ISSN: 2692-7608 DOI: 10.6981/FEM.202012_1(12).0030

Green Supply Chain Pricing Coordination Strategy Considering Retailers' Fairness Concerns

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Abstract

This paper studies the secondary green supply chain composed of a single manufacturer and a single retailer, and establishes a Stackelberg game model that considers retailers' fairness concerns and consumers' green awareness when leading manufacturers invest in green emission reduction technologies. Analyze the optimal pricing strategy of the supply chain under the centralized and decentralized decision-making, and use the Nash bargaining fairness concern equilibrium point as a reference point to establish a fair utility function to compare the optimal pricing strategies under each mode, and finally make it fair through the revenue sharing contract The green supply chain of concern behavior retailers has been coordinated and optimized. Studies have shown that: (1) The increase in consumers' green awareness has expanded the demand for the green market, but it will increase the fairness concerns of retailers; (2) The green market service coefficient affects the supply chain's pricing decisions, and the green market The service factor is determined by the consumer's green awareness and the manufacturer's emission reduction cost factor; (3) The introduction of revenue sharing contracts can effectively increase supply chain profits under decentralized decision-making, enabling manufacturers and retailers to achieve Pareto improvements at the same time.

Keywords

Green Supply Chain; Fairness Concerns; Supply Chain Pricing Coordination.

1. Introduction

In recent years, as consumers pay more attention to green energy-saving and environmentally friendly products and green healthy food, green consumption has become a new fashion, and the market demand for green products has gradually increased. How to set a reasonable price for the green supply chain And designing a reasonable coordination mechanism to make scientific decisions is an urgent problem for green supply chain companies.

At present, domestic and foreign scholars' research on green supply chain pricing strategies mainly focuses on the decision-making influence of government actions such as channel structure and subsidy incentives. Among the representative studies in terms of channel structure are: Jafar et al. (1) studied the optimal pricing and coordination of a three-tier (manufacturer, distributor, and retailer) dual-channel green supply chain, and provided model support for the study of multi-tier supply chain management. Jamali et al. (2) studied the pricing problem of channel competition between a green product manufacturer and a non-green product manufacturer in the green supply chain, and found that when each member of the supply chain is concentrated in activities, it not only improves the supply The greenness of the chain also increases the overall profit of the supply chain. Fan Hehua et al. (3) studied and analyzed the expected profits of the traditional retail and online direct sales channels under decentralized and centralized decision-making due to the randomness of carbon emission reduction and demand, and finally gave the best channel sales plan , And draw the conclusion that the channel selection decision depends on the consumer's preference coefficient of the

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channel itself, the manufacturer's marginal production cost, the randomness of channel demand, and carbon emission reduction. Yang Shihui et al. (4) considered the cost of carbon emissions in retail channels and direct sales channels, compared and analyzed the optimal pricing decisions under different channel structures, and found that the greenness of the supply chain under dual channels is higher than that under a single channel higher. Representative studies on the influence of government actions such as subsidy incentives on supply chain decision-making include: Huang et al. (5) studied and compared the performance of the green supply chain under the three subsidy modes of green credit, manufacturing subsidy and sales subsidy around the manufacturers with limited funds, and provided useful management advice for enterprises and the government. Simin et al. (6) designed a green credit financing model subject to carbon emission constraints, compared it with trade credit financing, and found that both can effectively curb the carbon emissions of manufacturers, and there is a win-win situation for manufacturers and suppliers. Shang Wenfang et al. (7) considered the impact of product greenness, sales effort, optimal subsidy rate, and the influence of various factors on price decision-making under the three situations of no government subsidies, government grants R&D subsidies to manufacturers, and government grants green promotion subsidies to retailers. Changes in the influence of each member's profit. Fu Duanxiang et al. (8) found that government subsidies have an impact on the pricing strategies of risk aversion manufacturers and retailers, the greenness of products, and the overall profits of all parties in the supply chain, and that increased government subsidies can reduce the impact of risk aversion on their own profits. Damaging effect.

The introduction of the supply chain coordination mechanism is to optimize the revenue of the supply chain system and coordinate the uneven and unequal distribution in the supply chain. Peng et al. (9) studied two competing manufacturers and examined the impact of green investment on the level of green manufacturing and supply chain performance. By introducing cost sharing contracts, the conflicts between the two parties were reduced and the profits of the supply chain system were coordinated. Song et al. (10) studied the green supply chain game model under the coordination of revenue sharing contracts and performed a numerical analysis on it, and found that revenue sharing contracts have a positive impact on the performance of the green supply chain and can improve the green level of products. Zhou Yanju et al. (11) took the retailer-led bilateral monopoly green supply chain as the research object, and discussed the wholesale price contract and cost on the basis of considering the influence of consumer environmental awareness, product green level, price and other factors on demand. The impact of sharing contracts and two-part contracts on the demand for green products, supply chain members' profits and channel profits, it is found that two-part contracts can achieve a win-win situation for supply chain members and increase the market demand for green products. Cheng Susu et al. (12) coordinated the cooperation between members of the green supply chain through the dynamic wholesale price mechanism, so that the green technology level, product greenness and retail price of the supply chain are close to the situation under centralized decision-making.

