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Integration and Optimization of E-Commerce Industry Cluster and Green Supply Chain Network under the Background of Rural Revitalization

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Abstract: Supply chain optimization is a process of continuous improvement, because the actual supply chain will adjust with the change of social reality. This paper proposes a supply chain integration and optimization algorithm SCIO based on multi tree. Based on the concept of GHG, combined with the background of rural revitalization, this paper uses SCIO to analyze the supply chain selection strategy and the degree of temporary cooperation, the degree of consumers' preference for network supply chain, and the price sensitivity coefficient. The research shows that the minimum average gap of SCIO is 1.41%, the maximum average gap is 3.75%, the average gap is less than 5%, and the average gap of each case is 3.25%. In terms of solution time, the minimum time is 12.1s, the maximum time is 48S, the average time of small-scale case is 12.7s, and the average time of large-scale case is 31.5s. Compared with the classical supply chain game model, the comprehensive performance of this model is improved by more than 32%. When the degree of temporary cooperation is less than a certain threshold, the manufacturer should set a higher wholesale price. When the degree of temporary cooperation is greater than a certain threshold, the manufacturer should set a higher wholesale price.

1. Introduction

With the rise of e-commerce industry, the rural commodity trading mode is gradually transferred to the online mode. However, the current e-commerce industry supply chain is facing unprecedented impact, such as ecological impact, widening economic gap and other factors leading to low integration of green supply chain. The related research is mainly on the algorithm of the supply chain itself, and the impact of the mainstream G614 virus on the e-commerce industry after the ncov-2019 mutation is still under study.

Jiang WK reviewed more than 1000 published researches in the field of sustainable supply chain management, but most of the influential researches are conceptual models and case studies, while the number of papers on optimizing complex sustainable supply chain with effective algorithms is still small [1]. Tsay A summarized 87 papers in the field of supply chain network design, covering the mathematical model considering economic, environmental and social indicators [2]. Huang W found that most studies only focus on carbon emission and cost indicators of e-commerce industry, while other sustainability indicators rarely appear in the study of supply chain optimization [3]. More importantly, there is still a certain distance between the indicators studied by Modak NM and the indicators actually concerned by enterprises and society [4]. More representative research, such as Chen K Y, introduced the triple bottom line of sustainable development into supplier evaluation and selection decisions [5].

Compared with the research of economic side related indicators, the number of literature related to environmental and social side indicators is still relatively small. Hua G studied how to balance the cost of supply chain and carbon emissions of e-commerce industry [6]. He P studied the supply price risk of external capability of Supply Chain Based on multi-layer logistics service [7]. Rodriguez B summarized and analyzed the optimization algorithms introduced in 220 papers, and proposed five future research directions in this field, one of which is to explore efficient optimization algorithms to solve complex and accurate sustainable supply chain models [8]. Hsiao L sells its products through its own network supply chain (network direct selling dual supply chain mode) [9]. Many scholars at home and abroad think that it is necessary for manufacturers to introduce network supply chain. For example, Zhao LX found that manufacturers' dual supply chain structure can attract more customers, so manufacturers can always benefit from the dual supply chain structure [10]. The above research has carried on the different angle research to the e-commerce industry green supply chain network, but at present there is no systematic research and integrated optimization to the e-commerce supply chain, so there is a great possibility of different problems in the actual operation process.

This paper describes the current situation of the development of e-commerce industry supply chain and various problems in reality. Most of the previous studies only consider a single index of the supply chain, it is difficult to integrate the supply chain with time. Based on the concept of GHG and the background of rural revitalization, this paper proposes a supply chain integration and optimization model (SCIO), which is used to analyze the selection strategy of supply chain and the degree of temporary cooperation, the degree of consumers' preference for network supply chain, and the price sensitivity coefficient.

2. Supply Chain Status and Integrated Optimization Model

2.1. Current Supply Chain of Large e-Commerce Industry

As the traditional supply chain network design problem has been proved to be NP hard, even if only a single economic index is considered, it is difficult for large-scale examples to increase the complexity of the model when the environmental and social indexes are acceptable, thus further improving the difficulty of solution [11]. Therefore, it is a severe challenge to solve large-scale

examples efficiently. On the other hand, manufacturers sell their products through the self support mode of retailers such as JD Mall, dangdang.com and suning.com (i.e. network distribution dual supply chain mode) [12]. Then, for manufacturers, what kind of dual supply chain structure to achieve their own profit maximization is an important problem [13]. Dual supply chain supply chain has always been the focus of academia. On the basis of previous research and field research, green supply chain GHG index is incorporated into the sustainable supply chain model. SCIO (supply chain integration and optimization) index, commodity operation (PRTR) data and enterprise environmental performance data are used to analyze the carbon emission, waste gas emission, waste water emission and solid waste emission of e-commerce industry on the environmental side. In this paper, a mixed integer linear model of multi-level, multi product type and multi energy mode is proposed, which combines the number of local jobs created by manufacturers and distributors and the traditional economic side indicators as the triple bottom line indicators of sustainable supply chain four kinds of integer discrete decision variables, and each index was de dimensioned [14].

When the retailer does not carry out local supply chain integration, the online direct retail price of the dual supply chain manufacturer is lower than that of the two cases where the retailer carries out supply chain integration. This is because at this time, the manufacturer can not obtain the ad promotion temporary cooperation effect in the latter two cases, and can only attract consumers' online purchase through lower direct selling prices [15]. Secondly, when a dual supply chain manufacturer is willing to cooperate with its retailer in the supply chain to stimulate the retailer to increase investment in the supply chain optimization, this disguised cost increase for the manufacturer makes him ask the retailer for a higher wholesale price of goods, thus further pushing up the retail prices of both sides of the supply chain in the online supply chain and offline supply chain [16]. Thirdly, when the retailer carries out supply chain optimization and the manufacturer of dual supply chain does not participate in the cooperative supply chain, the wholesale price charged by the manufacturer to the retailer is the lowest. Because the retailer's supply chain optimization has spillover effect on the manufacturer's online supply chain sales, it can be considered as a kind of compensation given by the manufacturer to the retailer through low wholesale price [17]. We can get the following management enlightenment: when a retailer carries out local supply chain optimization, if he wants to cooperate with (not with) a dual supply chain manufacturer to share the advertising cost, he needs to pay more than when he does not carry out supply chain optimization [18].

