, and achieving multiple wins in the end [7–9], such as “Green Supply Chain Innovation Project” of GE [10], “closed-loop recyclable plastic supply chain” of Dell [11], “Supplier Corporate Social Responsibility (CSR) Agreement” of Huawei [12], and the circular economy model of HP [13]. As the green environmental protection is valued by members of the supply chain, the rational allocation of increased costs and benefits based on green R&D is more focused by MGSC, and the coordination mechanism of the supply chain is strengthening too.

In addition to the cost pressures caused by green R&D, the development of green trade also is hindered by some unfavorable international factors such as the rising international trade protectionism-tariff [14]. Since 2018, the Sino-U.S. Trade conflict has caused billions of dollars loss, which has had a serious impact on the automotive and technology industries [15]. The profit margins of retailing, manufacturing, and construction companies were squeezed by the trade conflict, and they had to pass on the increased cost to their customers. The tariff cost is transferred to upstream and downstream enterprises through the supply chain, for MGSC, which will disrupt organization structure, weaken the competitiveness, and damage the greening level of the supply chain. It would be expected that cross-border trade will be challenged by trade conflicts for the future, and trade frictions will make it more difficult for multinational supply chains to move green. Therefore, it is significant to study the impact of import tariff on MGSC pricing decisions and performance.

Based on this, this paper attempts to explore an effective coordination mechanism to make the costs and benefits of MGSC rationally allocated and the economic performance and environmental performance of MGSC improved. In addition, the role of tariff fluctuation in supply chain coordination contracts and supply chain decision was explored, and a measure to cope with tariff fluctuations was tried to be found. In this paper, the coordination of a two-level MGSC was considered, consisting of a manufacturer and a retailer facing the challenge of increasing import tariff. The export-oriented green products are produced by the manufacturer according to environmental standards and then were sold to the importing country consumers by the import retailer. The previous researches on green supply chain were concentrated within a country. The novelty of this paper is to explore a contract that can coordinate MGSC, which was not previously covered. In the context of green development, there is a certain practical significance to explore the impact of tariff fluctuations on corporate decision conforms, for it is in line with the current trend of economic development. This paper is intended to answer the following questions:

- (1) The optimal decisions of MGSC under different supply chain models
- (2) Propose a contract that can be used to coordinate the MGSC
- (3) The impact of import tariff on supply chain optimal decisions and supply chain contract
- (4) The method to cope with tariff fluctuations

First, a centralized decision model (model CS) and a decentralized decision model (model DS) were constructed. The model CS is a benchmark for comparative analysis of several decentralized models below. Then, a R&D cost sharing contract model (model RD) was proposed, and the effect of the R&D cost sharing contract on supply chain performance was discussed. This contract was chosen because R&D cost is the direct cost of developing green technology, and the retailer sharing a part of R&D cost is the

most direct and effective internal coordination policy to increase the enthusiasm of the manufacturer [8]. Our findings showed that the R&D cost sharing contract enables the supply chain to achieve Pareto improvement but cannot achieve perfect supply chain coordination. A quantity discount-cost sharing contract model (model QD) was further proposed and explored to see if it can achieve supply chain coordination. The quantity discount is widely used to coordinate the supply chain, which has a significant effect on reducing supply chain risk and increasing profitability of each supply chain member [16]. However, the R&D cost sharing contract can directly improve the greenness. Therefore, the environmental performance and economic performance of the supply chain can be simultaneously improved by the jointed contract of R&D cost sharing and quantity discount. Finally, a theoretical derivation and numerical simulation were combined to analyze the impact of import tariff and the green preference of consumers in the importing country on MGSC performance.

The rest of this paper is organized as following: Section 2 reviews the related literature; Section 3 completes the model descriptions and model assumptions; Section 4 shows the construction and solution process of models and the discussion of models; Section 5 performs numerical analysis; and Section 6 presents the conclusions and future research directions.

2. Literature Review

In this section, the related research can be summarized from three streams: the green supply chain operations, the import tariff effect, and the supply chain coordination contracts.

2.1. The Green Supply Chain Operations. Green supply chain requires supply chain members to incorporate environmental awareness into corporate management and supply chain operations and improve products' compatibility with the environment without affecting their functionality and quality [17, 18]. Chung and Tsai [19] early put forth that the quality of products could be improved by manufacturers through green technology innovation. Green development can protect the environment and enhance the competitiveness of products [20]. Papagiannakis et al. [21] also pointed out that, to improve corporate profit and image, for enterprise, producing green products and taking a green development path are effective means. Under the upsurge of "green sustainable development," the demand for green products is gradual increasing, which will inevitably have a major impact on the reform of the economic development model. The green supply chain considering environmental awareness is gradually becoming the focus of attention [22]. Research on this topic has proliferated since 2010 [23]. Extensive researches were based on the different game behaviors such as supply chain member Nash equilibrium or Stackelberg leader-follower game and analyzed the optimal product greenness decision and pricing decision of supply chain system. These studies considered different decision

environments, such as different supply chain structures [24], determinism and uncertainty of demand [25, 26], symmetric and asymmetric information [27, 28], green preference of consumers [29–31], green product attributes (development-intensive and marginal cost-intensive) [24], and different design strategies of green products [32]. Furthermore, some scholars took into account the factors such as risk aversion behavior [33] and fairness preference attribute [34] of supply chain participants when constructing the game model so that the research of supply chain was more practical living environment. With the rapid development of the economy, product diversity is increasingly. The competition between green products and ordinary products is more intense [35]. The alternative competition and price competition of products further caused multilevel supply chain competition [34, 36, 37], supply chain-chain competition [25, 29, 38], and channel conflicts [7, 8], which also attracted the attention of scholars. Above researches provide rich theoretical bases for pricing decisions in green supply chain. Another major research hotspot in the green supply chain is the improvement of supply chain performance. Green products contribute the supply chain members gain market share and improve the economic performance of the supply chain. At the same time, additional costs are brought. The expensive investment in green innovation and R&D technology makes many manufacturers lack R&D motivation. The government's regulation of green development is particularly important in this case. Hafezalkotob [39] showed that government intervention policies were conducive to the establishment and implementation of green supply chain. Pantumsinchai [40] and Yang and Xiao [41] indicated that government incentives could make the green level of products increased and the economic and environmental performance of enterprises improved. Madani and Rasti-Barzoki [42], Sinayi and Rasti-Barzoki [43], and Liu et al. [44] considered the government as a major player in the supply chain, and they introduced social welfare indicators and optimized the supply chain from three different latitudes: product pricing (economic performance), greenness level (environmental performance), and consumer surplus (social performance). Government intervention is essentially an external coordination method for green supply chains, and supply chain performance can also be improved through internal coordination. Since the main research in this paper is the coordination contract of MGSC, the contract will be reviewed and summarized in detail in the third part of this chapter. Through the retrieval of above literatures, it is easy to find that the research of green supply chain has achieved rich results. However, these literatures only consider members within a country. When the manufacture and the retailer are located across different borders, the supply chain is often subject to strike by import tariff. It is greatly significant to study the impact of tariff fluctuations on the operation of supply chain, for it enriches the green supply chain theory.

2.2. The Import Tariff Effect. Import tariff is an industrial policy widely adopted by the world. The fluctuation of tariff affects the cost of the enterprise, interferes with the operational decisions of the enterprise, and thereby influences

the development of the supply chain. From the prospect of corporate profit, Abraham et al. [45] pointed out that comparing the increase in import tariff with the import competition sector, import tariff was more likely to lead to lower profit in the export sector. Bustos [46] found the reduction of import tariff significantly promoted technological upgrading of export enterprises. Through analyzing the effects of different trade policies on China's imports during 2000–2006, Imbruno [47] concluded that tariff reduction and trade liberalization promoted the development of manufacturing. Handley and Limão [48] found that the increase in trade policies uncertainty reduced the value of enterprises becoming exporters and led to a decline in new market entry rates. Felbermayr et al. [49] studied the effects of import tariff on corporate profit and social welfare considering the different roles of demand transfer and cost transfer. Based on this conclusion, Crowley et al. [50] adopted econometric theory to analyze the impact of the “tariff panic” effect, which was caused by the uncertainty of trade policy on Chinese companies entering foreign markets. Scholars have discussed the impact of tariff fluctuation from different perspectives such as enterprise profit, technological innovation, product market entry, and social welfare. It can be seen that tariff plays an important role in cross-border trade. For a MGSC, the manufacturer needs to bear additional green R&D cost and the import tariff, which would dampen the enthusiasm of the manufacturer for green R&D investment and hinder the development of green products. Meanwhile, the increased cost of import tariff is transmitted upstream and downstream through the supply chain, leading the retailers' profit to be squeezed and consumer welfare to be reduced, and having an adverse impact on the green development of the supply chain.

2.3. The Supply Chain Coordination Contracts. Through sharing information, knowledge, risk, and profit among supply chain members, the supply chain system can be coordinated, thereby improving the efficiency of the supply chain and benefiting each member [51]. The generally used coordination contracts are revenue sharing contract [52–58], two-part tariff contract [7, 28, 57, 59, 60], buyback contract [52, 57, 61], wholesale price contract [28, 38, 52, 56, 58, 62], cost sharing contract [8, 58, 62, 63], quantity discount contract [27, 64–67], and so on. Xu et al. [58] pointed out that both the wholesale price contract and the cost sharing contract could achieve supply chain coordination under cap-and-trade regulation. Swami and Shah [7] employed two-part tariff contract to slow down the channel conflicts in green supply chain. Dai et al. [61] found that the buyback contract could effectively coordinate the supply chain in the case of providing quality assurance services. Considering the greenness of products affecting demand, Du et al. [55] coordinated the supply chain by designing revenue sharing and price discount contract. Toptal and Cetinkaya [64] explored quantity discount contract for supply chain coordination based on carbon credit sharing under carbon trading policies. Zissis et al. [27] adopted the quantity discount contract to achieve supply chain coordination in the case of discrete

information asymmetry. However, above contracts are not always able to achieve complete coordination of the supply chain, and different conclusions can be obtained under different research conditions. Pu et al. [68] used a cost sharing contract to solve the problem of consumer free-riding in the two-channel supply chain under stochastic demand. In the context of demand information asymmetry, Li [28] found that comparing with a wholesale price contract without information sharing, a two-part tariff contract with shared information is more likely to benefit both the manufacturer and the retailer. Dong et al. [57] discussed buyback contract, revenue sharing contract, and two-part tariff contract in a stochastic demand environment and concluded that only revenue sharing contract could coordinate the supply chain, whereas the buyback contract and two-part tariff contract cannot. Song and Gao [69] found that the bargaining revenue sharing contract was better than the retailer-led revenue sharing contract at improving the green level of products and the total profit of the supply chain. Gan et al. [52, 70] constructed a supply chain model consisting of a risk-neutral supplier and a risk-averse distributor, and the study proved that the wholesale price contract, the buyback contract, and the revenue sharing contract could not coordinate the supply chain with risk averse, but the risk sharing contract with the downside-risk constraint could achieve the coordination of such supply chain. Kim and Park [71] also confirmed that exchange-rate risk sharing contract was able to improve the performance of multinational supply chain. Given dual fairness in a distribution channel, Nie and Du [66] pointed out that neither of wholesale price contract and quantity discount contract could coordinate this dual-fairness channel, but a coordination mechanism that combines quantity discount contract with fixed fees could coordinate it. The above literatures showed that the contract coordination research of the supply chain system was quite plenty. For the green supply chain, the coordination mechanism mostly adopted the revenue sharing contract, the two-part tariff contract, and the cost sharing contract. There were few studies using the quantity discount contract. Toptal and Cetinkaya [64] applied quantity discount contract to low-carbon supply chain coordination. However, they did not consider consumers' preference of green products, which had certain limitations. Moreover, there were some differences in the modeling process between low-carbon supply chain and green supply chain. Therefore, comparing with the above researches, the innovation of this paper is to incorporate import tariff and green production into supply chain coordination and explore contracts for achieving MGSC coordination.