In reality, the rationality of supply chain members is limited, which often affects the decision-making and benefits of the supply chain. Therefore, more and more scholars have incorporated the psychology and sociology of behavioral economics based on irrational assumptions into the utility function, trying to modify the assumption of "self-interested" economic man. Fher et al. (13) first gave Evaluate the fair utility function and propose the FS model. Peral et al. (14) studied the upstream and downstream supply chain coordination issues related to the fairness of Nash bargaining.

In recent years, some scholars have also begun to consider the impact of fairness concerns on green supply chain decision-making. Zhang Hong et al. (15) considered and studied the combination of external factors, government subsidies and the fairness preferences of internal

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participants. Yao Fengmin et al. (16) studied the impact of retailer-led fairness concerns on closed-loop supply chain pricing strategies based on the three situations of supply chain members' fairness and neutrality, manufacturers' fairness concerns, and both parties' simultaneous fairness concerns. Li et al. (17) incorporated the fairness of retailers into the carbon emission reduction game model and found that the fairness concerns of retailers greatly affected prices and emission reduction decisions and profit levels, and when the cost of emission reduction was high, retailers had the most Good behavior with fairness concerns. Lou Gaoxiang et al. (18) studied the optimal green innovation and pricing decisions of the green supply chain in three scenarios: fairness and neutrality, supplier fairness concerns, and manufacturer fairness concerns. Yang Haoxiong et al. found that manufacturers pay more attention to fairness than retailers under fair concerns, and the overall utility of the supply chain has increased to a certain extent. Shi Pingping studied the impact of fairness concerns on green supply chain pricing strategies, product greenness, supply chain parties and overall profits, and used revenue sharing contracts to coordinate cooperation between supply chain members and increase the supply chain Profit.

This study combines the issue of green product pricing with retailers' fairness concerns. By constructing a manufacturer-led Stackelberg game model, the cost of emission reduction technology in the production process of manufacturers is considered, and Nash bargaining between both parties in the supply chain is taken as a reference point for fairness concerns , Research is based on consumers' green preferences and the influence of retailers with fairness concerns on supply chain pricing decisions. The research introduces consumers' green preferences to reflect the changes in the green market, compares the impact of whether retailers have fair concerns on the profits of the supply chain system, and uses revenue sharing contracts to assess the supply chain system of retailers with fair concerns Coordinate.

2. Problem description and symbol description

2.1. Problem Description

Study the secondary supply chain consisting of a manufacturer and a retailer. The manufacturer is in a dominant position. Both parties make decisions based on maximizing their own profits. The manufacturer sells its products to the retailer at a certain wholesale price, and the retailer The product is sold to the market at a certain selling price. In order to respond to the call for green and sustainable development, manufacturers are committed to green technology innovation and develop low-carbon products. Products with green properties will attract more customers with green preferences. In the production and sales process of green products, the dominant manufacturer may make more profits. At this time, retailers with relatively small profits are more likely to be dissatisfied compared with manufacturers, which may sacrifice their own interests (reducing wholesale (Quantity, wholesale frequency) to pursue fairness in profit, that is, to make retailers act as decision-makers concerning fairness. The research takes the retailer and the manufacturer's Nash bargaining solution as a fair reference point, and the retailer takes the maximization of fair utility as the decision-making goal.

2.2. Model assumptions

(1) Let the green cost invested by the manufacturer be a quadratic function of its emission reduction level: $\frac{1}{2}\theta g^2$.

(2) Let the demand function of green products be: $a-p+kg$.

(3) Let the utility function of the retailer under fairness concerns be: $V_r=(1+\lambda)\pi_r-\frac{\lambda(1+\lambda)}{2+\lambda}\pi_{sc}$.

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(4) It is assumed that the manufacturer is a fair and neutral decision-maker, and the retailer is a fair-concerned decision-maker, and the information of both parties is symmetrical.

(5) Both manufacturers and retailers are risk-neutral, and both have profit maximization as their decision-making goal.

The numerical parameters involved in the study are as follows:

Non-decision variable			
symbol	meaning	symbol	meaning
a	Total market potential	π_m	Manufacturer profit
k	Consumer green awareness	π_r	Retailer profit
λ	Retailer fairness concerns	V_r	Retailer utility
θ	Manufacturer's emission reduction level cost factor	π	Overall supply chain profit
c	Manufacturer production cost		
Decision variable			
w	Manufacturer wholesale price	p	Retailer product retail price
g	Manufacturer's green emission reduction level		

3. Model

3.1. Centralized decision

Based on the above related assumptions, the overall profits of manufacturers, retailers and green supply chains are:

$$\pi_m = (w-c)(a-p+kg) - \frac{1}{2}\theta g^2 \tag{1}$$

$$\pi_m = (w-c)(a-p+kg) - \frac{1}{2}\theta g^2 \tag{2}$$

$$\pi_m = (w-c)(a-p+kg) - \frac{1}{2}\theta g^2 \tag{3}$$

Under centralized decision-making, manufacturers and retailers are regarded as a whole. At this time, upstream and downstream enterprises consider the overall interests of the supply chain and pursue the overall profit maximization of the supply chain as their operational goals. So it leads to p and g Hessian matrix.