2.2. E-Commerce Industry Carbon Emission Evaluation Method and Commodity Pricing Advertising Decision

The carbon emission of e-commerce industry generated by manufacturers in the process of producing products mainly comes from energy consumption. The carbon emission of e-commerce industry generated in the process of transportation mainly comes from the energy consumption of means of transportation. The carbon emission of e-commerce industry generated by each unit of energy consumption is the product of the GHG (green house gas) emission factor of the energy and the unit energy consumption [19]. It can be calculated according to the product sum of operation time and emission rate of each exhaust outlet in the factory during production [20]. The waste

water discharged by the manufacturer in the process of producing products is the total waste water discharged by each waste water outlet of the factory in the process of producing products. It can be calculated according to the product summation of the running time and discharge rate of each wastewater outlet in the factory during production [21]. The solid waste emissions generated by solid waste emission manufacturers in the production process include general industrial solid waste emissions and hazardous waste emissions [22]. Number of jobs the total number of jobs created by a manufacturer or distributor in the place where it is located. Number of enterprise accidents the total number of accidents occurred by the manufacturer or distributor since the establishment of the factory [23]. The weight of the number of jobs, the number of enterprise accidents and the number of over standard rectification in the social side is determined according to the SCIO evaluation guide of the green supply chain SCIO index [24].

For the commodity pricing and advertising decision-making when both sides of the supply chain cooperate in the supply chain, consider that an upstream manufacturer sells a commodity to the end consumer through both offline and online supply chains. The offline traditional supply chain adopts the mode of cooperation with a retailer for sales, while the online supply chain adopts the online direct selling mode [25]. When manufacturers are willing to cooperate with retailers in supply chain planning, in order to optimize their profits, manufacturers first release their online direct selling price PD, wholesale price W and the cost sharing ratio t of participating retailers in the supply chain. On this basis, retailers decide their retail pricing PR and supply chain integration effort a.

In order to bring sustainable development into the decision-making of manufacturing supply chain and balance its triple bottom line effectively by using enterprise information resources, based on SCIO index, this paper proposes a network model of manufacturing sustainable supply chain, which coordinates economic benefits, environmental pollution and social responsibility as a whole and promotes the balanced development of them, and studies an efficient evolutionary algorithm. Firstly, based on the eight indicators of economic, environmental and social sides, a mixed integer linear model of multi-level, multi product type and multi energy mode is constructed, and a method of standardizing and integrating multiple optimization objectives is proposed. Secondly, the multi tree structure representation of supply chain network is designed. Based on this, an adaptive multi tree forest evolutionary algorithm is proposed, and the solution accuracy of the algorithm is significantly improved by adjusting the adaptive parameters. Furthermore, as the goods are more suitable for online sales, the degree of substitution between manufacturers' two supply chains is higher, or the spillover effect of retailer advertising on manufacturers' online direct selling supply chain sales is stronger, the gap of retailer advertising effort between the two situations will become larger and larger. This is because in the face of the above changes, the dual supply chain manufacturers who participate in the cooperative supply chain will provide a greater share of the supply chain cost for their retailers, which will make the retailers work harder on the optimization of the supply chain, resulting in the increasing gap of the retailer's advertising effort compared with the situation that the two sides do not cooperate in the supply chain.

2.3. Green Supply Chain Integration and Optimization Model

In the aspect of mathematical modeling, most researches focus on the improvement of single process, such as facility location or green manufacturing. It can be expressed as the basis of supply chain optimization

$$E_0 = E_w + E_{nb} + E_t - \mathrm{Ic} \tag{1}$$

$$E = \frac{\sum_{j=1}^{k}\sum_{h=1}^{k}\sum_{t=1}^{n_j}\sum_{r=1}^{n_h}\left|y_{ij} - y_{hr}\right|}{2n^2 u} \tag{2}$$

In this paper, the research on cooperative supply chain decision-making of product pricing in single supply chain is reviewed in detail. With the increasing number of manufacturers adopting dual supply chain operation, the research on cooperative supply chain in the supply chain system of dual supply chain manufacturers has attracted more and more attention in recent years. One kind of research only focuses on the cooperative supply chain decision-making of both sides of the supply chain, but does not involve the pricing decision-making of goods:

$$\sum\nolimits_T = diag(\max(\sigma_i - \upsilon, 0)) \tag{3}$$

$$\mathrm{E_j} = \frac{\frac{1}{2u_j}\sum_{i=1}^{n_j}\sum_{r=1}^{n_j}\left|y_{ji} - y_{jr}\right|}{n_j^2} \tag{4}$$

$$Ew = \sum_{j=1}^{k} G_{jj} p_j s_j \tag{5}$$

Assuming that the retailer's local advertising expenditure is entirely borne by the manufacturer, when the manufacturer chooses to set up an online direct supply chain to compete with its retailer, the study finds that the new online supply chain has a significant impact on the manufacturer's advertising support policy, and the way and degree of the impact vary with the product's online sales adaptability:

$$\mathrm{E}_{jh} = \frac{\sum_{Z=1}^{h_j}\sum_{r=1}^{n_h}\left|y_{ji} - y_{hr}\right|}{n_j n_h (u_j + u_h)} \tag{6}$$

$$E_{nb} = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j) D_{jh} \tag{7}$$