3. Model Description

This section describes a two-level MGSC model consisting of a manufacturer (index M) and a retailer (index R) in a single period. The manufacturer and the retailer both are risk-neutral and rational decision makers. The manufacture is assumed to produce green products, which are exported to abroad. The retailer in abroad suffered import tariff sells these green products to customers with green preference. The manufacturer in exporting country is the leader of the Stackelberg game, and the retailer in importing country is

the follower. The following assumptions are made, and the symbols are listed in Table 1:

- (1) The greenness of the product is variable and increases with the increase in green investment from the manufacturer. In reality, it can be shown by the manufacturer through the carbon labels, the recycling rate of used parts, the energy efficiency indicators, and so on. Generally, the marginal cost of green investment is incremental [35], the green investment is assumed as $I = (ke^2/2)$, where k denotes the product green investment cost parameter and e is the greenness level; the higher the greenness level, the more environmentally friendly the product.
- (2) The market demand q of green products is affected by both price and greenness level [29]. The demand function is assumed linear as $q(p, e) = a - bp + \beta e$, where a denotes the potential demand of the products in the importing country, b is the sensitivity parameter of consumers demand to retail price changes, and β is the green preference of consumers in the importing country. w is set to denote the wholesale price of green products, and c is set to represent the unit production cost of green products unaffected by the green investment.
- (3) The retailer needs to pay import tariff to the importing country customs when importing green products. The import tariff is levied according to the imported products quantity. T is set to denote the tariff.
- (4) Consumers in the importing country have green preference attributes and pay close attention to the green utility between the greenness level and the retail price. Therefore, a green performance price ratio is introduced to measure consumers' green utility. Reference to Dai et al.'s research [72], $r = (e/p)$ is assumed as the green performance price ratio. A high ratio shows a green product which gives superior greenness level with a lower product price.

Subscripts m , r , and sc are employed to denote the manufacturer, the retailer, and the whole supply chain, respectively. Considering the above assumptions, the manufacturer's, the retailer's, and the supply chain's profit functions are given as

$$\pi_m = (w - c)q - \frac{1}{2}ke^2, \quad (1)$$

$$\pi_r = (p - w)q - Tq, \quad (2)$$

$$\pi_{sc} = (p - c)q - \frac{1}{2}ke^2 - Tq. \quad (3)$$

4. The Model Solutions and Discussion

4.1. The Decentralized and Centralized Decision Model. In this section, the decentralized decision supply chain model (model DS) and the centralized decision supply chain model (model CS) are presented. Then, the optimal decisions between the two benchmark models are compared.

TABLE 1: The description of the symbols.

Symbols	Explanation
a	The potential market demand for green products in the import country
b	Sensitivity of consumer demand to price
c	Production cost per unit of green product
e	Greenness level of green products
I	The green investment
k	Parameter of green investment cost
p	The market retail price
q	The market demand
r	The green performance price ratio for a green product
w	The wholesale price
v	The highest wholesale price offered by the manufacturer
u	Wholesale price quantity discount coefficient
β	The green preference of consumers in the importing country
T	The specific tariff ratio
ϕ	The cost sharing ratio of R&D investment

In model DS, the manufacturer and the retailer are independent of each other; each member of the supply chain thinks of his own interests and makes decisions based on maximizing his own interests. As the leader of the supply chain, first the manufacturer determines the wholesale price w and the greenness level e . Then, the retailer makes the retail price p . The equilibrium solutions are derived in Appendix, and the results are shown in Table 2.

In model CS, the manufacturer and the retailer are integrated as a whole, which is an ideal benchmark supply chain model, and the Pareto optimality of the supply chain profit can be achieved. In this model, members of the supply chain make decisions from the perspective of the whole profit of the supply chain, and the decisions variables of the supply chain are the greenness and retail price of green products. The results and proofs are reported in Appendix D.

Proposition 1. *The equilibrium solutions between model CS and model DS meet the order $e^{C^*} > e^{D^*}$, $r^{C^*} > r^{D^*}$, $\pi_{sc}^{C^*} > \pi_{sc}^{D^*}$.*

The proof is shown in Appendix D.

Proposition 1 indicates that, in model DS, the greenness level of green products does not reach the optimal level, the green utility of the importing country consumers is worse, and the supply chain does not maximize profit. There is the double marginalization phenomenon.

Previous researches have shown that the manufacturer could gain a bigger market share, higher product added value, stronger brand competitiveness through green production, and the retailer benefit from green production too [73, 74]. Therefore, the retailer has the motivation to actively share the R&D cost of the manufacturer so as to reduce the cost pressure of the manufacturer and encourage the manufacturer to develop products with high levels of greenness, thereby making overall supply chain performance improved.

4.2. The R&D Cost Sharing Contract Model (RD). Through cost sharing contract, the profits of supply chain members can be redistributed; furthermore, the performance level of enterprises and supply chain system also can be improved. Toktay and Wei [75] studied the cost sharing behavior between the two production sectors of new and remanufactured products and found that the cost sharing could achieve the optimal profit for the company by adjusting the transfer price. Tsao and Sheen [76] pointed out that an appropriate promotion cost sharing ratio was able to increase the profit of all supply chain members. Zhang et al. [77] found that double-sided advertising cost sharing contract could achieve supply chain coordination. Ghosh and Shah [8] and Yang and Chen [78] showed that green cost sharing contract could be used to improve product greenness and supply chain performance. It is easy to conclude that cost sharing is an effective way to improve the performance of the supply chain.

Based on this, a R&D cost sharing contract model (model RD) is introduced, in which the retailer determines the proportion of cost sharing to make his own profit maximization. The game order of supply chain members is shown as Figure 1: the retailer first offers a sharing proportion ϕ ($0 < \phi < 1$) of the R&D cost. The manufacturer accepts or rejects the offer. If the manufacturer accepts the offer, the retailer shares ϕ proportion of the R&D cost and the manufacturer affords $1 - \phi$ proportion of the R&D cost. Then, the manufacturer determines the wholesale price w and product greenness e based on the share of the distribution provided by the retailer. Finally, the retailer makes the retail price p according to the manufacturer's decisions.

Under the above assumptions, the profit functions of the manufacturer and the retailer are listed, respectively, as

$$\begin{aligned}\pi_m &= (w - c)q - \frac{1}{2}k(1 - \phi)e^2, \\ \pi_r &= (p - w)q - \frac{1}{2}k\phi e^2 - Tq.\end{aligned}\tag{4}$$

TABLE 2: Comparison of equilibrium solutions for the three game models.

Variable	Decentralized	R&D cost sharing	Quantity discount-cost sharing
e	$(\beta(a-bc-bT)/(4bk-\beta^2))$	$(2\beta(a-bc-bT)/(8bk-3\beta^2))$	$(\beta(a-bc-bT)/(2bk-\beta^2))$
w	$(2k(a-bc-bT)/(4bk-\beta^2))+c$	$((8bk-\beta^2)(a-bc-bT)/2b(8bk-3\beta^2))+c$	$(bku^*(a-bc-bT)/(2bk-\beta^2))+c$
p	$((k(3a+bc+bT)-\beta^2(c+T))/(4bk-\beta^2))$	$((8bk(3a+bc+bT)-3\beta^2(a+3c+3T))/4b(8bk-3\beta^2))$	$((k(a+bc+bT)-\beta^2(c+T))/(2bk-\beta^2))$
q	$((bk(a-bc-bT)/(4bk-\beta^2))$	$((8bk-\beta^2)(a-bc-bT)/4(8bk-3\beta^2))$	$(bk(a-bc-bT)/(2bk-\beta^2))$
r	$(\beta(a-bc-bT)/(k(3a+bc+bT)-\beta^2(c+T)))$	$(8b\beta(a-bc-bT)/(8bk(3a+bc+bT)-3\beta^2(a+3c+3T)))$	$(\beta(a-bc-bT)/(k(a+bc+bT)-\beta^2(c+T)))$
π_m	$(k(a-bc-bT)^2/2(4bk-\beta^2))$	$((8bk-\beta^2)(a-bc-bT)^2/8b(8bk-3\beta^2))$	$\geq (k(a-bc-bT)^2/2(4bk-\beta^2))$
π_r	$(bk^2(a-bc-bT)^2/(4bk-\beta^2)^2)$	$((8bk+\beta^2)(a-bc-bT)^2/16b(8bk-3\beta^2))$	$\geq (bk^2(a-bc-bT)^2/(4bk-\beta^2)^2)$
π_{sc}	$(k(6bk-\beta^2)(a-bc-bT)^2/2(4bk-\beta^2)^2)$	$((24bk-\beta^2)(a-bc-bT)^2/16b(8bk-3\beta^2))$	$(k(a-bc-bT)^2/2(2bk-\beta^2))$

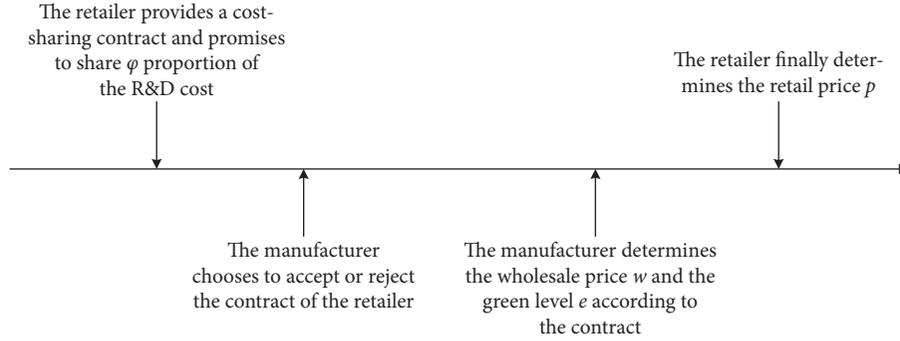


FIGURE 1: Game order of the R&D cost sharing model.

The results are summarized in Table 2 (refer Appendix D for proof).

Proposition 2. *The optimal cost sharing proportion is $\phi^* = (\beta^2/8bk)$.*

The proof is shown in Appendix D.

Proposition 2 indicates that when the environmental awareness of consumers in importing country is higher, the retailer is willing to share more green R&D cost. Furthermore, the environmental awareness of consumers has an increasing marginal utility in the incentive effect of the retailer. It is interesting that the R&D cost sharing ratio provided by the retailer is independent of the tariff. In other words, the model RD is not affected by the import tariff. It is stable in responding to international tariff shock and contributes to build robust supply partnerships between the manufacturer and the retailer.