$$\begin{pmatrix} -2 & k \\ k & -\theta \end{pmatrix}$$

When $2\theta - k^2 > 0$, the matrix is negatively definite, and the profit function curve of the entire supply chain is a joint concave function of p and g, with a uniquely determined optimal solution. After solving in reverse order, the first-order partial derivatives of p and g are obtained:

$$\frac{\partial \pi_{sc}}{\partial p} = 0 \Rightarrow p = \frac{a+c+gk}{2}$$

$$\frac{\partial \pi_{sc}}{\partial g} = 0 \Rightarrow g = \frac{k(c-p)}{2}$$

The optimal solution can be obtained after the combination is:

$$p^* = \frac{\theta(a+c) - ck^2}{2\theta - k^2}$$

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$$g^* = \frac{k(a-c)}{2\theta - k^2}$$

Substitute p^* and g^* into (3) to get: $\pi_{sc}^* = \frac{(a-c)^2\theta}{2(2\theta-k^2)}$.

3.2. Decentralized decision

Under decentralized decision-making, manufacturers and retailers are two independent decision-making bodies with inconsistent goals, each aiming at maximizing their own interests. Here, we discuss the manufacturer-led model *Stackelberg*. The manufacturer first determines the wholesale price and product greenness, and the retailer determines the best retail price based on the manufacturer's decision p_1^*. Finally, the manufacturer formulates strategies based on the retailer's response function. At this time, due to their own operations within the supply chain, retailers' fairness concerns will change, and the total profit of the supply chain system and the income of each member will be affected to varying degrees. We will decentralize decision-making from retailers' unfair preferences and exist with retailers. The decentralized decision-making of fair preference explores the utility of both.

3.2.1. Distributed decision-making under the retailer's non-fair concern behavior

In the solution process, the reverse order solution method can be used again, which assumes that the retailer has determined the retail price on the premise of knowing the manufacturer's wholesale price.

That is: $\frac{\partial \pi_r}{\partial p} = 0$, get:

$$p_1 = \frac{a + g_1 k + w_1}{2} \tag{4}$$

Substitute (4) into (1) and find the Hessian matrix of w_1 and g_1 : $\begin{pmatrix} -1 & \frac{k}{2} \\ \frac{k}{2} & -\theta \end{pmatrix}$. When $4\theta - k^2 > 0$,The profit function curve of the entire supply chain is a joint concave function of w_1 and g_1, with a uniquely determined optimal solution. Then find the first partial derivative of π_m with respect to w_1 and g_1 so that it is 0.

$$\frac{\partial \pi_m}{\partial w_1} = 0 \Rightarrow w_1 = \frac{a + c + g_1 k}{2} \tag{5}$$

$$\frac{\partial \pi_m}{\partial g_1} = 0 \Rightarrow g_1 = \frac{k(c - w_1)}{2\theta} \tag{6}$$

Combine (5) and (6) to get:

$$w_1^* = \frac{2\theta(a+c) - ck^2}{4\theta - k^2} \tag{7}$$

$$g_1^* = \frac{k(a-c)}{4\theta - k^2} \tag{8}$$

Substituting (7) and (8) into (4) can get the best retail price as:

$$p_1^* = \frac{\theta(3a+c) - ck^2}{4\theta - k^2} \tag{9}$$

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Finally, substituting (7)～(9) into (1)～(3) and d respectively, the overall profit of the manufacturer, retailer and supply chain without fairness concerns of the retailer is:

$$\pi_{m1}^* = \frac{\theta(a-c)^2}{2(4\theta-k^2)}$$

$$\pi_{r1}^* = \frac{\theta^2(a-c)^2}{(4\theta-k^2)^2}$$

$$\pi_{sc1}^* = \frac{\theta(6\theta-k^2)(a-c)^2}{2(4\theta-k^2)^2}$$

It can be seen that, $\pi_{m1}^* > \pi_{r1}^*, \pi_{sc1}^* < \pi_{sc}^*$. That is, under the decentralized decision-making, the overall profit of the supply chain system is less than the supply chain revenue under the centralized decision-making situation. Because the manufacturer is the dominant player, therefore, without considering fairness concerns under decentralized decision-making, the manufacturer gets more profits than the manufacturer.

3.2.2. Retailer's decentralized decision-making under fair concerns

We assume that the retailer's fairness concern is a λ .While analyzing the decentralized decision-making of the supply chain when retailers have fairness concerns, the manufacturer-led *Stackelberg* model is still analyzed. The retailer determines the retail price p_2^* according to the principle of maximizing profit, The manufacturer makes the optimal decision based on the retailer's reaction function.