It is related to the service cost coefficient of traditional retailers, that is, when the service cost coefficient of traditional retailers is small, the manufacturer should set a higher wholesale price in the dual supply chain mode of network distribution. When the service cost coefficient of traditional retailers is greater than a certain threshold, the manufacturer should set a higher wholesale price under the network direct selling dual supply chain mode

$$\mathrm{E}_t = \sum_{j=2}^{k}\sum_{h=1}^{j-1} G_{jh}(p_j s_h + p_h s_j) D_{jh}(1 - D_{jh}) \tag{8}$$

Almost all literatures assume that the proportion of local advertising expenditure given to

retailers by manufacturers in cooperative supply chain planning is exogenous, rather than as a decision variable of supply chain game. These assumptions for the purpose of simplifying the analysis are not consistent with the reality of cooperative supply chain operation in most supply chain systems

$$D_{jh} = \frac{d_{jh} - P_{jh}}{d_{jh} + P_{jh}} \tag{9}$$

$$d_{jh} = \int_0^{\infty} dF_j(y) \int_0^{y} (y - x) dF_h(x) \tag{10}$$

$$d_{jh} = \int_0^{\infty} dF_h(y) \int_0^{y} (y - x) dF_j(y) \tag{11}$$

In fact, according to the characteristics of different commodities, such as demand elasticity coefficient, production cost, online sales compatibility and other factors, manufacturers generally make decisions to provide different wholesale prices and participation proportion of cooperative supply chain to offline retailers for the purpose of optimizing their own operation performance. This can be seen in the cooperative supply chain agreements issued by some manufacturers in the real business environment. At the same time, all the researches on the commodity pricing and cooperative supply chain in the single traditional supply chain also take the wholesale price of commodities and the share ratio of cooperative supply chain as the decision variables of manufacturers, rather than exogenous given:

$$f(x) = \frac{1}{Nh} \sum_{i=1}^{N} k(\frac{X_i - x}{h}) \tag{12}$$

$$k(x) = \frac{1}{\sqrt{2\pi}} \exp(-\frac{x^2}{2}) \tag{13}$$

In view of this, this paper takes the dual supply chain manufacturer supply chain system as the research object, and considers the joint influence of commodity pricing and retailer's local advertising in the dual supply chain on the supply chain demand. In order to make the pricing and advertising strategy of the dual supply chain more realistic, the manufacturer's wholesale price and the retailer's participation in the supply chain cooperation are considered to optimize their own revenue, they will make decisions on the proportion of advertising sharing in the supply chain, and build game decision models respectively from three different situations: no supply chain cost on both sides of the supply chain, retailers bear their own local supply chain cost, and supply chain cooperation on both sides of the supply chain:

$$h_t = \tanh(w_c x_t + u_c(r_t \Theta h_{t-1}) + b_c) \tag{14}$$

$$h_t = z_t \Theta h_{t-1} + (1 - z_t) \Theta h_t \tag{15}$$

When manufacturing enterprises make supply chain decisions, they should consider the economic benefits and take the environmental and social indicators into consideration. At the same time, manufacturing enterprises need to establish a sense of sustainable supply chain

decision-making, strengthen their own sustainable supply chain management mode, and increase the number of suppliers, manufacturers, distributors and customers in the manufacturing sustainable supply chain the cooperation of sustainable development strategy between enterprises makes the whole sustainable development of manufacturing supply chain enter a virtuous circle

$$P = \sigma t = \frac{\sqrt{\frac{1}{n}\sum_{i=1}^{n}(FI_{it} - FI_{it})^2}}{FI_{it}} \tag{16}$$

$$u_{(j|i)} = w_{ij} A_i \tag{17}$$

$$s_j = \sum_i c_{ij} u_{(j|i)} \tag{18}$$

Under the two dual supply chain models, the profits of manufacturers increase with the increase in the level of service provided by traditional retailers. Therefore, manufacturers should encourage traditional retailers to provide better service levels, so there are:

$$\ln(\frac{PI_{it}}{PI_{it}-1}) = \alpha + \beta \ln PI_{it} - 1 + v_i + \Im_t \tag{19}$$

For sellers, the exchange of data and information can make sellers more accurately grasp the market demand information, make accurate replenishment, and avoid the loss caused by hoarding in response to the sudden demand of the market. Considering two competing third-party issuers, the retailer's profit function is as follows:

$$r = \frac{\alpha}{1-\beta} \tag{20}$$

$$\theta = -\frac{1}{T}\ln(1+\beta) \tag{21}$$

For the third-party publishing enterprises, the transportation business can optimize the asset storage and responsibility arrangement and reduce the transportation cost by sharing the shipping plan information in the early stage. Therefore, the profit functions of E and R are as follows:

$$\ln(\frac{FI_{it}}{FI_{it}-1}) = \alpha + \beta \ln FI_{it} - 1 + \varphi X_{it} - 1 + v_i + \tau_t \tag{22}$$

$$k_{t1}[i] = \sum_j \cos(w_i^1, w_j^2) \tag{23}$$

This paper analyzes and compares the commodity pricing and supply chain cost strategies in different situations, in order to provide a reference for the supply chain enterprises with a large number of dual supply chain operations to make reasonable commodity pricing and advertising decisions.

3. Integration and Optimization Design of e-Commerce Industry Cluster and Green Supply

Chain Network

3.1. Model

Based on the concept of GHG and the background of rural revitalization, this paper proposes a supply chain integration and optimization model (SCIO), which is used to analyze the selection strategy of supply chain and the degree of temporary cooperation, the degree of consumers' preference for network supply chain, and the price sensitivity coefficient.

3.2. Methods and Basic Conditions of Supply Chain

According to the characteristics of the sustainable supply chain problem, the quantity decision depends on the location decision, and only the selected manufacturer can produce and transport. Therefore, the location decision can be regarded as the primary decision-making objective, and the quantity decision can be determined only after the location decision. Therefore, a more efficient search method is to construct the first level solution space for binary discrete variables, and add a second level solution space for integer discrete decision variables on each node of the solution space.

