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Research Article

Analysis of Supply Chain Optimization Method and Management Intelligent Decision under Green Economy

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As environmental issues become the focus of global attention, low-carbon economy based on the concept of low energy consumption, low pollution, and sustainable development is becoming the focus of global attention. This new trend brings new challenges and opportunities to supply chain management. In view of the current new trend, each node enterprise in the supply chain should have the dual compatibility of economy and environment. How to balance the profits of supply chain nodes is an important issue for traditional enterprises under the guarantee of environmental benefits and green supply chain management. This paper takes the green transformation of enterprises as the breakthrough point, combined with the comparison of three green supply chain models. Considering the different preferences of enterprises for environmentally friendly goals, a green supply chain model is constructed when manufacturers and retailers consider different goals. This paper discusses the impact of environmental preferences of manufacturers and retailers on the supply chain system. It is found that when the manufacturer's environmental preference is 1, the supply chain profit of the biobjective model is up to 1901. The results show that the model can achieve the dual optimization of the profit target and environmental friendly target and achieve the effect of green supply chain optimization.

1. Introduction

With the development of market economy, the supply chain system has gradually matured, and at the same time, new problems have arisen. The supply chain needs to pay more attention to the concept of low carbon and environmental protection in its development, and the optimization of the supply chain network of green economy has become an opportunity for enterprises to make rapid progress. In that optimization of green supply, more and more people begin to pay attention to the environmental factors of suppliers and manufacturers. People are also looking for suitable models in order to balance the relationship between them and weigh more environmental factors. Most of them put forward mathematical programming models for green supply chain structure. For example, Wu et al. [1] put forward an integer mixed model to solve the cost problem. The construction of mathematical model also has limitations in the actual supply chain, and the simulation results usu-

ally need to be corrected artificially. For the complexity of the problem, we can refer to the traditional accurate methods, software simulation, or heuristic algorithms proposed in reference [2]. The stochastic programming model proved by Xu and Nozick [3] is also significant. The model weighs the relationship between cost and environment. According to the actual situation, the same model can solve different problems, such as the same stochastic programming model. Soleimani et al. [4] considered using environmental risk value (CVaR) as an environmental risk evaluator and optimized the environmental impact caused by the supply chain path, and changing expectations in the supply chain in the secondary supply market mentioned in reference [5], fuzzy algorithm can be used to positively stimulate the demand of suppliers to improve the green degree of the supply chain network. Ahi and Searcy [6] add the customer factor of random variable in the supply chain and also found that the customer will lead to the environmental coordination of the supply chain. Reference [7] puts forward a value model that

can optimize risk to reflect the uncertainty of supply chain flow process. Literature [8] analyzes the main behavior of green supply chain management from 2006 to 2016 and expounds the practice of green supply chain management from a comprehensive perspective. According to Xu et al. [9], a large number of country supply chain approaches are categorized, based on 32 different stress scenarios. Luthra et al. [10] proposed that internal management and competitive green supply chain management are the key to achieve green supply chain management performance. In analyzing the indicators of enterprises, the benefits of green environment can also be realized, and the purpose of green economy can be achieved [11, 12]. References [13–15] take multiobjective analysis, supply chain structure analysis, the relationship between suppliers and manufacturers, and the environmental value of green supply chain as analysis factors to seek the optimal solution.

This paper will analyze and compare the multiobjective model with the basic model and single-objective model and explore the influence of the factors such as cost, price, and profit of manufacturers and retailers on the degree of environmental preference to determine the supply chain optimization method under the green economy.

2. Green Supply Chain and Its Basic Model

2.1. Green Supply Chain. In the process of supply chain and circulation, the products are transferred to upstream and downstream enterprises and customers and passed to consumers through a certain route [16]. Supply chain is a network structure built around suppliers, manufacturers, distributors, and retailers, and its theoretical basis has formed a systematic and rich one. If enterprises connected with supply are represented by nodes and links between enterprises are represented by line segments, in a word, the supply chain can realize the interaction between raw materials and consumers through activities such as planning, acquisition, storage, sales, and service and meet people's production and living needs [17].