Corollary 1. *The optimal equilibrium solutions between RD and DS meet the order $e^{RD^*} > e^{D^*}$, $w^{RD^*} > w^{D^*}$, $p^{RD^*} > p^{D^*}$, $r^{RD^*} > r^{D^*}$.*

The proof is shown in Appendix D.

Corollary 1 shows that if the retailer shares a part of the manufacturer's R&D cost, compared to the model DS, both the greenness level and the green performance price ratio of the products are increased in the RD model. Therefore, the RD model is more beneficial than the classical wholesale price contract from an environmental perspective. Additionally, the wholesale price and the retail price of the green products are both higher in the RD model than that in DS model. This is because compared with the price advantage brought by the cooperation of members of the supply chain, the cost effect caused by the increase in product greenness is more effective.

Corollary 2. *The optimal equilibrium solutions of profits meet the order $\pi_m^{RD^*} > \pi_m^{D^*}$, $\pi_r^{RD^*} > \pi_r^{D^*}$, $\pi_{sc}^{C^*} > \pi_{sc}^{RD^*} > \pi_{sc}^{D^*}$.*

The proof is shown in Appendix D.

Corollary 2 shows that the profits of both the manufacturer and the retailer are improved in the RD model. The retailer bearing a portion of R&D cost cuts down the cost of R&D investment on green products of the manufacturer. Accordingly, the manufacturer has the incentive to develop greener

products, which will attract more green consumers and enhance the market demand. For the retailer, the increase in the market demand makes up for this cost and generates additional revenue, so the retailer also has incentive to motivate the manufacturer to increase R&D enthusiasm through the R&D cost sharing contract. In addition, the whole profit of the supply chain is increased in the RD model, and the additional revenue that the manufacturer got is more than twice the retailer. The reason is that the retailer determines the cost sharing ratio without knowing the manufacturer's decisions and losing the first-mover advantage. The manufacturer can benefit from the cost sharing and the utility of consumer green preference; however, the retailer can only benefit from the utility of consumers' green preference. Only when the green preference of consumers in the importing country is high enough, the retailer's profit increase can approach 50% of the manufacturer's profit increase. On the contrary, Corollary 2 indicates that the whole profit of the supply chain is less than the maximizing profit under the supply chain integration. As the benefits of supply chain members from cost sharing are shifted by the wholesale price, the overall profit of the supply chain is less than the maximum profit under supply chain integration. Therefore, the RD model can achieve Pareto improvement of the supply chain, but it cannot bring perfect coordination of supply chain.

4.3. The Quantity Discount-Cost Sharing Contract Model (QD). Section 4.2 shows that the R&D cost sharing contract can facilitate cooperation between the manufacturer and the retailer and significantly weaken the "double marginalization" of the supply chain; however, it cannot coordinate MGSC to the centralized decision level. Facing complex decision environments, a single contract may not be able to coordinate supply chain. Some researchers are trying to combine different coordination mechanisms to achieve complete coordination of the supply chain, such as the two-tariff and cooperative advertising contract [36], the fixed payment with cost sharing contract [37], the transfer pricing and Nash bargaining hybrid coordination mechanism [79], the revenue and cost sharing contract [80], and the two-part tariff with revenue sharing contract [81]. In order to achieve perfect coordination of the supply chain, this academic idea is referred in this section, and a quantity discount-cost sharing contract is introduced. On the basis of inheriting the advantages of the R&D cost sharing contract, in this

contract, the manufacturer can encourage the retailer to increase the product order quantity (i.e., market demand) through quantity discount. In short, this contract has a double-sided incentive for the manufacturer and the retailer to facilitate supply chain coordination. In the quantity discount-cost sharing contract model (model QD), the game sequence of supply chain members is shown in Figure 2. First, the retailer bears a certain proportion of the R&D cost to encourage the manufacturer to conduct green production. Then, the manufacturer accepts or rejects the offer. If the manufacturer accepts the offer, he will provide the retailer product greenness e and a wholesale price with quantity discount from the perspective of maximizing the profit of the entire supply chain. The wholesale price is set as $w = v - uq$, where v denotes the upper bound of wholesale price offered by the manufacturer and u is the quantity discount coefficient on the wholesale price. Finally, the retailer determines the retail price based on the decisions of the manufacturer.

In this structure, the profit functions of the manufacturer, the retailer, and the supply chain are, respectively, as follows:

$$\pi_m = (v - uq - c)q - \frac{1}{2}k(1 - \phi)e^2, \quad (5)$$

$$\pi_r = (p - (v - uq))q - \frac{1}{2}k\phi e^2 - Tq, \quad (6)$$

$$\pi_{sc} = (p - c)q - \frac{1}{2}ke^2 - Tq. \quad (7)$$

The equilibrium solutions are derived in Appendix D, and the results of the model QD are shown in Table 2.

Proposition 3. *When $U_L < u^* < U_U$, the model QD has the optimal strategy (v^*, u^*) with $v^* = (2bku^*(a - bc - bT)/(2bk - \beta^2)) + c$, which can make the supply chain perfectly coordinated. That is, $e^{QD^*} = e^{C^*}$, $p^{QD^*} = p^{C^*}$, $q^{QD^*} = q^{C^*}$, and $\pi_{sc}^{QD^*} = \pi_{sc}^{C^*}$.*

The proof is shown in Appendix D.

Proposition 3 shows that the quantity discount-cost sharing contract can achieve perfect coordination of the supply chain. The retailer bears a part of the manufacturer's R&D cost, which motivates the manufacturer's R&D enthusiasm on greenness of products. The manufacturer provides a quantity discount wholesale price, which reduces the wholesale cost and motivates the retailer to increase products order quantity. When the contract parameters provided by the manufacturer are $((2bku^*(a - bc - bT)/(2bk - \beta^2)) + c, u^*)$ with condition of $U_L < u^* < U_U$, the total profit of the supply chain is equal to $\pi_{sc}^{C^*}$. The greenness level and pricing decision in the model QD are consistent with the model CS.

Corollary 3. *In the model QD, the remaining profit of the supply chain can be freely distributed between the manufacturer and the retailer. The larger the quantity discount coefficient, the more favorable it is to the manufacturer.*

The proof is shown in Appendix D.

It is proved that the transfer payment between the manufacturer and the retailer increases with the increase in the quantity discount coefficient, that is, as u^* increases, the greater remaining profit of the supply chain is distributed by the manufacturer, and the smaller remaining profit of the supply chain is obtained by the retailer. When $U_L \leq u^* < ((U_U + U_L)/2)$, the remaining profit of the supply chain got by the retailer is more than the manufacturer; when $((U_U + U_L)/2) < u^* \leq U_U$, it is more beneficial to the manufacturer who obtains more remaining profit from the supply chain than the retailer. Thus, for the manufacturer, he can effectively prevent the outflow of profit by setting a quantity discount coefficient meeting $((U_U + U_L)/2) \leq u^* \leq U_U$. Furthermore, it is found that when $0 < \phi < 1$, U_L is always positive. Therefore, through flexibly setting a R&D cost sharing ratio, the retailer can encourage the manufacturer to implement the quantity discount mechanism to coordinate the MGSC, as the performance of the supply chain is improved. Since the threshold of the manufacturer quantity discount coefficient decreases with the increase in the R&D cost sharing coefficient provided by the retailer, the retailer can effectively bind the manufacturer's behavior by establishing a reasonable R&D cost sharing ratio, thereby improving own marginal profit from the contract cooperation.

In summary, in order to effectively solve the double marginalization of MGSC, this paper explores two types of contracts used for improving the environmental performance and economic performance of MGSC through cooperation of the supply chain members. After the above deduction, it is found that compared with the wholesale price contract (i.e., decentralized decision), though the R&D cost sharing contract can make product's green level, consumers' green utility and supply chain members' profit improved, and MGSC cannot be coordinated to Pareto optimality. The quantity discount-cost sharing contract was further proposed. Unlike the unilateral incentives of the retailer to the manufacturer in the R&D cost sharing contract, this contract enables mutual incentives between the manufacturer and the retailer. The result shows that the quantity discount-cost sharing contract can achieve complete coordination of MGSC. Different from the only optimal decision of the RD model, the contract parameters of model QD can be flexibly set by the manufacturers and the retailer to achieve free distribution of residual profits in MGSC.

Corollary 4. *The increase in tariff is not conducive to the green development of multinational supply chain, and the closer the cooperation between the manufacturer and the retailer, the greater the adverse effects of tariff on supply chain.*

The proof is shown in Appendix D.

It is easy to conclude that the increase in the import tariff reduces the greenness of the products and the green performance price ratio and damages the profit of the supply chain enterprise. As tariff increases, the retailer's total cost of obtaining green products has increased, while the profit of his has decreased. In order to maintain a certain profit, the retailer transfers some of tariff cost to consumers by raising sales price. As a result, the green utility of consumers gaining will be reduced, eventually leading to a decline in market demand.

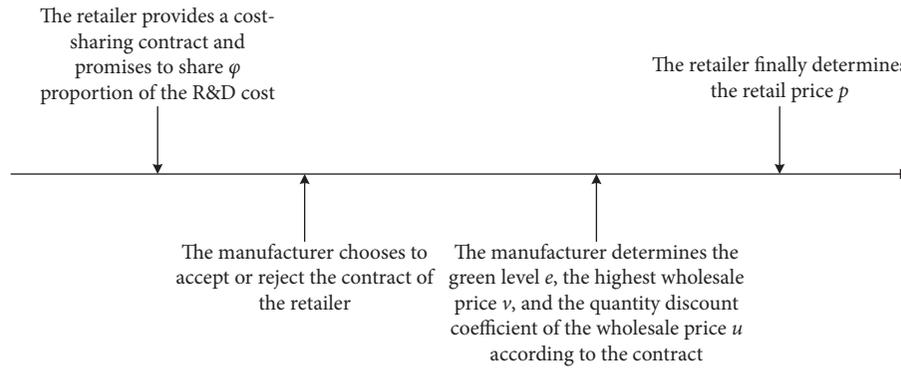


FIGURE 2: Game sequence of the quantity discount-cost sharing contract model.

Coping with this situation, the manufacturer has to provide a lower wholesale price to encourage the retailer to increase the order quantity; meanwhile, the manufacturer's profit is squeezed. What's more is the need also from the manufacturer to bear the cost of R&D; as a result, the enthusiasm of the manufacturer's green R&D decreases. A highly collaborative supply chain structure is more seriously affected, for the links between the manufacturer and the retailer are closer, and tariff cost is more efficiently passed to upstream and downstream through the supply chain. In the previous section, it is shown that the performance of MGSC can be improved by coordination contract. Therefore, facing fluctuating tariff, supply chain members should strengthen cooperation and compensate for the MGSC losses caused by tariff fluctuation through the increased environmental performance and economic performance coming from cooperation. For example, in the Sino-US trade friction, when the US import vehicle tariff increased from 25% to 40%, the suggested retail price of Mercedes-Benz increased by only 4%, this is because manufacturers and distributors of Mercedes-Benz digest most of the tariff cost through internal cooperation in the supply chain, and the negative impact of tariff increases is effectively reduced [82].

5. Numerical Examples

Based on the control variable method and sensitivity analysis idea, the software of Maple and Matlab is employed to carry out numerical simulation analysis. The tariff and the green preference of consumers are used as independent variables to analyze the situation in which the relevant decision variables and contract parameters are affected. In this section, the theory finds of this paper are better explained; additionally, more meaningful management insights are explored.