Based on the above considerations, this paper proposes a supply chain integration and optimization algorithm SCIO based on multi tree. SCIO algorithm uses a multi tree to describe the nodes in the first level solution space, which is a decision result of location problem. The location decision of each level in the supply chain is mapped to the node selection of each level in the multi tree, and the supply relationship between each level is mapped to the weight of each node in the multi tree. The simplex method is used to search the optimal nodes in the second level solution space, that is, the value of integer discrete decision variables. Since the simplex method is less difficult to solve continuous variables than discrete variables, in order to further improve the efficiency of the algorithm, the integer discrete variables in the model are relaxed to continuous variables. Based on the above design, the algorithm initially constructs a solution forest based on multi tree to search multiple nodes in the first layer solution space at the same time. Then the initial solution forest is iterated to search the optimal solution in the first level solution space. In addition, a variety of adaptive mechanisms are designed to dynamically change the probability and location of fixed-point pruning and random node replacement, so as to maintain the diversity of solution forest and overcome the premature phenomenon of solution forest. Cost the purchasing cost of the supplier is provided by the supplier, the production cost of the manufacturer in the production process is provided by the manufacturer, the factory building and closing costs of the manufacturer or distributor are estimated by the manufacturer or distributor combined with the scale and location, and the cost of the supplier, manufacturer and distributor in the transportation process is calculated based on the historical transportation cost.

For the characteristics of each link of the supply chain, the raw materials purchased from the suppliers need to be transported to the corresponding manufacturers. After the manufacturers produce the products, the products are transported to the corresponding distributors, and then the distributors transport the goods to the customers according to the order demand. The indicators

involved in the network design include the economic side, the environmental side and the social side: the economic side indicators include raw material procurement costs, product production costs, raw materials and product transportation costs, as well as the fixed operating costs of manufacturers and distributors. The environmental side indicators include the carbon emissions from the e-commerce industry generated by the transportation of raw materials to the manufacturer, the carbon emissions from the e-commerce industry generated by the manufacture of the manufacturer's products, the emissions of waste gas, waste water and solid waste, the carbon emissions from the e-commerce industry generated by the transportation of products to the distributors, and the carbon emissions from the e-commerce industry generated by the transportation of products to the customers. The social side indicators are the number of local jobs, the number of enterprise accidents and the number of over standard rectification.

4. Integration and Optimization Analysis of E-Commerce Industry Cluster and Green Supply Chain Network

4.1. Integration and Optimization Analysis of Temporary Behavior in Each Link of Supply Chain

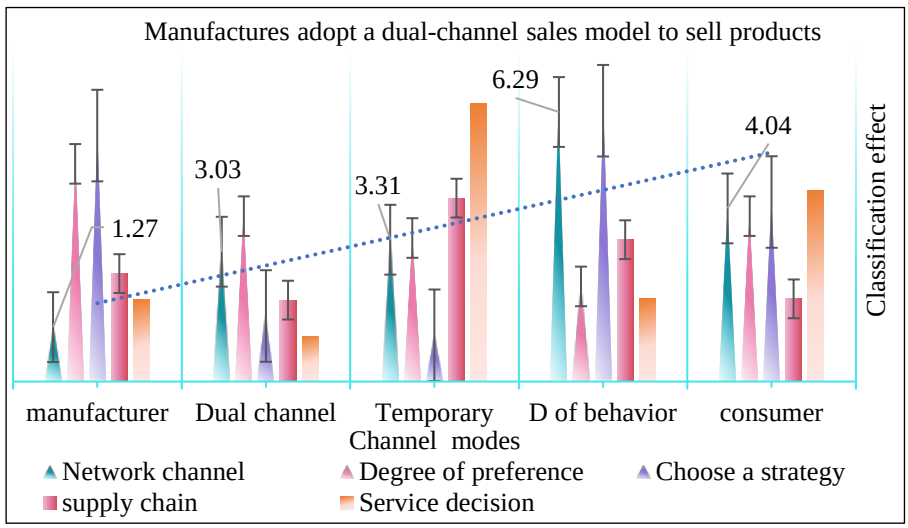

Figure 1: Manufacturers adopt a dual-channel sales model to sell products

As shown in Figure 1, more and more manufacturers adopt the dual supply chain sales mode to sell their products, while different manufacturers have different dual supply chain sales modes. In this paper, we consider two kinds of dual supply chain modes, namely, the dual supply chain mode of network direct selling composed of offline retailers' physical sales and manufacturers' online sales, and the dual supply chain mode of network distribution composed of offline retailers' physical sales and online retailers' online sales. We study the manufacturer's mode selection and the optimal pricing and service decision of the supply chain under the temporary cooperative behavior, and discuss the mechanism Furthermore, it analyzes the influence of the degree of temporary cooperation behavior and the degree of consumers' preference on the selection strategy of manufacturer's network supply chain mode, the optimal pricing and service decision of supply

chain.

Table 1: Manufacturer's channel selection strategy and temporary cooperation behavior

Item	Network channel	Degree of preference	Choose a strategy	supply chain	Service decision
manufacturer	1.27	5.08	5.74	2.52	1.91
Dual channel	3.03	3.86	1.53	1.9	1.06
Temporary	3.31	3.35	1.08	4.28	6.48
SCIO	6.29	2.22	6.32	3.31	1.93
consumer	4.04	3.86	4.19	1.93	4.45

As shown in Table 1, the manufacturer's supply chain selection strategy is related to the degree of temporary cooperation behavior, the degree of consumers' preference for network supply chain, and the price sensitivity coefficient. Furthermore, the influence of consumers' temporary cooperation behavior and network supply chain preference on manufacturer's supply chain selection and pricing decision is analyzed. It is found that when consumers' preference for network supply chain is low, manufacturers should choose network distribution dual supply chain mode. At this time, temporary cooperation behavior will not affect manufacturer's supply chain mode selection decision. However, when consumers' online supply chain preference and temporary cooperation behavior are relatively high, manufacturers should choose online direct selling dual supply chain mode.