In 1996, the American Manufacturing Research Association introduced the concept of environmental protection and environmental awareness in the supply chain. The concept of green supply chain is preliminarily put forward [18]. After years of development and application, many scholars have studied the green supply chain. It is considered that environmental protection should be fully considered in supply chain management, improve the utilization rate of supply chain resources and strengthen the energy-saving management of supply chain, integrate supply chain resources according to the green energy-saving mode, including a series of supply chain links such as suppliers, logistics and transportation, warehousing, product design, manufacturing, and consumption recovery, and further improve the environmental protection ability of supply chain. Green supply chain can effectively enhance the competitiveness of enterprises, realize the sustainable development and improvement of enterprise resources, and strengthen the scientific and normative supply operation of enterprises with green production and environmental protection as the biggest goal [19]. Green supply

chain management includes five key parts: green procurement, green design, green production, green logistics, and green recycling. This paper expounds the main contents of green supply chain in detail from the aspects of suppliers and manufacturers.

2.2. Basic Model of Green Supply Chain. Green supply chain model is composed of raw material acquisition, production, assembly, distribution, and sales of specific products.

It can be abstracted as a network structure composed of a series of node sets and edge sets. Let $G_i = [N_i, L_i]$ and I denote a supply chain N_i composed of a node set L_i and an edge set G_i, which denotes a supply chain network composed of all competing supply chains. Let S represent the set of all potential market chains. Let X and $\forall a$ represent the market chain and nonnegative product flow, respectively. The side flow is the sum of the flow of the market chain in which it participates, that is,

$$X = \sum \delta_{as} X_s, \forall a \in L. \tag{1}$$

Each edge has a certain capacity constraint, so that $u_a \geq 0$ represents the nonnegative capacity constraint on edge a, and the capacity of each edge is the upper limit of product flow on that edge. Thus, the following inequality constraint in formula (2) holds

$$0 \leq X_a \leq u_a, \forall a \in L. \tag{2}$$

The edge cost is related to the product flow through the edge that is shown in

$$C_a = C_a(X_a), \forall a \in L. \tag{3}$$

Generally speaking, one edge is allowed to participate in multiple market chains in the model:

$$C_{as}(X_a) = \frac{C_a(X_a)}{X_a}. \tag{4}$$

Let p_{ij} denote the retail price of product I in market J, which depends on market demand; set market demand d_{ij}, that is,

$$p_{ij} = p_{ij}(d_{ij}), \forall i, j. \tag{5}$$

3. Green Supply Chain Model Based on Multiobjective Optimization

3.1. Overview of Multiobjective Optimization Theory. Multiobjective optimization generally studies the optimization of multiple objective functions in a given region, also known as multiobjective programming. In many fields, such as economy, management, military affairs, science, and engineering design, it is often difficult for people to measure the implementation quality of the whole plan with one index. Therefore, it is often necessary to compare multiple indicators, even if there are contradictory and complex

relationships among multiple targets. As early as the end of the 19th century, some foreign scholars studied it, and French economist Pareto and mathematicians such as Neumann, Kuhn, and Tucker took the lead in exploring multiple target problems [20]. Experts can often form the following methodologies on multiobjective problems: first, the main objective method, linear weighting method, and ideal point method are taken as examples to simplify multiobjective into single-objective and double-objective solutions as much as possible; the second is the hierarchical sequence method of solving the optimal solution of the second important goal on the basis of the optimal set of the important goal every time by assigning the goal value; third, it is solved by simplex method, analytic hierarchy process combining qualitative and quantitative methods and other multiobjective decision-making methods [21–23]. By constructing a two-level green supply chain model composed of a manufacturer and a retailer, the model is simulated as Figure 1. In the green supply chain, there is a positive correlation between the manufacturer's greenness and the wholesale price; that is, with the increase of greenness, the wholesale price will often increase.

3.2. Manufacturer's Single-Objective Model considering Profit and Environmental Friendliness.

When the manufacturer considers the single objective of profit and environmental friendliness, the manufacturer takes the maximization of profit and environmental friendliness as the decision objective, and the retailer takes the maximization of its own profit as the decision objective. The optimization functions are formulas (6) and (7), respectively:

$$\text{Max } \pi_m(w, g) = (w - c_m)(a - bp + kg) - \frac{1}{2}zg^2, \quad (6)$$

$$\text{Max } \pi_r(p) = (p - w - c_r)(a - bp + kg). \quad (7)$$

Firstly, the wholesale price and greenness of products are defined by the manufacturers; secondly, retailers depend on the manufacturer's decision to set the price of products; finally, retailers sell their products to consumers to meet market demand. According to the above game order, the reverse induction method is used to solve the problem. For formula (7), the response function (8) of retailers is obtained by the first-order optimality condition:

$$p = \frac{a + kg + b(w + c_r)}{2b}. \quad (8)$$

Substituting formula (8) into formula (6), the Hessian matrix of π_m is calculated as

$$H = \begin{bmatrix} -b & \dfrac{k}{2} \\ \dfrac{k}{2} & -z \end{bmatrix}. \quad (9)$$