Then the utility function expression of the retailer with fair concern behavior at this time is:

$$V_r = (1+\lambda)\pi_r - \frac{\lambda(1+\lambda)}{2+\lambda}\pi_{sc} \tag{10}$$

Substitute (1)～(3) into (10) and solve according to the reverse order, Let $\frac{\partial V_r}{\partial p} = 0$, do the first-order partial derivative of p to get:

$$p = \frac{1}{4}\left[2(a+g_2k+w_2)+\lambda(w_2-c)\right] \tag{11}$$

Substitute (11) into (1), and find the Hessian matrix of w_2, g_2 : $\begin{pmatrix} -\frac{1}{2}(2+\lambda) & \frac{k}{2} \\ \frac{k}{2} & -\theta \end{pmatrix}$, At this time, when $\frac{1}{2}\theta(2+\lambda)-\frac{k^2}{4}>0$, the supply chain profit curve is a joint concave function of w_2 and g_2, and it has a uniquely determined optimal solution. Then find the first partial derivative of π_m with respect to w_2 and g_2 so that it is 0.

$$\frac{\partial \pi_m}{\partial w_2} = 0 \Rightarrow w_2 = \frac{a+c+g_2k+c\lambda}{2+\lambda} \tag{12}$$

$$\frac{\partial \pi_m}{\partial g_2} = 0 \Rightarrow g_2 = \frac{-k(c-w_2)}{2\theta} \tag{13}$$

The optimal solution obtained by combining (12) and (13) is:

$$w_2^* = c + \frac{2\theta(a-c)}{2\theta(2+\lambda)-k^2} \tag{14}$$

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$$g_2^* = \frac{k(a-c)}{2\theta(2+\lambda)-k^2} \tag{15}$$

Substituting (14) and (15) into (11) can obtain the optimal retail price for retailers' fairness concerns under decentralized decision-making:

$$p_2^* = \frac{-3a\theta(2+\lambda)+c\left[2k^2-\theta(2+\lambda)\right]}{2\left[k^2-2\theta(2+\lambda)\right]} \tag{16}$$

Substituting (14)～(16) into (1)～(3) respectively to obtain the optimal utility solution of the manufacturer and the retailer under the retailer's fairness concern:

$$\pi_{m2}^* = \frac{(a-c)^2\theta}{2\left[2\theta(2+\lambda)-k^2\right]}$$

$$V_r^* = \frac{\theta(a-c)^2\left[k^2+\theta(1+\lambda)(2+\lambda)\right]}{2\left[2\theta(2+\lambda)-k^2\right]^2}$$

Proposition 1:

When the green market service coefficient $\frac{k^2}{\theta}$ is small, the optimal retail price p^* under centralized decision-making is less than the optimal retail price p_1^* under decentralized decision-making when retailers have no fairness concerns; when the green market service coefficient is moderate, the optimal retail price under centralized decision-making is equal to the optimal retail price when retailers have no fair concerns under decentralized decision-making; when the green market service coefficient is large, the optimal retail price under centralized decision-making is greater than The optimal retail price when retailers have no fairness concerns under decentralized decision-making. The optimal retail price of p_1^* retailer without fairness concerns under decentralized decision-making is greater than the optimal retail price of a retailer with fair concerns p_2^*; under decentralized decision-making, the optimal wholesale price of a retailer without fair concerns w_1^* is greater than the optimal wholesale price of a retailer with fair concerns w_2^*.

Prove: $p*-p_1^* = \frac{2\theta(a-c)(k^2-\theta)}{(k^2-4\theta)(k^2-2\theta)}$, The optimal price in both cases is determined by $k^2-\theta$.

And from the above: $\begin{cases} 4\theta-k^2>0 \\ 2\theta-k^2>0 \end{cases} \Rightarrow 0<\frac{k^2}{\theta}<2$,

There are three situations at this time: $\begin{cases} p^*<p_1^*, 0<\frac{k^2}{\theta}<1 \\ p^*=p_1^*, \frac{k^2}{\theta}=1 \\ p^*>p_1^*, 1<\frac{k^2}{\theta}<2 \end{cases}$,

$p_1^*-p_2^* = \frac{3\lambda\theta k^2(a-c)}{2(k^2-4\theta)(k^2-2\theta)(2+\lambda)}>0$. The same can be obtained:

$w_1^*-w_2^* = \frac{4\lambda\theta^2(a-c)}{(k^2-4\theta)\left[k^2-2\theta(2+\lambda)\right]}>0$. Proposition 1 is proved.

ISSN: 2692-7608 DOI: 10.6981/FEM.202012_1(12).0030

Through the analysis of the proof of proposition 1, it can be seen from the results that the smaller the green market service coefficient, the weaker the green awareness of consumers, and the smaller the impact on market demand. At this time, the attributes of the supply chain are closer to the traditional supply chain system, and the decision is centralized. When the green market service coefficient is higher, the consumer’s green awareness will increase and market demand will increase. At this time, the retail price of retailers under decentralized decision-making is lower than the retail price under centralized decision-making; When the green market service coefficient is moderate, due to the increase of consumers' green awareness on the market demand, the reduction cost coefficient of manufacturers will relieve the problem of product retail price increase to a certain extent. At the same time, under decentralized decision-making, the enhancement of consumers' green awareness can reduce wholesale prices to a certain extent.

Corollary 1:

Retail prices increase as consumers’ green awareness increases, and decrease as manufacturers’ abatement cost coefficients increase, and manufacturers’ wholesale prices decrease as retailers’ fairness concerns increase.