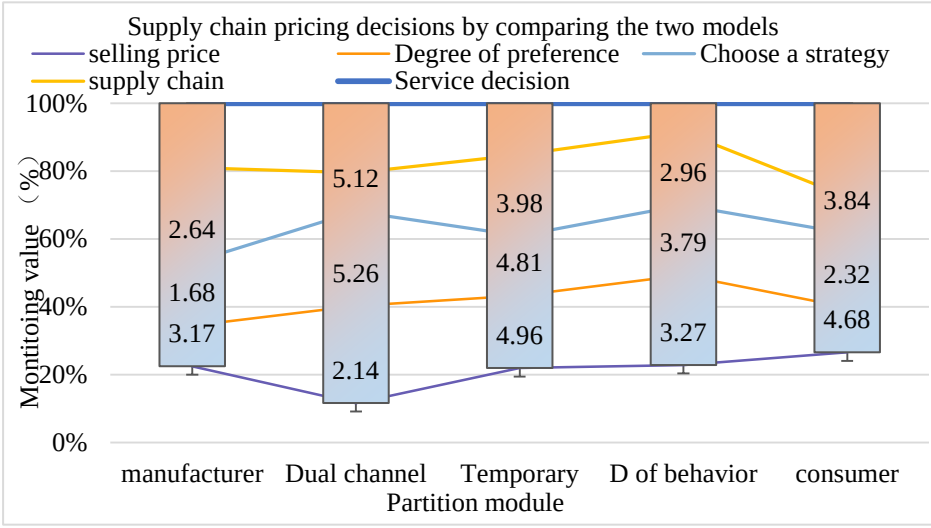

Figure 2: Supply chain pricing decisions by comparing the two models

As shown in Figure 2, by comparing the supply chain pricing decisions under the two modes, it is found that the higher the consumers prefer the network supply chain or the degree of temporary cooperation, the lower the manufacturer's optimal wholesale price and the traditional retailer's sales price under the two modes. At the same time, with the increase of the degree of temporary

cooperation, the sales price of the two modes should be set lower. However, the degree of consumers' preference for the network supply chain has different influence on the sales price of the network supply chain under different modes. The more consumers prefer the network supply chain, the lower the selling price should be set in the network distribution dual supply chain mode, and the higher the selling price should be set in the network direct supply chain mode.

Table 2: Consumers prefer online channels under two dual-channel models

Item	Manufacturer	Dual channel	Temporary	D of behavior	Consumer
selling price	3.17	2.14	4.96	3.27	4.68
Degree of preference	1.68	5.26	4.81	3.79	2.32
Choose a strategy	2.64	5.12	3.98	2.96	3.84
supply chain	3.94	2.09	5.4	3.08	1.9
Service decision	2.67	3.77	3.43	1.22	4.86

As shown in Table 2, through the comparison of service decisions, it is found that the increase of consumers' preference for online supply chain or temporary cooperation degree under the two dual supply chain modes will cause retailers to reduce their service level, and the service level of traditional retailers under the dual supply chain mode of online distribution will be higher than that of the dual supply chain mode of online direct sales. This paper mainly considers the impact of temporary cooperation behavior on manufacturer's supply chain selection strategy. Future research can further expand the model from the aspects of return or low-carbon.

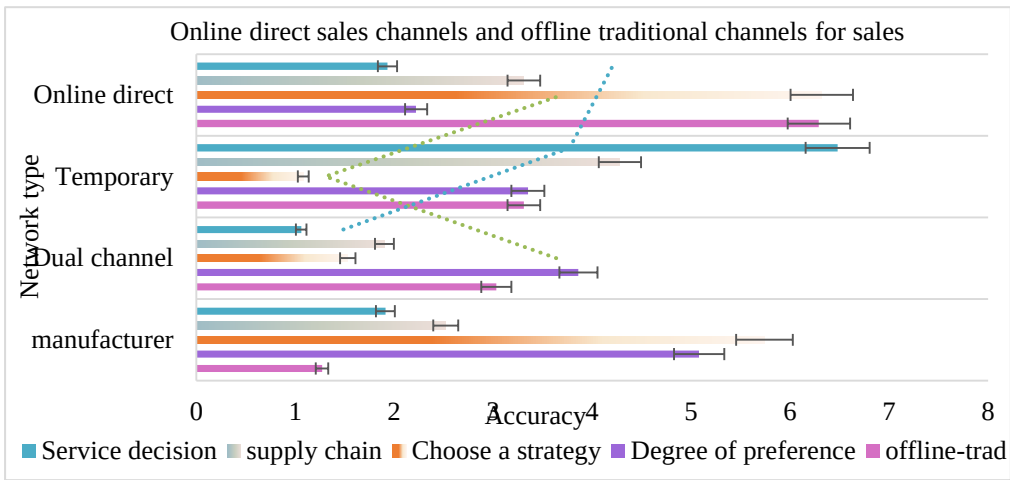

Figure 3: Online direct sales channels and offline traditional channels for sales

As shown in Figure 3, under the background of the vigorous development of China's Internet economy, many manufacturing enterprises will make use of online direct selling supply chain and offline traditional supply chain for sales at the same time, so the dual supply chain supply chain system is common in reality. Commodity pricing and supply chain cost decision-making are

important issues in dual supply chain supply chain management. For example, this paper explores and analyzes commodity pricing and supply chain cost decision-making in dual supply chain manufacturer supply chain system under different business scenarios. However, through literature review, it is found that most of the current studies assume that the wholesale price of the manufacturer's goods or the share ratio of local advertising expenditure in the cooperative supply chain planning is set to a predetermined constant value for the sake of simplification.