When the Hessian matrix satisfies $4bz - k^2 > 0$, there is a unique optimal solution for the manufacturer's profit func-
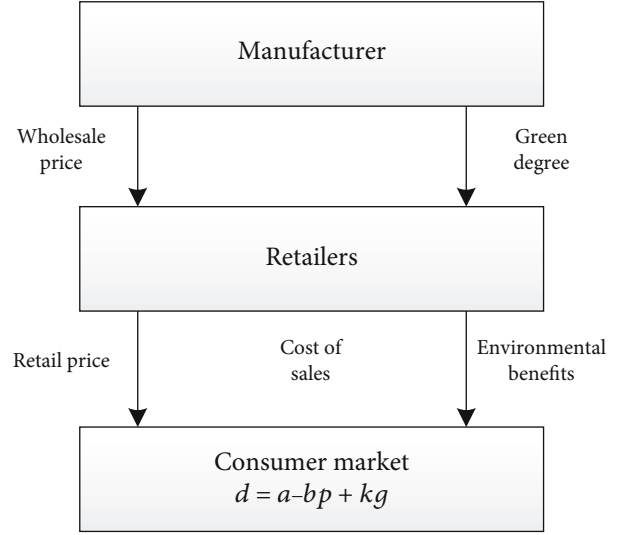

FIGURE 1: Supply chain model of manufacturer and retailer.

tion. Combined with the formula, the most suitable wholesale price (10) and product greenness (11) are solved:

$$W = \frac{2[a + b(c_m - c_r)]Z - c_m k^2}{4bz - k^2}, \quad (10)$$

$$g = \frac{[a - b(c_m + c_r)]}{4bz - k^2}. \quad (11)$$

Substituting formula (10) and formula (11) into formula (8), the retailer's optimal retail price is obtained as

$$p = \frac{[3a + b(c_m + c_r)z - (c_m + c_r)k^2]}{4bz - k^2 ee}. \quad (12)$$

By substituting formulas (10) and (11) into formulas (6) and (8), respectively, the optimal product demand is obtained, and the optimal profits of manufacturers and retailers are as follows:

$$d = \frac{[a - b(c_m + c_r)]bz}{4bz - k^2}, \quad (13)$$

$$\pi_m = \frac{[a - b(c_m + c_r)]^2 z}{2(4bz - k^2)}, \quad (14)$$

$$\pi_r = \frac{[a - b(c_m + c_r)]^2 bz^2}{2(4bz - k^2)^2}. \quad (15)$$

From formulas (13) and (14), the maximum profit of the whole supply chain can be obtained as follows:

$$\pi = \frac{[a - b(c_m + c_r)]^2 (6bz - k^2)z}{2(4bz - k^2)^2}. \quad (16)$$

3.3. Two-Objective Model considering Both Profit and Environmental Friendliness for Manufacturers and Retailers. In addition to manufacturers' consideration of environmental friendliness, retailers, as downstream enterprises in the supply chain, are more susceptible to the influence of consumers' green preferences. The green supervision of the government, the public opinion guidance of the media, and the social services of non-profit organizations all urge retailers to implement green supply chain management [24]. I think the most likely application scenario of the dual-objective model is the automobile supply chain, because the vigorous development of new energy vehicles at present well reflects the environmental friendliness and the double harvest of supply chain profits. When both manufacturers and retailers consider profit and environmental friendliness at the same time, both manufacturers and retailers take profit and environmental friendliness maximization as their decision objectives. In this paper, superscript *mr* is introduced to represent the decision under *MR* model. The manufacturer's multiobjective optimization function is

$$\text{Max } F_m^{mr} = (\pi_m^{mr}, f^{mr}). \tag{17}$$

Of which, $\pi_m^{mr} = (w - c_m)(a - bp + kg) - 1/2zg^2$ and $f^{mr} = (a - bp + kg)g$. The retailer's multiobjective optimization function is