Prove: $\frac{\partial p^*}{\partial k}=\frac{2\theta k\left(a-c\right)}{\left(k^2-2\theta\right)^2}>0$, in the same way, we can get: $\frac{\partial p_1^*}{\partial k}>0$, $\frac{\partial p_2^*}{\partial k}>0$;

$\frac{\partial p^*}{\partial \theta}=-\frac{k^2\left(a-c\right)}{\left(k^2-2\theta\right)^2}<0$, in the same way, we can get: $\frac{\partial p_1^*}{\partial \theta}<0$, $\frac{\partial p_2^*}{\partial \theta}<0$;

$\frac{\partial p_2^*}{\partial \lambda}=\frac{3\theta k^2\left(c-a\right)}{2\left[k^2-2\theta\left(2+\lambda\right)\right]^2}<0$, in the same way, we can get: $\frac{\partial w_2^*}{\partial \lambda}<0$.Corollary 1 is proved.

From the research results of Corollary 1, it can be seen that the increase of consumers' green awareness has driven the increase of green market demand. For this reason, manufacturers have increased the input cost of emission reduction technologies, which has caused the wholesale and retail prices of green products to rise; With the increase in wholesale prices, retailers in the position of followers will lose their own interests whether they sell at the original price or increase the price and lose customers. At this time, retailers are more concerned about fairness, and manufacturers in the leadership position should take timely measures To ease the fairness concerns of retailers and avoid greater losses to the supply chain system and other members.

Proposition 2:

The green level of products in the green supply chain under centralized decision-making is greater than its green level under decentralized decision-making, and when retailers have fair concerns, the manufacturer’s product green level is further reduced.

Prove: $\begin{cases} g_1^*-g_2^*=\frac{2\lambda k\theta\left(a-c\right)}{\left(k^2-4\theta\right)\left[k^2-2\theta\left(2+\lambda\right)\right]}>0 \\ g^*-g_1^*=\frac{2k\theta\left(a-c\right)}{\left(k^2-4\theta\right)\left[k^2-2\theta\left(2+\lambda\right)\right]}>0 \end{cases} \Rightarrow g^*>g_1^*>g_2^*$.Proposition 2 is proved.

Through the analysis of the proof of Proposition 2, it is shown that the green supply chain can provide higher green services to the market under the centralized decision-making mode. This is because when the manufacturer and the retailer make decisions as a whole, the intermediate cost is reduced and the emission reduction is reduced. The costs are borne by both parties, and the market dividends brought about by emissions reduction have provided a positive impact

ISSN: 2692-7608 DOI: 10.6981/FEM.202012_1(12).0030

on both parties. In the case of decentralized decision-making, although both parties bear the dividends of the green market at the same time, the manufacturer has to bear the cost of abatement alone. This cost is eventually converted to a wholesale price and transferred to the retailer, thereby affecting both parties. In order to alleviate this phenomenon, manufacturers can only reduce emissions. When retailers have fair concerns, they will be unfair to the increase in retail prices caused by the increase in wholesale prices and ultimately the decline in their profits. Therefore, they should adopt Measures, even at the expense of the level of profit maintenance, make the strategy unfavorable for supply chain decision-making, at this time will further lead to a decline in the level of emission reduction.

Corollary 2:

When a retailer has fair concerns, the manufacturer's green emission reduction level will decrease as the fairness concern increases, and the greater the retailer's fairness concern, the lower the manufacturer's emission reduction level.

Prove: $\frac{\partial g_2^*}{\partial \lambda} = \frac{2k\theta(c-a)}{\left[k^2-2\theta(2+\lambda)\right]^2} < 0$. Corollary 2 is proved.

From the research results of Corollary 2, it can be seen that when retailers have fair concerns, the service coefficient of the green market will show a downward trend. At this time, the market demand for green products will also decrease. Manufacturers observe that the green market is in If the situation is not ideal, it will reduce the production of green products and reduce the investment in green emission reduction technologies, and the level of green emission reduction is also declining. When the retailer’s fairness concern is greater, the retailer will increase its revenue by increasing the retail price or reducing the wholesale volume of green products to the manufacturer. At this time, the demand trend of the green product market will be more obvious. The benefits of emission reduction technology to manufacturers are very small, so manufacturers' emission reduction levels will become lower and lower.

Proposition 3:

The profit of the manufacturer under the retailer’s fairness concern is smaller than the manufacturer’s profit under the fairness and neutrality of the retailer; the profit when the retailer has the fairness concern behavior is also smaller than the profit under the fairness and neutrality of the retailer.

Prove: $\pi_{m1}^* - \pi_{m2}^* = \frac{\lambda\theta^2(a-c)^2}{(k^2-4\theta)\left[k^2-2\theta(2+\lambda)\right]} > 0$, in the same way, we can get: $\pi_{r1}^* - \pi_{r2}^* > 0$.

Proposition 3 is proved.

Through the analysis of the proof of Proposition 3, it can be seen from the results that the profits of manufacturers and retailers are less than those of fair and neutral retailers when retailers have fair concerns. When retailers have fair concerns, they use their own interests. Maximization is the operational goal. In order to meet the needs of the green market, manufacturers will invest in green technology to improve the green level of products, leading to a certain increase in the wholesale price of products. Retailers will reduce or increase the wholesale of green products in order to stabilize their own income. The retail price of green products. In this way, the green market will shrink and the manufacturer’s profit will be reduced. Retailers under fairness and neutrality will follow the manufacturer’s production and sales plan. The demands of the green market will also be met. Consumers’ green preference will also gradually increase, and retailers’ profits will also rise at this time.