The green preference of consumers is one of the important factors affecting green buying behavior, and it directly determines the market demand of green products, which is reacted in the market demand function [55, 81]. Therefore, the green preference of consumers in importing country is chosen as the independent variable. In addition, tariff fluctuation also affects the pricing decisions of supply chain members for MGSC and ultimately interferes the overall performance of the supply chain. Since the R&D cost sharing coefficient set by the retailer can satisfy $u^* > 0$ within the range of $(0, 1)$, the quantity discount-cost sharing contract is always

effective. For easy comparison, the cost sharing ratio is assumed in model QD as the same as model RD, where $\phi^{RD^*} = \phi^{QD^*} = (\beta^2/8bk)$, and besides, the wholesale price discount coefficient of the manufacturer takes the midpoint value of the optimal value interval, where $u^* = ((U_U + U_L)/2)$; that is, the manufacturer and the retailer share the remaining profits of the MGSC on average. To ensure that the studies are carried out within the feasible region, the customs import and export tariff and the researches of Ghosh and Shah [8] and Song and Gao [69] are referred to fulfill the parameters assignment of this paper. $T = 0.5$ and $\beta \in (30, 40)$ are set when doing sensitivity analysis on consumer preference, and $\beta = 35$ and $T \in (0.3, 1.5)$ are set when doing sensitivity analysis on tariff, and set the other parameter values shown as in Table 3.

5.1. The Sensitivity Analysis of Contract Parameters. In this section, the impact of consumers' green preference and tariff on different contractual parameters was analyzed. Figure 3 illustrates that the stronger the consumers' environmental awareness is, the more active the retailer is to apportion R&D cost with the manufacturer. Figure 4 shows the R&D cost sharing rate provided by the retailer is not affected by tariff fluctuation. It can be seen from Figures 5 and 6 that the feasible region of the wholesale price quantity discount coefficient is shrunk as the tariff increases, and the range of the highest wholesale price provided by the manufacturer also is decreased. Although the model QD achieves supply chain coordination, the flexibility of contractual parameters provided by the manufacturer is reduced, which is detrimental to the enthusiasm of the retailer to participate in cooperation. Similarly, it can be found that, as the environmental awareness of consumers in importing country increases, the consumers' green preference increases, which would increase the feasible region of the wholesale price discount coefficient and the highest wholesale price and finally incentive the retailer to actively participate in cooperation. In a word, consumers' green preference and tariff have the opposite effect on coordination contracts.

5.2. The Impact of Consumers' Green Preference on Supply Chain Performance. In this section, the function images of each decision variable with respect to consumers' green

TABLE 3: Parameter assignment.

Parameter	Value
a	1000
b	50
c	3
k	45

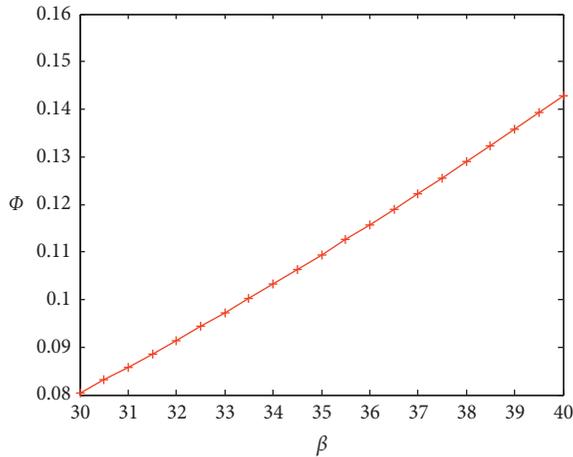


FIGURE 3: R&D cost sharing coefficient vs β .

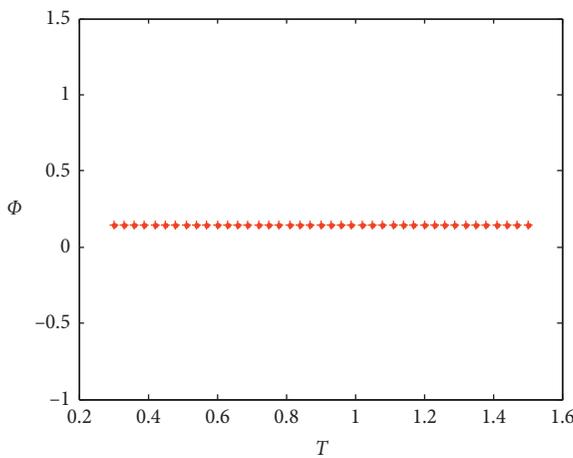


FIGURE 4: R&D cost sharing coefficient vs T .

preference are plotted, and the effect of consumers' green preference on supply chain performance is analyzed.

Figures 7–12 illustrates that, with the increasing awareness of environmental protection among consumers in importing country, the demand for the green products has increased, which plays a positive role in promoting the manufacturer to develop products with higher greenness. Although high greenness products lead to a higher market price, the product's green performance price ratio increases (refer Figure 7), which means the product purchased by consumers is more valuable for money; the profits of the manufacturer, the retailer, and the supply chain system will also be improved at the same time. Obviously, the

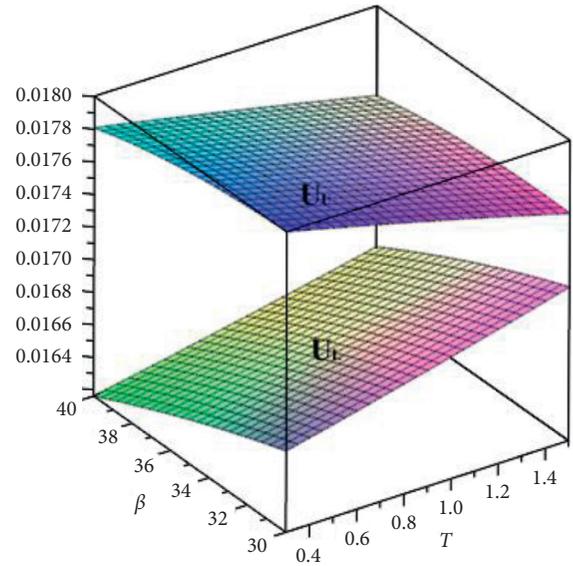


FIGURE 5: Wholesale price quantity discount coefficient vs β and T .

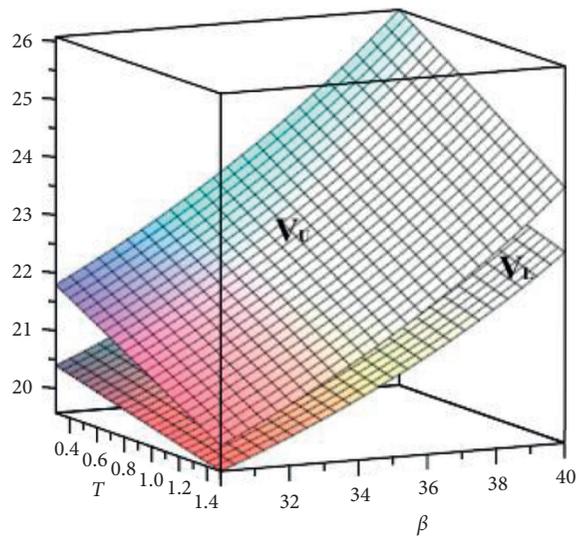


FIGURE 6: The highest wholesale price offered by the manufacturer vs β and T .

development of MGSC will be promoted by the continuously improving consumers' environmental awareness.

Comparing the variables under different contract conditions, it is possible to conclude that the cooperation between the manufacturer and the retailer can improve the greenness level of products, the green utility of consumers, and the profit of supply chain system. Furthermore, the closer the supply chain members cooperate, the better the effect of green preference of consumers in importing country. From the perspective of protecting environment, compared with decentralized decision, both contracts increase the greenness level of products and contribute to environmental protection. From the perspective of consumers in importing country, supply chain collaboration makes the green performance price ratio improved, and the

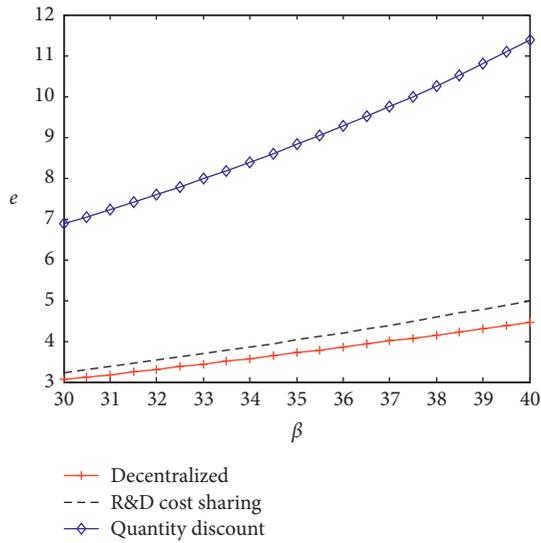


FIGURE 7: Optimal greenness level vs β .

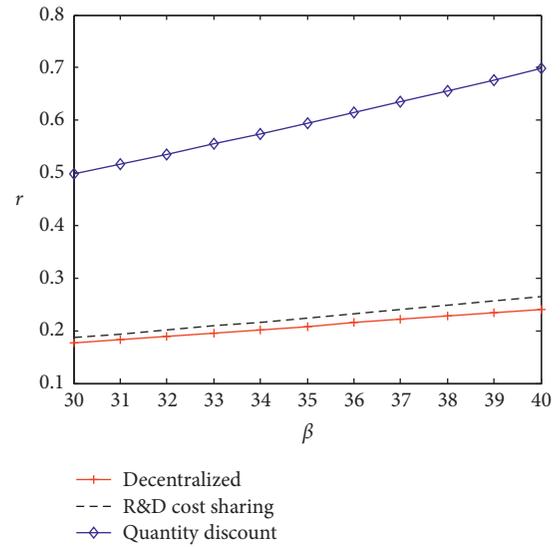


FIGURE 9: Optimal green performance price ratio vs β .

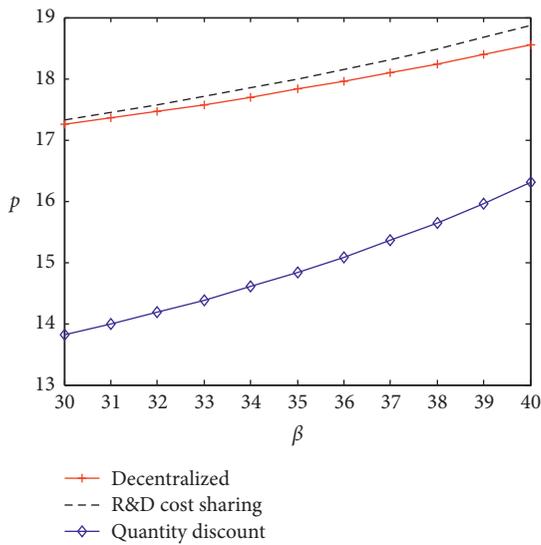


FIGURE 8: Optimal retail price vs β .