$$\text{Max } F_r^{mr} = (\pi_r^{mr}, f^{mr}). \tag{18}$$

Of which, $\pi_r^{mr} = (p - w - c_r)(a - bp + kg)$ and $f^{mr} = (a - bp + kg)g$. The decision-making goal of manufacturers and retailers is to achieve the synergistic optimization of profit and environmental friendliness, which is solved by linear weighting method. According to the target weight coefficients λ_m and λ_r of manufacturer and retailer, the multiobjective linear weighting function U_m of manufacturer is constructed as follows:

$$U_m^{mr} = \pi_m + \lambda_m f^{mr}. \tag{19}$$

The multiobjective linear weighting function of retailer is constructed as follows:

$$U_r^{mr} = \pi_r + \lambda_r f^{mr}. \tag{20}$$

λ_m and λ_r reflect the importance of environmental friendliness objectives λ_m and λ_r, and the greater the importance, the environmental friendliness objectives the more important the mark is. Especially, when $\lambda_m = 0$ and $\lambda_r = 0$, the optimization goal of manufacturers and retailers degen-

erates into profit single target case. Formula (19) can be converted to

$$\text{Max } U_m^{mr}(w, g) = (w - c_m)(a - bp + kg) - \frac{1}{2}zg^2. \tag{21}$$

Equation (20) is converted to

$$\text{Max } U_r^{mr}(p) = (p - w - c_r)(a - bp + kg). \tag{22}$$

The game sequence of the model is as follows: firstly, the manufacturer determines the wholesale price and greenness of products with the goal of optimizing profit and environmental friendliness; secondly, after observing the manufacturer's decision, retailers optimize the retail price of products with the goal of profit and environmental friendliness. In this paper, we use the inverse induction method to find the first derivative of P for formula (22) and make the first derivative equal to zero. We can see that the reaction function of retail price is

$$P^{mr} = \frac{a + kg + b(w + c_r) - \lambda_r bg}{2b}. \tag{23}$$

Substituting formula (23) into formula (21), the Hessian matrix of U_m is calculated as

$$H = \begin{bmatrix} -b & \dfrac{k - \lambda_m b + \lambda_r b}{2} \\ \dfrac{k - \lambda_m b + \lambda_r b}{2} & \lambda_m(k + \lambda_r b) - z \end{bmatrix}. \tag{24}$$

When $4bz - [(\lambda_m + \lambda_r)b + k]^2 > 0$ satisfied, Hessian matrix is negatively definite, and formula (24) has a unique optimal solution. On this basis, the first-order partial derivatives of W and G for U_m are obtained and made equal to zero, and the optimal wholesale price and product greenness of manufacturers and retailers considering economic profit and environmental friendliness at the same time are as follows:

$$w^{mr} = \frac{2[a + b(c_m - c_r)] - \lambda_r bc_m[((\lambda_m + \lambda_r)b + 2k)]}{4bz - [(\lambda_m + \lambda_r)b + k]^2}, \tag{25}$$

$$g^{mr} = \frac{[((\lambda_m + \lambda_r)b + k)][a - b(c_m + c_r)]}{4bz - [(\lambda_m + \lambda_r)b + k]^2}. \tag{26}$$

Formula (25) and formula (26) are substituted into the formula (23), and the optimal retail price of the retailer is obtained as follows:

$$p^{mr} = \frac{[3a + b(c_m + c_r)]z - (c_m + c_r)k - (\lambda_m + \lambda_r)[(\lambda_m + \lambda_r)ab + ak + b(c_m + c_r)k]}{4bz - [(\lambda_m + \lambda_r)b + k]^2}. \tag{27}$$

Parameter name	Parameter content	Weight coefficient
Demand function	$d^m = 200 - 2p + g$	1
R&D input cost	$I^m = 3g^2$	0.8
Manufacturer's production cost	$c_m = 10$	0.7
Retailer cost of sales	$c_r = 6, 0 \leq \lambda_m \leq 1.09$	0.9

By substituting formulas (25) and (27) into the corresponding equations, the optimal product demand is obtained as follows:

$$d^{mr} = \frac{[a - b(c_m + c_r)]bz}{4bz - [(\lambda_m + \lambda_r)b + k]^2}. \tag{28}$$