Corollary 3:

When a retailer has fair concerns, the manufacturer’s profit will decrease as the retailer’s fairness concern increases, and the retailer’s profit depends on the green market service coefficient $\frac{k^2}{\theta}$, among them, when $\frac{k^2}{\theta}$ is small, the retailer's fairness concern has a positive impact on retailer's profit; when $\frac{k^2}{\theta}$ is large, the retailer's degree of fairness concern is negatively related to its profit impact.

Prove: $\frac{\partial \pi_{m2}^*}{\partial \lambda} = -\frac{\theta^2 (a-c)^2}{\left[2\theta(2+\lambda)-k^2\right]^2} < 0$, $\frac{\partial \pi_{r2}^*}{\partial \lambda} = \frac{\theta^2 (a-c)^2 \left[k^2(7+2\lambda)-2\theta(2+\lambda)\right]}{2\left[k^2-2\theta(2+\lambda)\right]^3}$, at this time, the result of the first-order partial derivative is determined by $k^2 - \theta$, which is determined by $\frac{k^2}{\theta}$.

when $0 < \frac{k^2}{\theta} < 1, \frac{\partial \pi_{r2}^*}{\partial \lambda} \begin{cases} < 0, \lambda < \frac{4\theta - 7k^2}{2(k^2-\theta)} \\ > 0, \lambda > \frac{4\theta - 7k^2}{2(k^2-\theta)} \end{cases}$;

when $1 < \frac{k^2}{\theta} < 2, \frac{\partial \pi_{r2}^*}{\partial \lambda} \begin{cases} > 0, \lambda < \frac{4\theta - 7k^2}{2(k^2-\theta)} \\ < 0, \lambda > \frac{4\theta - 7k^2}{2(k^2-\theta)} \end{cases}$. Corollary 3 is proved.

From the research results of Corollary 3, it can be seen that the increased degree of retailers' fairness concerns will have a negative impact on manufacturers and the supply chain system as a whole. Retailers with fairness concerns may increase their own profits by increasing retail prices or Measures such as reducing the wholesale volume of green products will reduce the market demand for green products. On the one hand, manufacturers will lose profits from market demand, and on the other hand, retailers will reduce their willingness to wholesale to manufacturers. Manufacturers' profits become less and less as retailers' concerns about fairness increase. The retailer's profit depends on the size of the green market service coefficient. When the green market service coefficient is small, consumers' green awareness will increase, leading to increased demand for the green market, and manufacturers' reduction costs will decrease, leading to retailers' wholesale costs Decrease, both will increase the retailer's benefit.

4. Supply chain contract coordination

Under the revenue-sharing contract, the manufacturer distributes its own revenue to the manufacturer a certain percentage φ ($0<\varphi<1$). Under this coordination mechanism, the manufacturer is still the leader of the supply chain, and the retailer is the follower. Therefore, the optimization model under the revenue sharing contract can be obtained as:

$$\max_p \pi_r = (1+\lambda)(p-w)(a-p+kg) - \frac{\lambda(1+\lambda)}{2+\lambda}[(p-c)(a-p+kg) - \frac{1}{2}\theta g^2] + \varphi[(w-c)(a-p+kg) - \frac{1}{2}\theta g^2]$$

$$s.t. \begin{cases} w, g = \arg\max \pi_m \\ \max_{w,g} \pi_m = (1-\varphi)[(w-c)(a-p+kg) - \frac{1}{2}\theta g^2] \end{cases}.$$

At this time, the inverse solution method is still used to solve the optimization model, and the specific process is as follows:

First, solve the first-order partial derivative of π_r with respect to p and set it to 0 to obtain:

$$p(w,g,\varphi) = \frac{(1+\lambda)[2(a+gk+w)+(w-c)\lambda]+(c-w)(2+\lambda)\varphi}{4(1+\lambda)},$$

ISSN: 2692-7608 DOI: 10.6981/FEM.202012_1(12).0030

again, solve the first-order partial derivatives of π_m with respect to w and g and set them to 0: $w = c - \frac{(a-p)\theta}{k^2}$, $g = \frac{p-a}{k}$. Substituting $p(w,g,\varphi)$ into w and g, we can get:

$$w_{RS}^* = \frac{(1+\lambda)(2ck^2 - 2a\theta - c\theta\lambda) + c\theta(2+\lambda)\varphi}{2k^2(1+\lambda) - \theta(2+\lambda)(1+\lambda-\varphi)};$$

$$g_{RS}^* = \frac{2k(c-a)(1+\lambda)}{2k^2(1+\lambda) - \theta(2+\lambda)(1+\lambda-\varphi)}.$$

Substitute w_{RS}^* and g_{RS}^* into $p(w,g,\varphi)$ to get the optimal retail price under the revenue sharing contract:

$$p_{RS}^* = \frac{2ck^2(1+\lambda) - a\theta(2+\lambda)(1+\lambda-\varphi)}{2k^2(1+\lambda) - \theta(2+\lambda)(1+\lambda-\varphi)}.$$