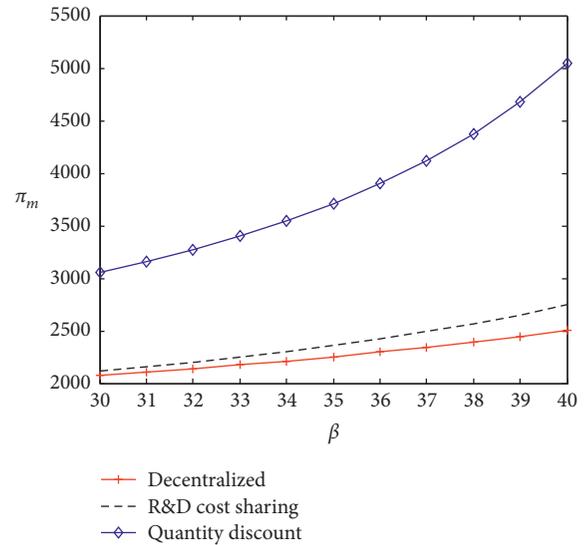


FIGURE 10: Optimal manufacturer's profit vs β .

green utility of consumers in importing country increased. From the perspective of supply chain members, the profits of the manufacturer and the retailer are improved in both model RD and model QD, so the supply chain members have the incentive to achieve contractual cooperation. The manufacturer can obtain the advantage of distributing the remaining profit of the supply chain through the quantity discount-cost sharing contract. Conversely, the retailer has greater autonomy in distributing the remaining profit of the supply chain through the R&D cost sharing contract. From the perspective of the supply chain system, the system profit is increased by both contract; model RD achieves Pareto improvement of MGSC, but model QD makes MGSC Pareto optimal and realizes supply chain coordination. At the same time, it is noticed that, in model QD, the increase in

consumers' green preference has the biggest promoting effect on the overall performance of MGSC, better than model DS and model RD.

5.3. The Impact of Tariff on Supply Chain Performance. In this section, the optimal decisions and performance of supply chain are reported with different tariffs in model DS, model RS, and model QS. As shown in Tables 4–6, the increase in tariff is found to have a negative impact on MGSC, which reduces the greenness of products, increases the retail price, diminishes the green utility of consumers in importing country, and damages the profit of the manufacturer, the retailer, and the supply chain. However, in different models, the degree of influence of the equilibrium variables is different. As shown in Table 7, when the tariff raised from 0.3 to 0.6, the variation in the variables is the smallest in model DS and is the largest in model

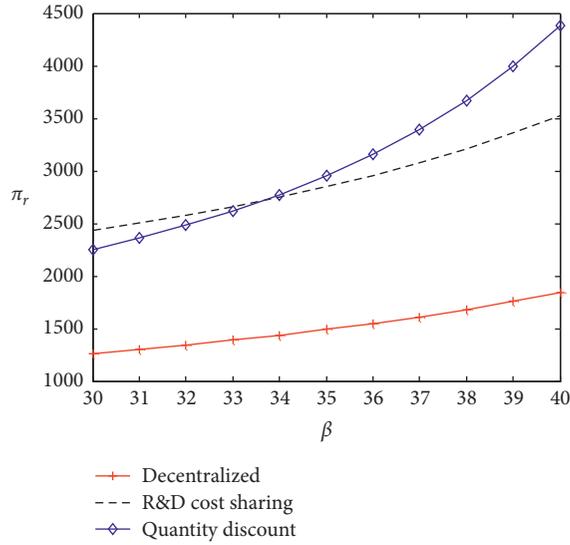


FIGURE 11: Optimal retailer's profit vs β .

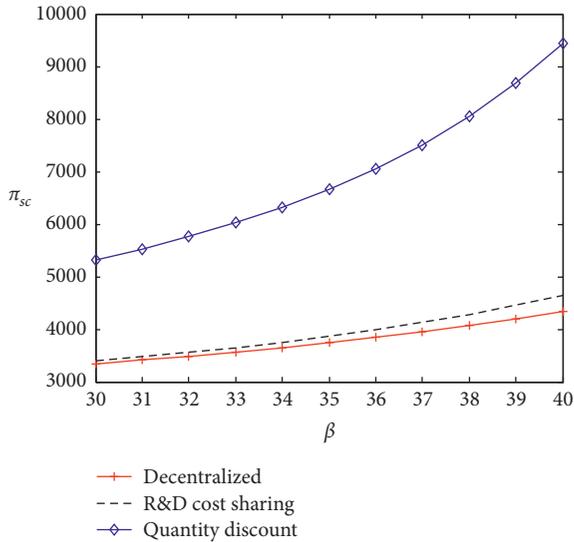


FIGURE 12: Optimal MGSC's profit vs β .

QD, which is consistent with Corollary 4. The same conclusion can be obtained by analyzing other tariff levels such as the tariff increase from 0.3 to 1.2.

Interestingly, although tariff increases has a negative impact on the operation of the MGSC, the change value of products' greenness and retail price are not affected by the size of tariff in the same model. For instance, in model DS, when the tariff is raised from 0.3 to 0.6, the products' greenness is reduced by 0.68 and the retail price is increased by 0.04. When the tariff is raised from 0.9 to 1.2, the products' greenness is still reduced by 0.68, and the increase in retail price is still 0.04. However, as the tariff increases, the decrease in green performance price ratio is slowing down, so are the profits of all parties in the supply chain. For example, in model RD, when the tariff is raised from 0.3 to 0.6, green performance price ratio is reduced by 0.00502, the manufacturer's profit is reduced by 86.1, the retailer's profit

TABLE 4: Optimal decision under DS vs. T .

T	e^D	p^D	r^D	π_m^D	π_r^D	π_{sc}^D
0.3	3.759	17.798	0.211	2308.69	1528.94	3837.63
0.6	3.691	17.838	0.207	2226.49	1474.50	3700.99
0.9	3.624	17.877	0.203	2145.78	1421.05	3566.82
1.2	3.556	17.917	0.198	2066.56	1368.58	3435.14
1.5	3.489	17.957	0.194	1988.82	1317.10	3305.93

TABLE 5: Optimal decision under RD vs. T .

T	e^{RD}	p^{RD}	r^{RD}	π_m^{RD}	π_r^{RD}	π_{sc}^{RD}
0.3	4.080	18.589	0.227	2418.24	2924.62	5342.87
0.6	4.007	18.682	0.223	2332.14	2820.49	5152.63
0.9	3.934	18.776	0.218	2247.60	2718.25	4965.84
1.2	3.860	18.869	0.214	2164.62	2617.89	4782.51
1.5	3.787	18.962	0.209	2083.20	2519.42	4602.62

TABLE 6: Optimal decision under QD vs. T .

T	e^{QD}	p^{QD}	r^{QD}	π_m^{QD}	π_r^{QD}	π_{sc}^{QD}
0.3	8.924	14.773	0.604	3807.65	3027.89	6835.54
0.6	8.763	14.867	0.589	3672.08	2920.08	6592.16
0.9	8.603	14.961	0.575	3538.96	2814.23	6353.19
1.2	8.443	15.055	0.561	3408.30	2710.33	6118.63
1.5	8.282	15.149	0.547	3280.10	2608.38	5888.48

TABLE 7: The variation of the variables in different models when the tariff increases from 0.3 to 0.6.

Models	Variables					
	Δe	Δp	Δr	$\Delta \pi_m$	$\Delta \pi_r$	$\Delta \pi_{sc}$
DS	-0.068	0.040	-0.004	-82.20	-54.44	-136.64
RD	-0.073	0.093	-0.005	-86.10	-104.13	-190.24
QD	-0.160	0.094	-0.015	-135.57	-107.81	-243.38

is reduced by 104.13, and the supply chain system's profit is reduced by 190.24. When the tariff is raised from 0.9 to 1.2, the reduction values corresponding to each decision variable are 0.00492, 82.98, 100.36, and 183.34.

Comparing the data in Tables 4–6, it can be concluded that the supply chain collaboration can greatly improve economic performance and environmental performance of MGSC under the same tariff level. For example, at the tariff level of 0.3, the manufacturer's optimal product greenness decision is 3.759 in model DS, while in model RD, the optimal product greenness is 4.080, and it is 8.924 in model QD. The increase in tariff reduces the greenness level of products, while supply chain collaboration can improve the greenness level of products. Therefore, it is suggested that supply chain members copy with the adverse effects of tariff growth through coordination within the supply chain.

5.4. The Impact of Consumers' Green Preference on Tariff. It was concluded that consumers' green preference and tariff have the opposite effects on the supply chain. Nowadays,

consumers' awareness of environmental protection is increasing. Can the antiadvantage effect of tariff increase be offset by increasing consumers' green preference?

The supply chain profit is considered as an indicator. When the tariff increases, consumers' green preference changes to maintain supply chain profit in various scenarios. First, the optimal decisions were given in different scenarios as the benchmark when the tariff is low (such as $T = 0.3$), as shown in Table 8. After that, the optimal value that consumers' green preference needs to achieve is obtained in different models; furthermore, the value of change in other decisive variables at this optimal value is acquired.

The results are illustrated in Tables 8–10. Δ presents the value of change in each decision variable at the same tariff, which is caused by the change in consumers' green preference. For example, $\Delta e^D = e^D|_{\beta=36.377} - e^D|_{\beta=30} = 0.883$ indicates that when the tariff is 0.9, in model DS, if the supply chain profit is the same as the profit value when the tariff is 0.3, the consumers' green preference needs to be raised from 30 to 36.377. At this time, the greenness level of products increases by 0.883.

Tables 8 and 9 show that, in model DS, when the tariff is 0.3 and the consumers' green preference is 30, the profit of the supply chain is $\pi_{sc}^D = 3012.70$. The profit of the supply chain is declining as tariff increases, but the increased profit coming from the improvement of consumers' green preference can compensate for this lost profit. Such as when the tariff is 0.6, the supply chain profit drops to 2905.43, if the consumers' green preference is increased from 30 to 33.362 at this time, and the supply chain profit can be restored to 3012.70. At the same time, it is found that all of the products' greenness and the profits of the manufacturer and the retailer are improved. Although the retail price is increased, the green performance price ratio is improved and consumers are able to achieve a greater green satisfaction. Similar conclusions can be obtained by analyzing Tables 10 and 11.

Comparing Tables 8–10, it is possible to conclude that the closer the cooperation between the manufacturer and the retailer, the stronger the ability to resist tariff fluctuation. When the tariff is raised from 0.3 to 0.6, if the supply chain profit is restored to the previous level, the consumers' green preference in model DS needs to be adjusted to 33.362 and be adjusted to 33.168 in model RD, while in model QD, only needs to be adjusted to 32.065. In model QD, the amount of change in consumers' green preference is minimal, in addition to the increments of the products' greenness, green performance price ratio, and profit of all parties in the supply chain which are better than the other two models.

Most companies generally take profit as decision goal in real life. However, emerging companies may pay more attention to brand effects to expand market share, such as attracting consumers' attention and improving brand awareness by providing high-green products. Therefore, the following part analyzes whether the consumers green preference can counteract the adverse effects of tariff increases when product greenness is seen as an optimization indicator.

TABLE 8: Benchmark optimal decisions of different models.

Models	Variables							
	T	β	e	p	r	π_m	π_r	π_{sc}
DS	0.3	30	3.093	17.217	0.180	1936.74	1075.96	3012.70
RD	0.3	30	3.275	17.299	0.189	1948.13	1076.60	3024.73
QD	0.3	30	6.958	13.738	0.507	2609.21	1748.44	4357.66

TABLE 9: Change in decision variables under DS.