The optimal profit of the whole supply chain is

$$\pi^{mr} = \frac{\left\{6bz - \left[3(\lambda_m + \lambda_r)^2 b^2 + 4(\lambda_m + \lambda_r)bk + k\right]^2\right\}[a - b(c_m + c_r)]^2 z}{2\left\{4bz - [(\lambda_m + \lambda_r)b + k]^2\right\}^2}. \tag{29}$$

4. Experimental Simulation Analysis

4.1. Data Preparation. In order to more intuitively verify the above conclusions and theorems, but also in order to better reflect the impact of supply chain considering different objectives on its decision-making results, this section uses Maple software to do numerical simulation analysis to explore the changes of environmental preference in different models. Set the relevant parameters of the supply chain as shown in Table 1; it mainly simulates the ideal environment, that is, the balance between supply and demand. Reducing the weight will affect the cost of sales coefficient of retailers, resulting in an increase in the weight of cost of sales.

The above values are substituted into three models, namely, basic model, single-objective model, and double-objective model, and the following rules are obtained.

Under three different conditions, the greenness of products will increase with the improvement of manufacturers' environmental preference, and it will always be $g^m > g^m(\mu)$ as shown in Figure 2. Although the single-objective model does not consider the green degree, the single-objective model considers the manufacturer's profit. When the manufacturer's environmental preference degree increases, it will inevitably lead to the increase of production cost and indirectly improve the product green degree:

As shown in Figure 3, by analyzing the changing trend of enterprise environmental friendliness under the three models, it is found that in three different cases, environmental friendliness will increase with the improvement of manufacturers' environmental preference; that is, environmental

friendliness is the largest in the two-objective model and the smallest in the basic model. Under this contract, the environmental friendliness goal of enterprises has been optimized and improved to some extent, but it has not achieved the perfect coordination towards centralization.

As shown in Figure 4, analyze the wholesale of products under the two models before and after coordination the trend of price change shows that the wholesale price of products always decreases with the increase of manufacturers' environmental preference, and the wholesale price of products in the double-objective model will always be less than that in the single-objective model. It can be seen that the manufacturer in a new sum can share the retailer's profits, and manufacturers can make profits by lowering the wholesale price, so as to promote the coordination of the whole supply chain decision-making and realize the optimization and improvement of the two objectives of profit and environmental friendliness.

As shown in Figure 5, the retail sales of products under the single-objective model and the double-objective model are analyzed. The change trend of price shows that the retail price of the products will first increase and then decrease with the increase of manufacturers' environmental preference. In addition, the increase in retail prices is relatively large in the overall trend; the decline is relatively large; that is, after manufacturers consider the goal of environmental friendliness, retailers follow the manufacturer's ring. With the improvement of environmental preference, more consumers are attracted by reducing retail prices and adopting the strategy of small profits but quick turnover market demand, so as to promote the Pareto improvement of the overall profit and environmental friendliness of the supply chain.

As shown in Figure 6, by analyzing the change trend of manufacturers' profits under the three models, it is found that retailers' profits will always increase with the increase of manufacturers' environmental preference, and retailers' profits will be optimized and improved after constant coordination. Therefore, although manufacturers share part of their own profits to retailers, manufacturers can still weaken the double marginal effect among supply chain members by adopting the strategy of small profits but quick turnover with lower product purchase price and realize the optimization and improvement of their own profits.