Substituting w_{RS}^*, g_{RS}^*, and p_{RS}^* into π_r, π_m, and π_{sc} respectively, the optimal profits of the manufacturer, retailer, and supply chain system under the revenue sharing contract are:

$$\pi_r^{RS} = \frac{2(a-c)^2 k^2 \theta(1+\lambda)^2[\lambda(1+\lambda) - (2+\lambda)\varphi]}{(2+\lambda)[-2k^2(1+\lambda) + \theta(2+\lambda)(1+\lambda-\varphi)]^2};$$

$$\pi_m^{RS} = \frac{2(a-c)^2 k^2 \theta(1+\lambda)^2(\varphi-1)}{[-2k^2(1+\lambda) + \theta(2+\lambda)(1+\lambda-\varphi)]^2};$$

$$\pi_{sc}^{RS} = \frac{2(a-c)^2 k^2 \theta(1+\lambda)^2(\lambda^2-2)}{(2+\lambda)[-2k^2(1+\lambda) + \theta(2+\lambda)(1+\lambda-\varphi)]^2}.$$

It can be seen that: $\pi_r^{RS} > V_r^*$, $\pi_m^{RS} > \pi_{m2}^*$, $\pi_{sc}^{RS} > \pi_{sc2}^*$. Compared with decision-making under decentralized decision-making, revenue sharing contract can improve the efficiency of the supply chain system, enabling manufacturers and retailers to achieve Pareto improvement at the same time, but it can only achieve partial coordination of the supply chain system, and cannot achieve complete coordination.

5. Data analysis

In order to better verify the conclusions and inferences of the previous propositions, here is a numerical example for comparison and analysis. Assume that the relevant parameters in this article are: $a = 5, \theta = 1, c = 2$.

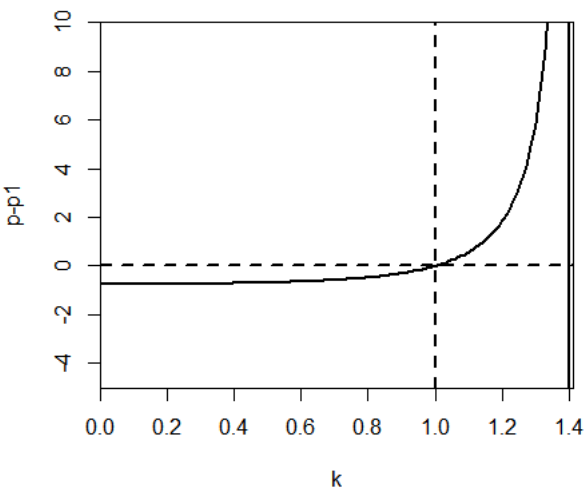

Figure 1: The impact of consumers' green awareness on retail prices without fair concerns

ISSN: 2692-7608 DOI: 10.6981/FEM.202012_1(12).0030

It can be seen from Figure 1 that changes in consumers' green awareness affect the relationship between retailer prices under decentralized decision-making when centralized decision-making and retailers have no fair concerns, when $0 < k < 1$, the optimal retail price under centralized decision-making is less than the optimal retail price under decentralized decision-making; when $k = 1$, the optimal retail price in both cases is equal; when $k > 1$,the optimal retail price under centralized decision-making is greater than the optimal retail price under decentralized decision-making. The optimal retail price under centralized decision-making is greater than the optimal retail price under decentralized decision-making. This further validates the related research results of proposition 1.

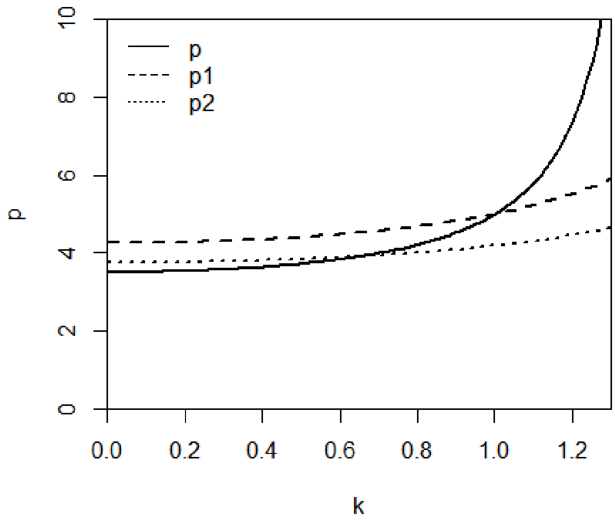

Figure 2: The impact of consumer green awareness on retail prices

It can be seen from Figure 2 that the retail price increases with the increase of consumers' green awareness, and the retail price of retailers without fair concerns is always higher than the retail price when retailers have fair concerns. This is because of the increase in green awareness. Driven the green market demand and increased investment in green emission reduction technologies, which in turn led to the increase in the wholesale and retail prices of products. At this time, retailers who are followers have to minimize losses in order to maximize their own profits, so fairness is concerned The greater the degree of retailers, the more conservative their decision-making, retail prices, like revenue, will not have a large increase. This further verifies the relevant research results of Corollary 1 in this paper.