T	π_{sc}^D	β	$\Delta\pi_{sc}^D$	Δe^D	Δp^D	Δr^D	$\Delta\pi_m^D$	$\Delta\pi_r^D$
0.6	2905.43	33.362	107.26	0.432	0.369	0.021	50.45	56.81
0.9	2800.11	36.377	212.58	0.833	0.740	0.039	99.25	113.32
1.2	2696.73	39.126	315.98	1.212	1.112	0.055	146.42	169.56
1.5	2595.29	41.661	417.43	1.574	1.486	0.070	191.92	225.51

TABLE 10: Change in decision variables under RD.

T	π_{sc}^{RD}	β	$\Delta\pi_{sc}^{RD}$	Δe^{RD}	Δp^{RD}	Δr^{RD}	$\Delta\pi_m^{RD}$	$\Delta\pi_r^{RD}$
0.6	2917.03	33.168	107.69	0.485	0.394	0.023	53.85	53.85
0.9	2811.28	35.998	213.85	0.950	0.797	0.044	106.92	106.92
1.2	2707.49	38.538	317.22	1.398	1.205	0.063	158.61	158.61
1.5	2605.65	40.870	419.09	1.838	1.622	0.081	209.54	209.54

TABLE 11: Change in decision variables under QD.

T	π_{sc}^{QD}	β	$\Delta\pi_{sc}^{QD}$	Δe^{QD}	Δp^{QD}	Δr^{QD}	$\Delta\pi_m^{QD}$	$\Delta\pi_r^{QD}$
0.6	4202.50	32.065	155.14	0.740	0.378	0.039	75.77	79.37
0.9	4050.16	33.971	307.49	1.465	0.764	0.075	149.98	157.51
1.2	3900.63	35.743	457.02	2.179	1.157	0.108	222.65	234.37
1.5	3753.91	37.400	603.73	2.888	1.558	0.138	293.79	309.94

TABLE 12: Benchmark optimal decisions of different models.

Models	Variables							
	T	β	e	p	r	π_m	π_r	π_{sc}
DS	0.3	35	3.759	17.798	0.211	2308.69	1528.94	3837.63
RD	0.3	35	4.080	17.967	0.227	2418.24	1546.71	3964.95
QD	0.3	35	8.924	14.773	0.604	3807.65	3027.89	6835.54

TABLE 13: Change in decision variables under DS.

T	e^D	β	Δe^D	Δp^D	Δr^D	$\Delta\pi_m^D$	$\Delta\pi_r^D$	$\Delta\pi_{sc}^D$
0.6	3.691	35.485	0.068	0.063	0.003	20.35	27.07	47.42
0.9	3.624	35.981	0.135	0.126	0.006	40.32	53.90	94.21
1.2	3.556	36.489	0.203	0.190	0.009	59.95	80.56	140.52
1.5	3.489	37.009	0.270	0.255	0.012	79.27	107.09	186.36

TABLE 14: Change in decision variables under RD.

T	e^{RD}	β	Δe^{RD}	Δp^{RD}	Δr^{RD}	$\Delta \pi_m^{\text{RD}}$	$\Delta \pi_r^{\text{RD}}$	$\Delta \pi_{sc}^{\text{RD}}$
0.6	4.007	35.418	0.073	0.064	0.003	25.09	25.09	50.18
0.9	3.934	35.846	0.146	0.129	0.007	49.97	49.97	99.94
1.2	3.860	36.283	0.220	0.194	0.010	74.56	74.56	149.12
1.5	3.787	36.728	0.293	0.260	0.013	98.87	98.87	197.74

TABLE 15: Change in decision variables under QD.

T	e^{QD}	β	Δe^{QD}	Δp^{QD}	Δr^{QD}	$\Delta \pi_m^{\text{QD}}$	$\Delta \pi_r^{\text{QD}}$	$\Delta \pi_{sc}^{\text{QD}}$
0.6	8.763	35.363	0.161	0.089	0.007	64.95	69.94	134.89
0.9	8.603	35.732	0.321	0.178	0.014	129.45	139.41	268.86
1.2	8.443	36.106	0.481	0.267	0.022	193.73	208.63	402.36
1.5	8.282	36.487	0.642	0.357	0.029	257.90	277.71	535.61

Similar points can be obtained by analyzing Tables 12–15, which means that the increase in consumers' green preference not only makes the products' greenness restored to the previous level but also increases the green performance price ratio and supply chain profit. All of performances of MGSC including environment, society, and economy get improved.

In summary, the negative effects of tariff increase can be offset by the enhancement of consumers' green preference. Nowadays, governments are vigorously propagating the importance of environmental protection and completing environmental education systems and regulations. Many civil environmental protection organizations and well-known companies are also actively involving in various environmental activities. These external factors have a great incentive for the improvement of consumers' green preference. Therefore, the supply chain members should actively respond to the government's call and make more consumers value environmental protection through advertising or public welfare activities, thereby promoting consumers' green preferences to be improved to compensate for the adverse impact of tariff increases on the green development of multinational supply chains.

6. Conclusion

Based on the background of tariff fluctuation, considering the cooperation between the manufacturer and the retailer in a single period, four models are established: model CS, model DS, model RD, and model QD. Through comparing and analyzing the optimal decisions and profits of different models, it is possible to conclude that there is the phenomenon of "double marginalization" in MGSC in model DS. The model RD can improve the performance of MGSC but cannot reach the optimal performance compared with model CS, while model QD can achieve perfect coordination of MGSC. In addition, import tariff has an adverse effect on the performance of MGSC. For contract parameters, the tariff does not affect the R&D cost sharing ratio provided by the retailer in model RD. However, in model QD, the increase in tariff shrinks the feasible region of the highest wholesale price and quantity discount coefficient offered by

the manufacturer, which hampers the cooperation of supply chain members.

For the supply chain performance, the increase in import tariff reduces the greenness level of products, the green performance price ratio, and the profit of the supply chain system. The closer the supply chain members cooperate, the greater the adverse effects of tariff. Interestingly, the change amount of products' greenness and retail price are not affected by the size of tariff in the same model. However, as the tariff increases, the decrease in green performance price ratio is slowing down, so are the profits of all parties in the supply chain. Through numerical simulation, the opposite effect of consumers' green preference and tariff on MGSC operation was concluded. Therefore, two feasible suggestions are proposed to cope with tariff growth: ① cooperation within the supply chain should be strengthened. Cooperation makes supply chain performance improved, which can effectively compensate for supply chain losses caused by tariff increases comparing with decentralized decision. ② The green preference of consumers in importing country should be improved, for the antiadvantage effect of tariff increase can be offset by the increasing consumers' green preference.

Promoting the cooperation between upstream and downstream enterprises of MGSC is not only a requirement for economic development and environmental protection but also an effective measure for multinational supply chain enterprises to cope with tariff fluctuation. To strength the impact of the quantity discount-cost sharing contract on coordinating MGSC, achieve a win-win situation for upstream and downstream enterprises, and reduce the adverse impact of tariff fluctuation, the following improvements are needed. Firstly, supply chain members should realize the importance of coordination and cooperation. Enterprises should not only focus on improving their own profit but also make decisions based on the long-term interests and strive to improve the overall economic performance and environmental performance of MGSC. Secondly, retailers should not regard the R&D of green products just as the responsibility of manufacturers; on the contrary, they should actively cooperate with manufacturers to promote the development of green product R&D and production. And additionally manufacturers should also adjust the wholesale price to reduce the purchasing pressure of retailers. Finally, the increase in consumers' green preference has a positive influence on improving supply chain system performance and reducing the adverse effects of tariff fluctuation. Therefore, the supply chain members can publicize the importance of environmental protection through advertising and other ways to further enhance consumers' awareness of environmental protection.

The research is based on a two-level supply chain consisting of a single manufacturer and a single retailer. In fact, there may be alternative competition between products. Therefore, in further work, MGSC will be considered consisting of multiple manufacturers and retailers, and it will be analyzed by the impact of tariff fluctuation and consumers' green preference on supply chain competition and coordination strategies.

Appendix

A. The Decentralized Decision Model

Employing the inverse induction method, first the profit function of the retailer is solved from equation (2):

$$\pi_r(p) = (p - w)(a - bp + \beta e) - T(a - bp + \beta e). \quad (\text{A.1})$$

Obtaining the first and second derivatives of p and setting the first derivative equal to zero, the response function of retail price is obtained:

$$p(e, w) = \frac{a + \beta e + b(T + w)}{2b}. \quad (\text{A.2})$$

Then, the profit function of the manufacturer is solved from equation (1):

$$\pi_m(w, e) = (w - c)(a - bp + \beta e) - \frac{1}{2}ke^2. \quad (\text{A.3})$$

Substituting equation (A.2) into equation (A.3), the first and second partial derivatives of $\pi_m(w, e) = (w - c)(a - bp + \beta e) - (1/2)ke^2$ and w are obtained and it is found that when $4bk - \beta^2 > 0$, π_m is a strict concave function about e and w .

Next, setting the first-order partial derivatives of e and w to zero, the optimal greenness and the optimal wholesale price of the manufacturer are solved:

$$e^{D*} = \frac{\beta(a - bc - bT)}{4bk - \beta^2}, \quad (\text{A.4})$$

$$w^{D*} = \frac{2k(a - bc - bT)}{4bk - \beta^2} + c.$$

Substituting e^{D*} and w^{D*} into equation (A.2), the optimal retail price of the retailer is obtained:

$$p^{D*} = \frac{k(3a + bc + bT) - \beta^2(c + T)}{4bk - \beta^2}. \quad (\text{A.5})$$

Finally, substituting e^{D*} , w^{D*} , and p^{D*} into the demand function, performance price ratio function, and equations (1)–(3), the corresponding market demand, performance price ratio, and the optimal profit of the manufacturer, retailer, and supply chain system are, respectively, as follows:

$$\begin{aligned} q^{D*} &= \frac{bk(a - bc - bT)}{4bk - \beta^2}, \\ r^{D*} &= \frac{\beta(a - bc - bT)}{k(3a + bc + bT) - \beta^2(c + T)}, \\ \pi_m^{D*} &= \frac{k(a - bc - bT)^2}{2(4bk - \beta^2)}, \\ \pi_r^{D*} &= \frac{bk^2(a - bc - bT)^2}{(4bk - \beta^2)^2}, \\ \pi_{sc}^{D*} &= \frac{k(6bk - \beta^2)(a - bc - bT)^2}{2(4bk - \beta^2)^2}. \end{aligned} \quad (\text{A.6})$$

B. The Centralized Decision Model

The overall profit maximization model of the supply chain is

$$\pi_{sc}(e, p) = (p - c)(a - bp + \beta e) - \frac{1}{2}ke^2 - Tq. \quad (\text{B.1})$$

First, the first and second partial derivatives of e and p are obtained, when satisfying the negative definition of the Hessian matrix, which is $2bk - \beta^2 > 0$, and π_{sc} is a strict concave function about e and p , which indicates that there is a unique optimal equilibrium solution that can be found in the supply chain.