Table 3: Hypothetical and real-life supply chains of dual-channel manufacturers

Item	Offline-trad	Degree of preference	Choose a strategy	Supply chain	Service decision
Manufacturer	1.27	5.08	5.74	2.52	1.91
Dual channel	3.03	3.86	1.53	1.9	1.06
Temporary	3.31	3.35	1.08	4.28	6.48
Online direct	6.29	2.22	6.32	3.31	1.93
Consumer	4.04	3.86	4.19	1.93	4.45

As shown in Table 3, these assumptions are not consistent with the actual supply chain operation of dual-supply chain manufacturers in real life. In reality, they are more often produced by manufacturers and their retailers in the online and offline supply chains. Decisions are made in the game process of pricing and supply chain costs.

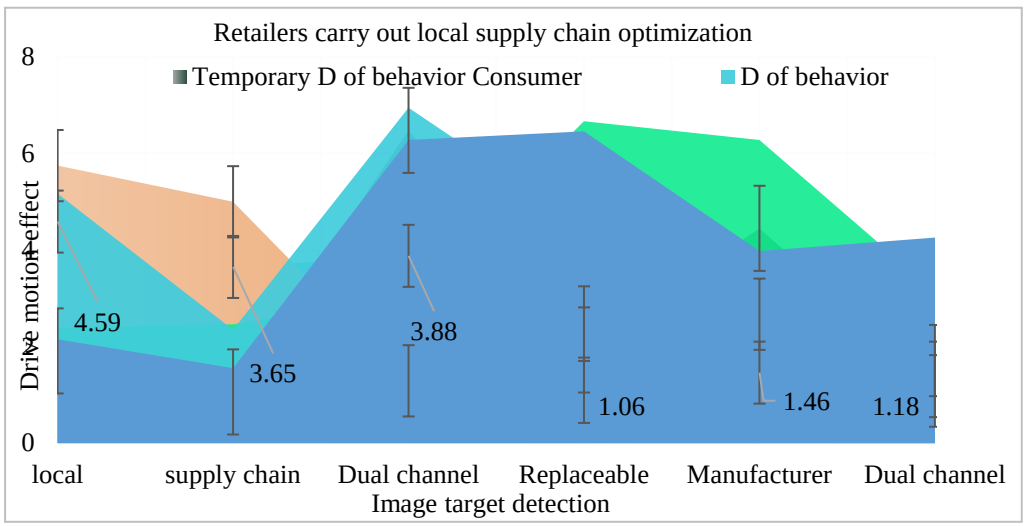

Figure 4: Retailers carry out local supply chain optimization

As shown in Figure 4, when the retailer carries out local supply chain optimization, the higher the degree of substitution between the manufacturer's two supply chains and the better the effect of retailer's supply chain optimization on promoting the sales of the two supply chains will benefit the manufacturer. This is because the higher the degree of substitution between manufacturers' two supply chains, or the better the promotion effect of supply chain optimization, will cause retailers to increase the degree of advertising efforts, which will not only help the retailer's own offline

supply chain sales, but also promote the manufacturer's online direct sales supply chain sales.

Table 4: The influence of retailer's profit and dual channels

Item	Local	Supply Chain	Dual Channel	Replaceable	Manufacturer	Dual Channel
Temporary D	1.91	1.06	6.48	1.93	4.45	1.22
D of behavior	4.59	3.65	3.88	1.06	1.46	1.18
Consumer	5.75	5	1.29	2.51	2.67	1.71
Choose a strategy	2.39	2.46	3.05	6.67	6.28	3.14
Supply chain	5.17	2.35	6.95	4.5	3.69	1.45
Service decision	2.15	1.55	6.28	6.46	3.98	4.26

As shown in Table 4, the impact on retailer's profit will be related to whether the manufacturer of dual supply chain participates in its cooperative supply chain. If the manufacturer does not participate in the cooperative supply chain, the higher the degree of mutual substitutability between the two supply chains, the better the effect of supply chain optimization on sales promotion, and also help to improve the retailer's profit. When the manufacturer participates in the cooperative supply chain, their effect on the retailer's profit is more complex and not fixed. We will discuss it further with a numerical example later. Secondly, different from the situation when retailers do not carry out supply chain optimization, the higher the compatibility of online sales is, the better the manufacturer's profit is.

4.2. Comparative Analysis of Performance and Effect of Supply Chain Integration and Optimization Model and Traditional Model Index

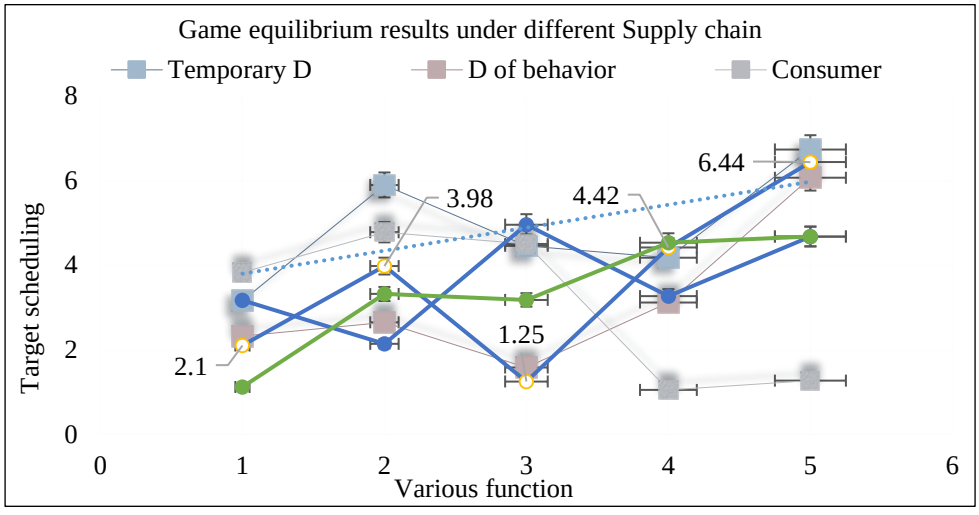

Figure 5: Game equilibrium results under different supply chain

As shown in Figure 5, combined with the game equilibrium results under different supply chain