As shown in Figure 7, the change trend of total profit of supply chain under three models is analyzed. It is found that under the basic model, the profit of supply chain will always decrease with the increase of manufacturer's environmental preference, while under the single-objective model, the profit of supply chain will always increase first and then decrease slowly with the increase of manufacturer's environmental preference. When the degree of manufacturer's environmental preference is small, the degree of manufacturer's environmental preference cannot increase indefinitely under the dual model, and the high green input cost will inhibit the green transformation and upgrading of supply chain to a certain extent. Obviously, when the goal is to maximize the overall green benefit of the supply chain, the optimal decision-making of the supply chain fails to maximize the
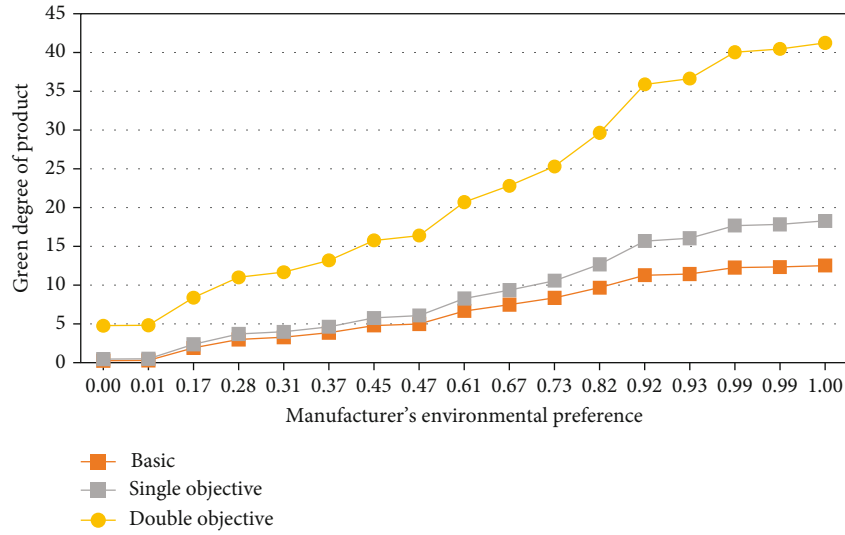
FIGURE 2: Change curve of product greenness before and after coordination.
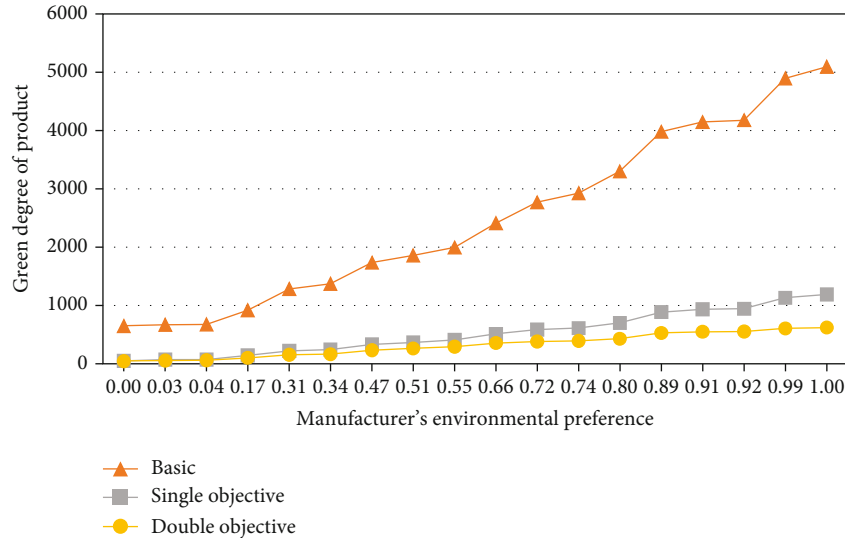

FIGURE 3: Change curve of environmental friendliness before and after coordination.

profit goal, which is because the supply chain will sacrifice economic profit and increase green R&D investment after considering the environmental friendliness goal, which will better meet its own expectation for multiobjective benefit. On the other hand, the total profit of the supply chain under the dual-objective model will always be higher than that of the single-objective model. It is concluded that the dual-objective model can achieve the dual optimization of profit goal and environmental friendliness goal and make it further achieve the desired effect.

5. Conclusion

When the current environment continues to deteriorate and resources are increasingly scarce, green supply chain has gradually aroused widespread concern, and improving the environmental friendliness in the process of product pro-