Then, the first-order partial derivatives of e and p are set to zero and the optimal greenness and the optimal retail price are obtained:

$$e^{C*} = \frac{\beta(a - bc - bT)}{2bk - \beta^2}, \quad (\text{B.2})$$

$$p^{C*} = \frac{k(a + bc + bT) - \beta^2(c + T)}{2bk - \beta^2}.$$

Finally, e^{C*} and p^{C*} are put into the demand function, performance price ratio function, and equation (B.1), and the corresponding market demand, performance price ratio, and the optimal profit of the supply chain system are acquired, which can be expressed, respectively, as follows:

$$q^{C*} = \frac{bk(a - bc - bT)}{2bk - \beta^2}, \quad (\text{B.3})$$

$$r^{C*} = \frac{\beta(a - bc - bT)}{k(a + bc + bT) - \beta^2(c + T)}, \quad (\text{B.4})$$

$$\pi_{sc}^{C*} = \frac{k(a - bc - bT)^2}{2(2bk - \beta^2)}. \quad (\text{B.5})$$

C. The R&D Cost Sharing Contract Model

First, the profit function of the retailer is obtained:

$$\pi_r = (p - w)(a - bp + \beta e) - T(a - bp + \beta e) - \frac{1}{2}k\phi e^2. \quad (\text{C.1})$$

Obtaining the first and second derivative of p and setting the first derivative equal to zero, the response function of retail price is obtained:

$$p(e, w) = \frac{a + \beta e + b(T + w)}{2b}. \quad (\text{C.2})$$

Then, the profit function of the manufacturer is acquired:

$$\pi_m = (w - c)(a - bp + \beta e) - \frac{1}{2}k(1 - \phi)e^2. \quad (\text{C.3})$$

Substituting equation (C.2) into equation (C.3), the first and second partial derivatives of e and w are obtained, and then, it was found that when $(\partial^2/\partial w^2)\pi_m * (\partial^2/\partial e^2)\pi_m - ((\partial^2/\partial e \partial w)\pi_m)^2 > 0$, which is $4bk(1 - \phi) - \beta^2 > 0$, π_m is a strict concave function about e and w .

Next, setting the first-order partial derivatives of e and w to zero, it is possible to get the following:

$$e(\phi) = \frac{\beta(a - bc - bT)}{4bk(1 - \phi) - \beta^2}, \quad (C.4)$$

$$w(\phi) = \frac{2k(1 - \phi)(a + bc - bT) - \beta^2 c}{4bk(1 - \phi) - \beta^2}. \quad (C.5)$$

Therefore, the optimal retail price is obtained:

$$p(\phi) = \frac{k(1 - \phi)(3a + bc + bT) - \beta^2(c + T)}{4bk(1 - \phi) - \beta^2}. \quad (C.6)$$

Putting equations (C.4)–(C.6) into equation (C.1), it is possible to obtain the following:

$$\pi_r(\phi) = \frac{k(a - bc - bT)^2(2bk(1 - s)^2 - \beta^2 s)}{2(4bk(1 - \phi) - \beta^2)^2}. \quad (C.7)$$

Then, the first derivative of ϕ is got:

$$\frac{\partial}{\partial \phi} \pi_r = \frac{k\beta^2(a - bc - bT)^2(8bks - \beta^2)}{2(4bk(1 - \phi) - \beta^2)^3}. \quad (C.8)$$

Next, the second derivative of ϕ is got:

$$\frac{\partial^2}{\partial \phi^2} \pi_r = -\frac{2bk^2\beta^2(a - bc - bT)^2(16bks + 8bk - 5\beta^2)}{(4bk(1 - \phi) - \beta^2)^4}. \quad (C.9)$$

So, π_r is a strictly concave function of ϕ when $16bks + 8bk - 5\beta^2 > 0$.

Setting the first-order partial derivatives of ϕ to zero, it is possible to get

$$\phi^* = \frac{\beta^2}{8bk}. \quad (C.10)$$

Finally, substituting ϕ^* into the above expressions, it can be obtained as follows:

$$\begin{aligned} e^{\text{RD}^*} &= \frac{2\beta(a - bc - bT)}{8bk - 3\beta^2}, \\ w^{\text{RD}^*} &= \frac{(8bk - \beta^2)(a - bc - bT)}{2b(8bk - 3\beta^2)} + c, \\ p^{\text{RD}^*} &= \frac{8bk(3a + bc + bT) - 3\beta^2(a + 3c + 3T)}{4b(8bk - 3\beta^2)}, \\ q^{\text{RD}^*} &= \frac{(8bk - \beta^2)(a - bc - bT)}{4(8bk - 3\beta^2)}, \\ r^{\text{RD}^*} &= \frac{8b\beta(a - bc - bT)}{8bk(3a + bc + bT) - 3\beta^2(a + 3c + 3T)}, \\ \pi_m^{\text{RD}^*} &= \frac{(8bk - \beta^2)(a - bc - bT)^2}{8b(8bk - 3\beta^2)}, \\ \pi_r^{\text{RD}^*} &= \frac{(8bk + \beta^2)(a - bc - bT)^2}{16b(8bk - 3\beta^2)}, \\ \pi_{\text{sc}}^{\text{RD}^*} &= \frac{(24bk - \beta^2)(a - bc - bT)^2}{16b(8bk - 3\beta^2)}. \end{aligned} \quad (C.11)$$

D. The Quantity Discount-Cost Sharing Contract Model

First, the profit function of the retailer is obtained:

$$\begin{aligned} \pi_r &= (p - (v - u(a - bp + \beta e)))(a - bp + \beta e) \\ &\quad - T(a - bp + \beta e) - \frac{1}{2}k\phi e^2. \end{aligned} \quad (D.1)$$

Obtaining the first and second derivatives of p ,

$$\begin{aligned} \frac{\partial}{\partial p} \pi_r &= (1 - 2bu)(a - bp + \beta e) - b(p - v - T), \\ \frac{\partial^2}{\partial p^2} \pi_r &= -2b(1 - bu). \end{aligned} \quad (D.2)$$

Thus, the retailer's profit function is a concave function about p when $0 < u < (1/b)$.

Setting the first derivative equal to zero, the response function of retail price is got:

$$p = \frac{(1 - 2bu)(a + \beta e) + b(T + v)}{2b(1 - bu)}. \quad (D.3)$$

Inspired by the retailer's proposal to share the R&D cost, the dominant manufacturer in MGSC is responsible for coordinating the supply chain through the quantity discount contract, and determine the appropriate e , v , and u to maximize the profit of the supply chain. Substituting equation (D.3) into equation (7), the profit function of the supply chain is obtained:

$$\pi_{sc} = \frac{(1 - 2bu)(a + \beta e - bc - bT)^2 + b(v - c)(a + \beta e - bc - bT)}{4b(1 - bu)^2} - \frac{1}{2}ke^2. \quad (D.4)$$

When $2bk - \beta^2 > 0$, the Hessian matrix is negative; that is, the supply chain system has the greatest profit.

Setting the first-order partial derivative to zero at the same time, the optimal decision of manufacturer can be obtained:

$$e^{QD*} = \frac{\beta(a - bc - bT)}{2bk - \beta^2} = e^{C*}, \quad (D.5)$$

$$v^* = \frac{2bku^*(a - bc - bT)}{2bk - \beta^2} + c. \quad (D.6)$$

Put equations (B.4)–(C.1) into equation (B.3) and get

$$p^{QD*} = \frac{k(a + bc + bT) - \beta^2(c + T)}{2bk - \beta^2} = p^{C*}. \quad (D.7)$$

Furthermore, it is possible to obtain

$$q^{QD*} = \frac{bk(a - bc - bT)}{2bk - \beta^2} = q^{C*},$$

$$w^{QD*} = \frac{bku^*(a - bc - bT)}{2bk - \beta^2} + c, \quad (D.8)$$

$$\pi_{sc}^{QD*} = \frac{k(a - bc - bT)^2}{2(2bk - \beta^2)} = \pi_{sc}^{C*}.$$

According to the principle of individual rationality, the manufacturer and the retailer consider cooperation only when their own income has increased. Therefore, to achieve the coordination of the MGSC through the quantity discount contract, it is necessary to ensure that the profits of the retailer and the manufacturer are not less than the respective profits before the coordination.

Putting equations (D.3)–(D.7) into equations (6) and (7), the respective profits of the manufacturer and the retailer are obtained:

$$\pi_m^{QD*} = \frac{k(2b^2ku^* - \beta^2(1 - \phi))(a - bc - bT)^2 + 2bck(2bk - \beta^2)(a - bc - bT)}{2(2bk - \beta^2)^2},$$

$$\pi_r^{QD*} = \frac{k(2bk(1 - bu^*) - \beta^2\phi)(a - bc - bT)^2 + 2bck(2bk - \beta^2)(a - bc - bT)}{2(2bk - \beta^2)^2}. \quad (D.9)$$

To guarantee the feasibility of the contract, it is required to meet $\begin{cases} \pi_m^{QD*} \geq \pi_m^{D*} \\ \pi_r^{QD*} \geq \pi_r^{D*} \end{cases}$. Solving the system of inequalities, the

feasible region of the quantity discount coefficient u is obtained:

$$\frac{2k}{4bk - \beta^2} + \frac{c(2bk - \beta^2)}{bk(a - bc - bT)} - \frac{\beta^2\phi}{2b^2k} \leq u^* \leq \frac{1}{b} \left(1 - \frac{c(2bk - \beta^2)}{k(a - bc - bT)} + \frac{(2bk - \beta^2)^2}{(4bk - \beta^2)^2} \right) - \frac{\beta^2\phi}{2b^2k}. \quad (D.10)$$

Letting $U_L = (2k/(4bk - \beta^2)) + (c(2bk - \beta^2)/bk(a - bc - bT)) - (\beta^2\phi/2b^2k)$, $U_U = (1/b)(1 - (c(2bk - \beta^2)/k(a - bc - bT)) + ((2bk - \beta^2)^2/(4bk - \beta^2)^2)) - (\beta^2\phi/2b^2k)$.

U_L is the subtraction function of ϕ and $U_L(\phi = 1) = (2bk - \beta^2/2b^2k(4bk - \beta^2)) + (c(2bk - \beta^2)/bk(a - bc - bT)) > 0$ can be obtained. When $0 < \phi < 1$, U_L is always positive.

$U_U - U_L = (1/b) - (((2bk - \beta^2)^2/b(4bk - \beta^2)^2) + (2k/(4bk - \beta^2)))$; obviously, $U_U - U_L < (1/b)$; thus, $[U_L, U_U] \in (0, (1/b))$.

In summary, the optimal value range of the quantity discount coefficient in the quantity discount contract is $U_L < u^* < U_U$.