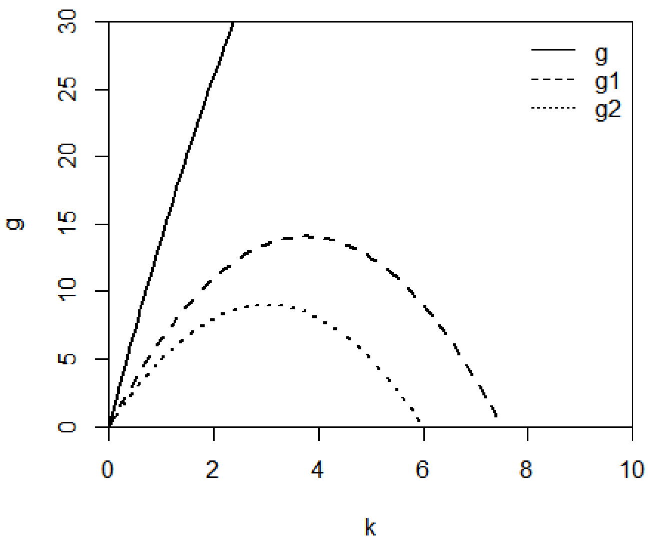

Figure 3: The impact of consumer green awareness on the level of green emission reduction

ISSN: 2692-7608 DOI: 10.6981/FEM.202012_1(12).0030

From the observation of Figure 3, it can be seen that the enhancement of consumers' green awareness can improve the green emission reduction level of manufacturers, but only under centralized decision-making, the emission reduction level can maintain a rapid development trend. Under the decentralized decision-making, both parties take the maximization of their own profits as the business goal. With the enhancement of consumers' green awareness, the level of emission reduction has shown a downward trend. The counter-effect brought by the platoon level is more obvious. This further verifies the related research results of Proposition 2 and Corollary 2.

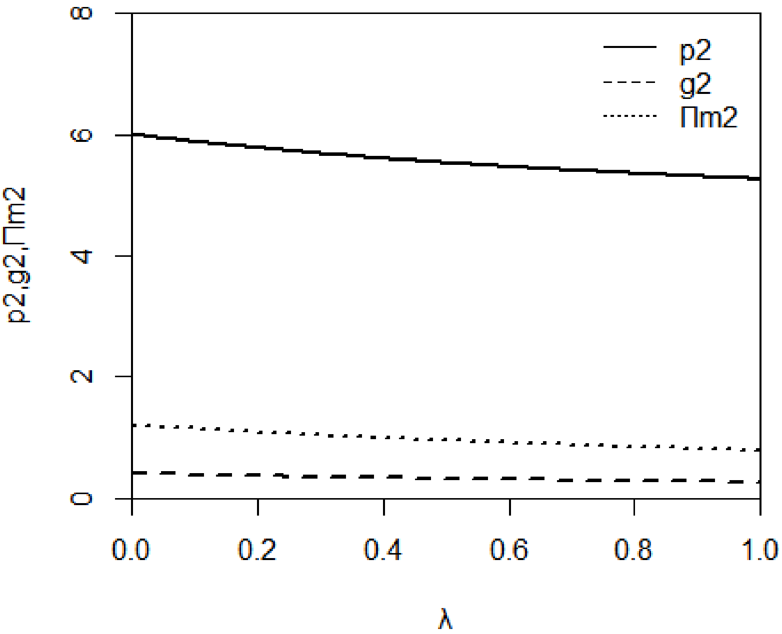

Figure 4: The impact of retailers' fair concerns on retail prices, green emission reduction levels and profits

From Figure 4, it can be seen that when retailers have fair concerns, the manufacturer's profit, retail price, and the manufacturer's green emission reduction level decrease with the increase in retailers' fairness concerns. Combining the previous numerical analysis, we know that green awareness The impact on emission reduction levels, optimal retail prices and fairness concern behaviors. At this time, I also know the harm of fairness concern behaviors to the operation of the supply chain system. Therefore, timely response measures should be taken to mitigate the effects of fairness concern behaviors on the overall revenue of the supply chain loss.

6. Conclusion

This paper uses green supply chain as the research background, uses Nash bargaining fairness utility function and game theory to compare the centralized decision-making model with the decentralized decision-making model of whether retailers have fair and concerned behaviors, and analyzes consumers' green awareness and green reduction. The impact of the level of emissions and fairness concerns on supply chain profits and green product pricing, and through revenue sharing contracts, the supply chain system is ultimately coordinated and optimized. The main conclusions are as follows:

(1) The green market service coefficient $\frac{k^2}{\theta}$ is positively correlated with consumers' green awareness, and negatively correlated with the manufacturer's emission reduction level coefficient, and the profit of retailers with fair concerns depends on the size of the green market service coefficient.

ISSN: 2692-7608 DOI: 10.6981/FEM.202012_1(12).0030

(2) With the increase of consumers' green awareness, although it seems that the demand for the green market is on the rise, at the same time the fairness concerns of retailers will also increase, and the green level of products has shown a downward trend.

(3) The profits of the manufacturer and the retailer under the fairness and neutrality of the retailer are higher than the profits of both parties under the fairness and concern behavior of the retailer. Therefore, manufacturers should take timely measures to alleviate retailers' fair concerns and avoid greater losses to the supply chain system and other members.

(4) The revenue sharing contract can improve the efficiency of the supply chain system, enabling manufacturers and retailers to achieve Pareto improvement at the same time, but it can only achieve partial coordination of the supply chain system, and cannot achieve a complete level of coordination.

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