decision-making situations, the sensitivity analysis is carried out for the relevant parameters, and the influence of the change of each parameter on the decision-making solution and profit of the participants is discussed. When retailers integrate the supply chain of the goods they sell, we can get the monotonic relationship between the effort and the relevant parameters. Compared with the optimal solution, the minimum average gap of SCIO is 1.41%, the maximum average gap is 3.75%, the average gap is less than 5%, and the average gap of each case is 3.25%. In terms of solution time, the minimum time is 12.1s, the maximum time is 48S, the average time of small-scale case is 12.7s, and the average time of large-scale case is 31.5s. Compared with the classical supply chain game model, the comprehensive performance of this model is improved by more than 32%.

Table 5: Manufacturers that adopt online and offline dual-channel operations in the upstream

Item	Temporary D	D of behavior	Consumer	Choose a strategy	Supply chain	Service decision
Service	3.16	2.32	3.83	2.1	3.17	1.12
EGNN	5.9	2.65	4.78	3.98	2.14	3.32
SFA	4.46	1.58	4.5	1.25	4.96	3.18
DML	4.18	3.12	1.05	4.42	3.27	4.53
RNN	6.74	6.07	1.27	6.44	4.68	4.68

As shown in Table 5, when a retailer carries out supply chain integration for a commodity, regardless of whether the upstream manufacturer adopting online and offline dual supply chain operation is willing to share the cost of supply chain integration, the effort degree of supply chain integration is negatively related to the compatibility coefficient θ of online sales of the commodity, while the direct influence coefficient K, indirect spillover coefficient δ and dual supply chain integration coefficient δ of retailer advertising. There is a positive correlation between the substitutability coefficients of stress chains.

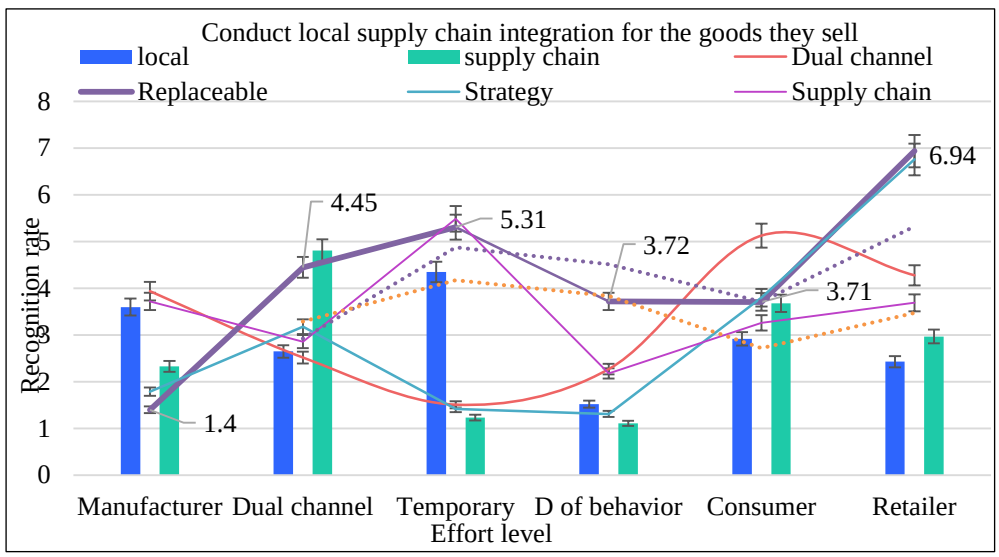

Figure 6: Conduct local supply chain integration for the goods they sell

As shown in Figure 6, when a retailer integrates the local supply chain of the goods it sells, if the goods are more compatible with the manufacturer's online supply chain sales, the retailer will be less motivated to carry out supply chain optimization regardless of whether the manufacturer is willing to share the retailer's advertising expenses. The reason behind this is that for the online supply chain to sell more compatible goods, a larger proportion of consumers will choose to buy through the online supply chain. At the same time, due to the spillover effect, the local supply chain optimization of retailers will also play the role of brand promotion and expanding awareness for their manufacturers and online supply chain to a certain extent. Therefore, retailers are more reluctant to integrate the supply chain for the sake of self insurance. Secondly, whether the retailer's local advertising directly promotes its own offline supply chain sales, or the spillover effect on manufacturers' online sales is stronger, it will cause retailers to increase their efforts to carry out supply chain optimization.

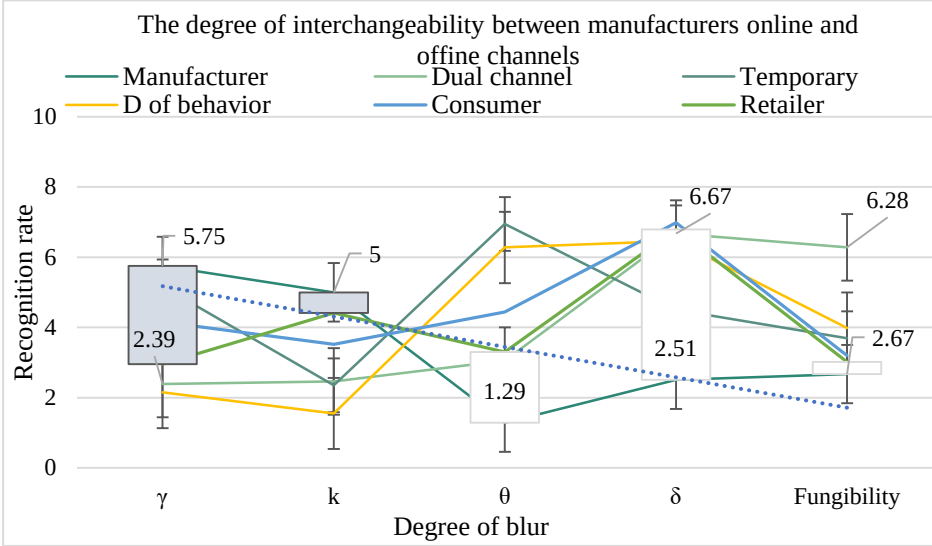

Figure 7: The degree of interchangeability between manufacturers' online and offline channels