Proof of Proposition 1

$$2bk - \beta^2 \leq 4bk - \beta^2 \implies \frac{\beta(a - bc - bT)}{2bk - \beta^2} \geq \frac{\beta(a - bc - bT)}{4bk - \beta^2} \implies e^{C^*} \geq e^{D^*},$$

$$r^{C^*} - r^{D^*} = \frac{2ak\beta(a - bc - bT)}{(k(a + bc + bT) - \beta^2(c + T))(k(3a + bc + bT) - \beta^2(c + T))} > 0. \quad (D.11)$$

$$\pi_{sc}^{C^*} - \pi_{sc}^{D^*} = \frac{2b^2k^3(a - bc - bT)^2}{(2bk - \beta^2)(4bk - \beta^2)^2} > 0.$$

Proof of Proposition 2. $(\partial/\partial\beta)\phi^* = (\beta/4bk) > 0$; $(\partial^2/\partial\beta^2)\phi^* = (1/4bk) > 0$, $\phi^* = (\beta^2/8bk)$; obviously, it can be seen from the expression that ϕ^* is not related to T . \square

Proof of Corollary 1

$$4bk - \frac{3}{2}\beta^2 \leq 4bk - \beta^2 \implies \frac{2\beta(a - bc - bT)}{8bk - 3\beta^2} \geq \frac{\beta(a - bc - bT)}{4bk - \beta^2} \implies e^{RD^*} \geq e^{D^*},$$

$$w^{RD^*} - w^{D^*} = \frac{\beta^4(a - bc - bT)}{2b(8bk - 3\beta^2)(4bk - \beta^2)} > 0,$$

$$p^{RD^*} - p^{D^*} = \frac{3\beta^4(a - bc - bT)}{4b(8bk - 3\beta^2)(4bk - \beta^2)} > 0, \quad (D.12)$$

$$r^{RD^*} - r^{D^*} = \frac{\beta^3(a - bc - bT)(3a + bc + bT)}{(8bk(3a + bc + bT) - 3\beta^2(a + 3bc + 3bT))(k(3a + bc + bT) - \beta^2(c + T))} > 0.$$

Proof of Corollary 2

$$\pi_m^{RD^*} - \pi_m^{D^*} = \frac{\beta^4(a - bc - bT)^2}{8b(8bk - 3\beta^2)(4bk - \beta^2)} > 0,$$

$$\pi_r^{RD^*} - \pi_r^{D^*} = \frac{\beta^6(a - bc - bT)^2}{16b(8bk - 3\beta^2)(4bk - \beta^2)^2} > 0,$$

$$\pi_{sc}^{RD^*} - \pi_{sc}^{D^*} = \frac{\beta^4(8bk - \beta^2)(a - bc - bT)^2}{16b(8bk - 3\beta^2)(4bk - \beta^2)^2} > 0,$$

$$\pi_{sc}^{C^*} - \pi_{sc}^{RD^*} = \frac{(a - bc - bT)^2(16b^2k^2 + \beta^2(2bk - \beta^2))}{16b(8bk - 3\beta^2)(2bk - \beta^2)^2} > 0. \quad (D.13)$$

The ratio of supply chain members' profit increase in RD model is $((\pi_m^{RD^*} - \pi_m^{D^*})/(\pi_r^{RD^*} - \pi_r^{D^*})) = (2(4bk - \beta^2)/\beta^2)$. Since $2bk - \beta^2 > 0$, $(2(4bk - \beta^2)/\beta^2) > (2 \cdot 2bk/$

$\beta^2) > 2$ is obtained; that is, the profit increase of the manufacturer is more than twice as much as the retailer. \square

The greater the consumers' green preference in importing country, the closer the retailer's profit growth to 50% of the manufacturer's profit growth. \square

Proof of Proposition 3. By solving QD model, the relationship between u and v can be obtained: $v^* = (2bku^*(a - bc - bT)/(2bk - \beta^2)) + c$.

According to the principle of individual rationality, the manufacturer and the retailer consider cooperation only when their own income has increased. Therefore, to achieve the coordination of the MGSC through this contract, it is necessary to ensure that the profits of the retailer and the manufacturer is not less than the respective profits before the coordination. \square

Putting equations (D.5)–(D.7) into equations (5) and (6), the respective profits of the manufacturer and the retailer can be acquired:

$$\pi_m^{QD^*} = \frac{k(2b^2ku^* - \beta^2(1 - \phi))(a - bc - bT)^2 + 2bck(2bk - \beta^2)(a - bc - bT)}{2(2bk - \beta^2)^2},$$

$$\pi_r^{QD^*} = \frac{k(2bk(1 - bu^*) - \beta^2\phi)(a - bc - bT)^2 + 2bck(2bk - \beta^2)(a - bc - bT)}{2(2bk - \beta^2)^2}.$$
(D.14)

To guarantee the feasibility of the contract, it needs to meet $\begin{cases} \pi_m^{QD^*} \geq \pi_m^{D^*} \\ \pi_r^{QD^*} \geq \pi_r^{D^*} \end{cases}$. Solving the system of inequalities and the feasible region of the quantity discount coefficient u ,

$$\frac{2k}{4bk - \beta^2} + \frac{c(2bk - \beta^2)}{bk(a - bc - bT)} - \frac{\beta^2\phi}{2b^2k} \leq u^* \leq \frac{1}{b} \left(1 - \frac{c(2bk - \beta^2)}{k(a - bc - bT)} + \frac{(2bk - \beta^2)^2}{(4bk - \beta^2)^2} \right) - \frac{\beta^2\phi}{2b^2k}.$$
(D.15)

Letting $U_L = (2k/4bk - \beta^2) + (c(2bk - \beta^2)/bk(a - bc - bT)) - (\beta^2\phi/2b^2k)$, $U_U = (1/b)(1 - (c(2bk - \beta^2)/k(a - bc - bT)) + ((2bk - \beta^2)^2/(4bk - \beta^2)^2)) - (\beta^2\phi/2b^2k)$.

U_L is the subtraction function of ϕ . $U_L(\phi = 1) = ((2bk - \beta^2)^2/2b^2k(4bk - \beta^2)) + (c(2bk - \beta^2)/bk(a - bc - bT)) > 0$ can be obtained. When $0 < \phi < 1$, U_L is always positive. $U_U - U_L = (1/b) - (((2bk - \beta^2)^2/b(4bk - \beta^2)^2) + (2k/(4bk - \beta^2)))$; obviously, $U_U - U_L < (1/b)$; thus, $[U_L, U_U] \in (0, (1/b))$.

In summary, the optimal value range of the quantity discount coefficient in the quantity discount contract is $U_L < u^* < U_U$.

At this point, comparing the optimal equilibrium solutions of model CS and model QD, it can be obtained that $e^{QD^*} = e^{C^*}$, $p^{QD^*} = p^{C^*}$, $q^{QD^*} = q^{C^*}$, and $\pi_{sc}^{QD^*} = \pi_{sc}^{C^*}$. \square

Proof of Corollary 3. From the above deduction, the relationship between u^* and ϕ can be acquired as $u^* = A - (\beta^2/2b^2k)\phi$, where $A \in [(2k/4bk - \beta^2) + (c(2bk - \beta^2)/bk(a - bc - bT))$, $(1/b)(1 - (c(2bk - \beta^2)/k(a - bc - bT)) + ((2bk - \beta^2)^2/(4bk - \beta^2)^2))]$, u^* is the subtraction function of ϕ .

The transfer payment between the manufacturer and the retailer is $TP = (k\phi e^2/2) + wq = A(b^2k^2(a - bc - bT)^2/$

$(2bk - \beta^2)^2)$, and TP is the increasing function of A . Furthermore, TP is also the increasing function of u^* .

When $u^* = U_L$, the profit of the manufacturer is minimal $\pi_m^{QD^*} = \pi_m^{D^*}$, the retailer gets all the remaining profit of MGSC $\pi_r^{QD^*} = \pi_{sc}^{C^*} - \pi_m^{QD^*}$, and his profit reaches the maximum.

When $U_L < u^* < ((U_U + U_L)/2)$, $\pi_r^{QD^*} - \pi_r^{D^*} > \pi_m^{QD^*} - \pi_m^{D^*} > 0$. The remaining profit in supply chain of the retailer gain is greater than the manufacturer.

When $u^* = (U_U + U_L)/2$, $\pi_r^{QD^*} - \pi_r^{D^*} = \pi_m^{QD^*} - \pi_m^{D^*} > 0$. The manufacturer and the retailer evenly distribute residual profit in the supply chain.

When $((U_U + U_L)/2) < u^* < U_U$, $\pi_m^{QD^*} - \pi_m^{D^*} > \pi_r^{QD^*} - \pi_r^{D^*} > 0$. The remaining profit in supply chain of the manufacturer gain is greater than the retailer.

When $u^* = U_U$, the profit of the retailer is minimal $\pi_r^{QD^*} = \pi_r^{D^*}$, the manufacturer gets all the remaining profit of MGSC $\pi_m^{QD^*} = \pi_{sc}^{C^*} - \pi_r^{QD^*}$, and his profit reaches the maximum. \square

Proof of Corollary 4

$$\begin{cases}
\frac{\partial}{\partial T} e^{D^*} = -\frac{b\beta}{4bk - \beta^2} \\
\frac{\partial}{\partial T} e^{RD^*} = -\frac{2b\beta}{8bk - 3\beta^2} \implies \left| \frac{\partial}{\partial T} e^{D^*} \right| < \left| \frac{\partial}{\partial T} e^{RD^*} \right| < \left| \frac{\partial}{\partial T} e^{QD^*} \right| = \left| \frac{\partial}{\partial T} e^{C^*} \right|, \\
\frac{\partial}{\partial T} e^{QD^*} = \frac{\partial}{\partial T} e^{C^*} = -\frac{b\beta}{2bk - \beta^2} \\
\frac{\partial}{\partial T} r^{D^*} = -\frac{a\beta(2bk - \beta^2)}{(k(3a + bc + bT) - \beta^2(c + T))^2} \\
\frac{\partial}{\partial T} r^{RD^*} = -\frac{32ab^2\beta(8bk - 3\beta^2)}{(8bk(3a + bc + bT) - 3\beta^2(a + 3c + 3T))^2} \implies \left| \frac{\partial}{\partial T} r^{D^*} \right| < \left| \frac{\partial}{\partial T} r^{RD^*} \right| < \left| \frac{\partial}{\partial T} r^{QD^*} \right| = \left| \frac{\partial}{\partial T} r^{C^*} \right|, \\
\frac{\partial}{\partial T} r^{QD^*} = \frac{\partial}{\partial T} r^{C^*} = -\frac{a\beta(2bk - \beta^2)}{(k(a + bc + bT) - \beta^2(c + T))^2} \\
\frac{\partial}{\partial T} \pi_{sc}^{D^*} = -\frac{bk(a - bc - bT)(6bk - \beta^2)}{(4bk - \beta^2)^2} \\
\frac{\partial}{\partial T} \pi_{sc}^{RD^*} = -\frac{(a - bc - bT)(24bk - \beta^2)}{8(8bk - 3\beta^2)} \implies \left| \frac{\partial}{\partial T} \pi_{sc}^{D^*} \right| < \left| \frac{\partial}{\partial T} \pi_{sc}^{RD^*} \right| < \left| \frac{\partial}{\partial T} \pi_{sc}^{QD^*} \right| = \left| \frac{\partial}{\partial T} \pi_{sc}^{C^*} \right|. \\
\frac{\partial}{\partial T} \pi_{sc}^{QD^*} = \frac{\partial}{\partial T} \pi_{sc}^{C^*} = -\frac{bk(a - bc - bT)}{2bk - \beta^2}
\end{cases} \quad (D.16)$$

Data Availability

The data used to support the findings of this study have not been made available because the data are simulation data. No other type of data was used to support this study.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Mengyue Zhai conceptualized the study and wrote the original draft. Mingwu Liu curated the data. Hong Fu performed formal analysis. Qiaoling Fu was responsible for investigation.

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