duction and circulation has become a hot issue of universal concern all over the world. On the one hand, enterprises attach great importance to their own economic profits. On the other hand, the green transformation of enterprises is a realistic demand facing today's society. Therefore, on the premise of maintaining the profit distribution between the upper and lower members of the supply chain, it has become an important issue in the field of supply chain management to achieve the environmental goal of green supply chain and promote the sustainable management of the whole channel. Based on the comparison of multiobjective, single-objective, and basic model optimization, this paper focuses on the different value cognition background of enterprises to environmental objectives, constructs a green supply chain model when manufacturers and retailers consider different objectives, discusses the influence of manufacturers' environmental preference on supply chain system, and designs an
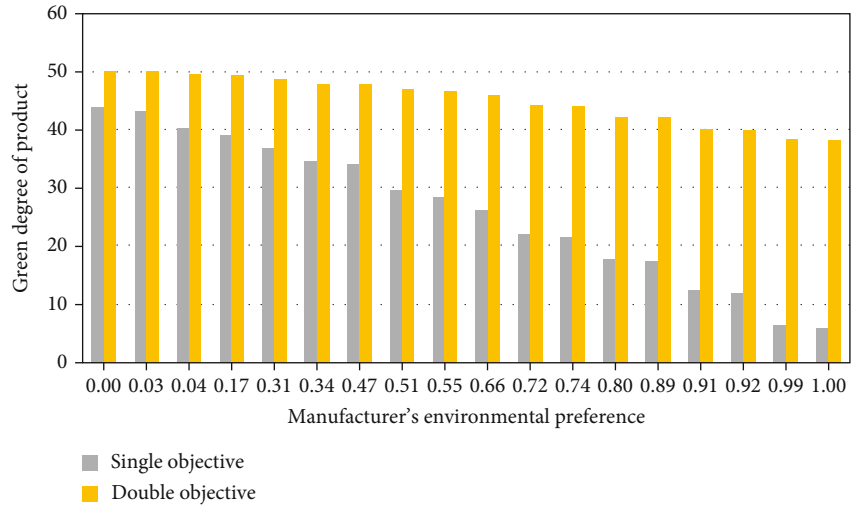
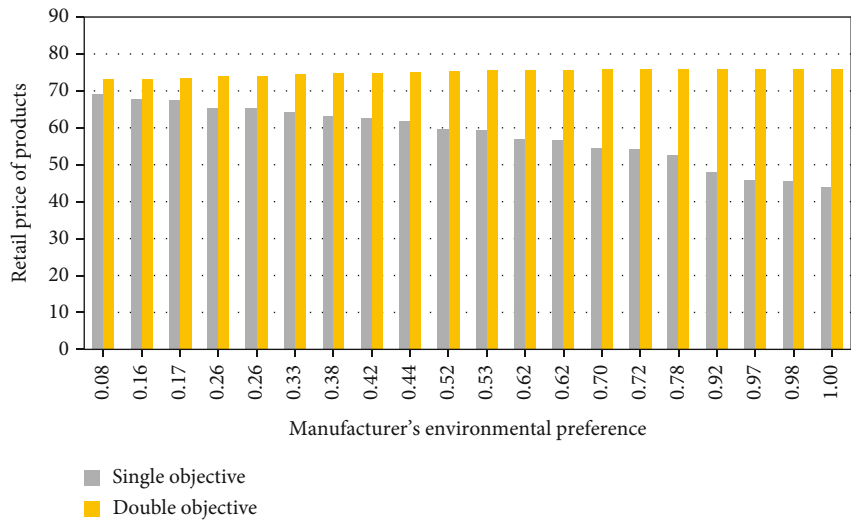FIGURE 4: Changes of wholesale price before and after coordination.

FIGURE 5: Changes of retail price of products before and after coordination.

effective optimization model. The main conclusions are as follows:

The basic supply chain optimization model is constructed. The supply chain model is based on the single-objective model of manufacturer only considering profit and environment and the dual-objective model of manufacturer and retailer considering profit and environment at the same time. The optimal decision of the three models is compared and analyzed, and the influence of environmental preference degree of manufacturer and retailer on supply chain is studied. The results show the following:

(1) Considering the goal of environmental friendliness by manufacturers and retailers can improve the green degree of products, the environmental friendliness of enterprises, and the total demand of products. With the improvement of environmental preference of manufacturers and retailers, the greenness and environmental friendliness of products are increasing; that is, the greenness, environmental friendliness, and product demand are the largest when manufacturers and retailers consider environmental friendliness at the same time and the smallest in the basic supply chain model. Obviously, considering the goal of environmental friendliness will significantly improve the environmental protection level of enterprises and occupy an advantage in the green consumption market

(2) When manufacturers consider profit and environmental friendliness at the same time, the higher the degree of environmental preference of manufacturers, the higher the retailer's profit and the lower the manufacturer's profit. When both manufacturers and retailers consider profit and environment-friendly objectives, manufacturers have lower environmental preference and retailers have higher environmental preference, while manufacturers have higher environmental preference and retailers properly consider environment-friendly objectives, which
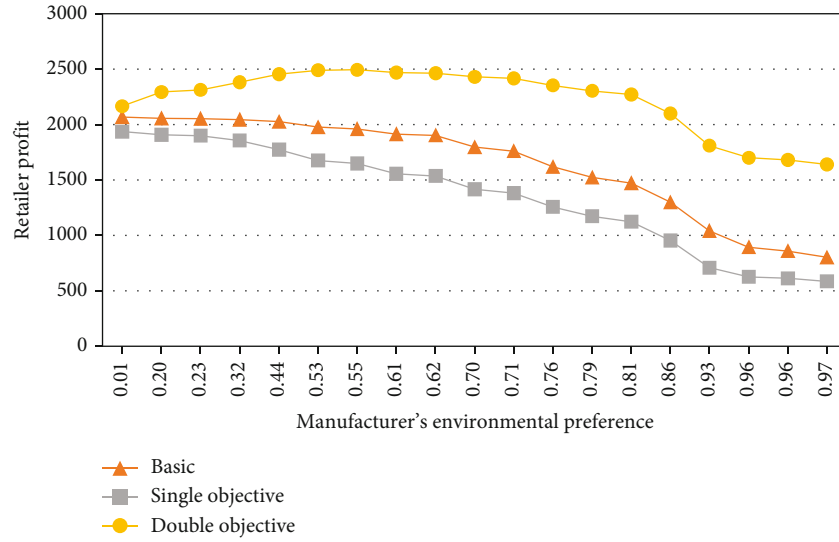
FIGURE 6: Curves of manufacturers' profits before and after coordination of three models.
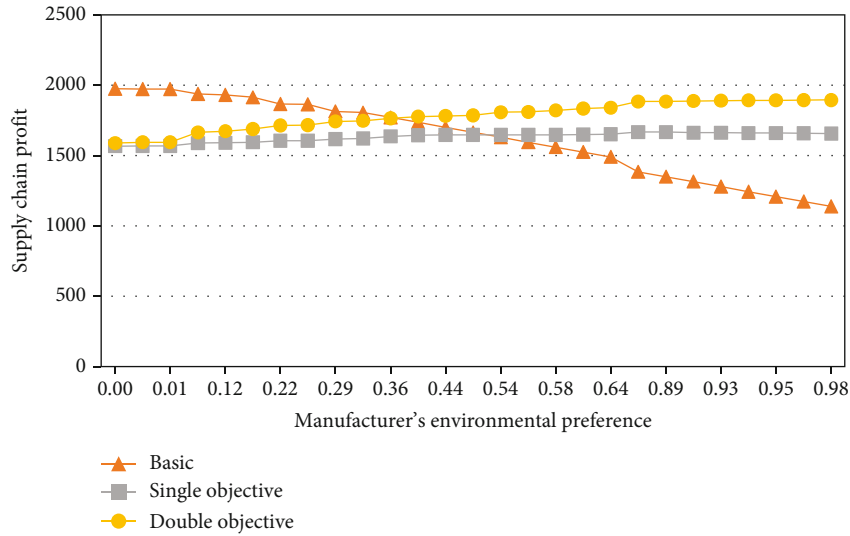

FIGURE 7: Change curves of supply chain profit before and after coordination of three models.

is beneficial to retailers' profits. The overall profit of supply chain increases at first and then decreases with the improvement of environmental preference of manufacturers and retailers. That is to say, under the premise that consumers have green preference, manufacturers and retailers properly consider the goal of environmental friendliness, which can not only improve the green degree of products but also promote the growth of supply chain profits and achieve a win-win situation between enterprise profits and ecological environment. Blind investment in green environmental protection will lead to serious damage to corporate profits

(3) Wholesale and retail prices increase first and then decrease with the increase of environmental preference of manufacturers or retailers, and the prices reach the highest when both manufacturers and retailers

consider profit and environmental friendliness at the same time. At the initial stage when manufacturers and retailers consider environmental objectives, the whole supply chain can adopt high price strategy and maximize its own benefits by increasing the income per unit product. However, when the degree of environmental preference is high, the cost of green R&D is high, and the whole supply chain adopts the price reduction strategy to promote the increase of product demand, thus realizing the overall optimization situation of "small profits but quick turnover"

Data Availability

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

Conflicts of Interest

The authors declared that they have no conflicts of interest regarding this work.

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