As shown in Figure 7, when the degree of substitutability between the manufacturer's online and offline supply chains is higher, retailers will also increase their efforts to optimize the supply chain, so as to promote the increase of commodity demand of the two supply chains, so as to reduce the pressure of competition between supply chains. Next, the monotonicity of the optimal proportion of the manufacturer's participation in the retailer's advertising expenses with respect to the relevant parameters is given when the manufacturer and its offline retailer cooperate in supply chain marketing. For a dual supply chain manufacturer supply chain without supply chain integration input, the manufacturer's profit is positively correlated with the substitutability coefficient γ between the dual supply chains and the compatibility coefficient θ of goods online sales, and the retailer's profit is negatively correlated with the compatibility coefficient θ of goods online sales, but has nothing to do with the substitutability coefficient γ between the dual supply chains, and the total profit of both sides of the supply chain is negatively correlated a positive correlation between γ and θ.

Table 6: When retailers carry out supply chain integration of goods

Item	Manufacturer	Dual channel	Temporary	D of behavior	Consumer	Retailer
γ	5.75	2.39	5.17	2.15	4.16	2.95
k	5	2.46	2.35	1.55	3.52	4.41
θ	1.29	3.05	6.95	6.28	4.44	3.3
δ	2.51	6.67	4.5	6.46	6.98	6.79
Fungibility	2.67	6.28	3.69	3.98	3.2	3.02

As shown in Table 6, when the retailer carries out supply chain integration of goods, and the upstream dual supply chain manufacturers are willing to share the cost of supply chain integration, the optimal proportion of manufacturers' participation in retailer's advertising expenditure will be positively correlated with the compatibility coefficient θ of online sales, the substitutability coefficient γ between online and offline dual supply chains, and the indirect spillover coefficient δ of retailer's advertising, respectively influence coefficient K of retailer advertising is negatively correlated.

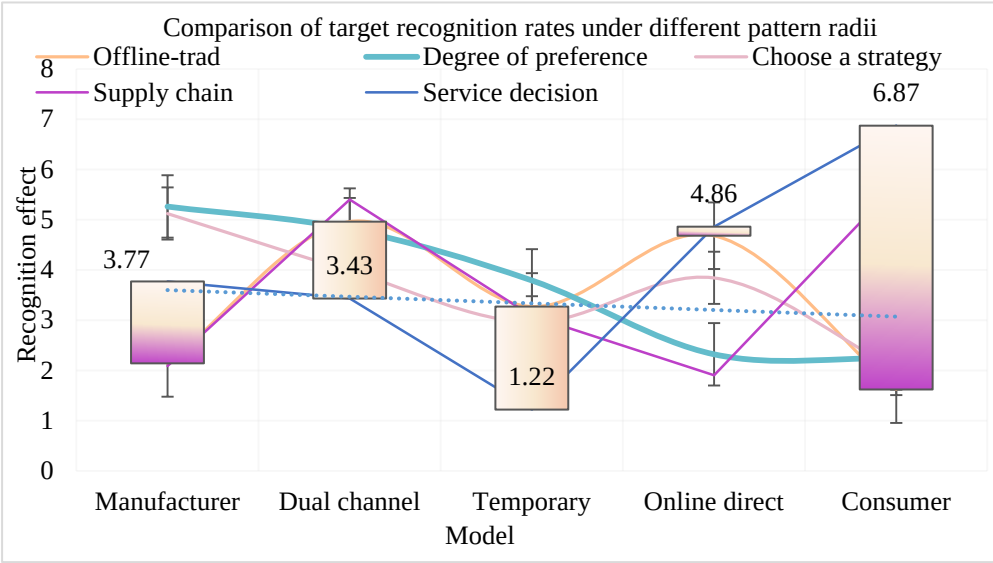

Figure 8: Manufacturer's participation in the cooperative supply chain

As shown in Figure 8, when the goods are more adaptable to online sales or the degree of substitution between two supply chains is higher, the manufacturers will increase their participation in the cooperative supply chain. This is because whether the more compatible the goods are with online sales or the higher the degree of substitutability between the two supply chains, it means that the competition between the two supply chains is intensified. In this case, manufacturers should give retailers a higher proportion of supply chain cost sharing, encourage retailers to increase their efforts to optimize the supply chain, and alleviate the impact of increased competition among supply chains by stimulating market demand.

Table 7: Promote the direct impact of its offline channel sales

Item	Offline-trad	Degree of preference	Choose a strategy	Supply chain	Service decision
Manufacturer	2.14	5.26	5.12	2.09	3.77
Dual channel	4.96	4.81	3.98	5.4	3.43
Temporary	3.27	3.79	2.96	3.08	1.22
Online direct	4.68	2.32	3.84	1.9	4.86
Consumer	1.62	2.24	2.03	5.69	6.87

As shown in Table 7, the more obvious the direct effect of retailer's supply chain optimization on promoting its own offline supply chain sales, or the weaker the indirect spillover effect on manufacturer's online supply chain, will make the manufacturer reduce the participation of cooperative supply chain and reduce the cost sharing proportion of retailer's supply chain.

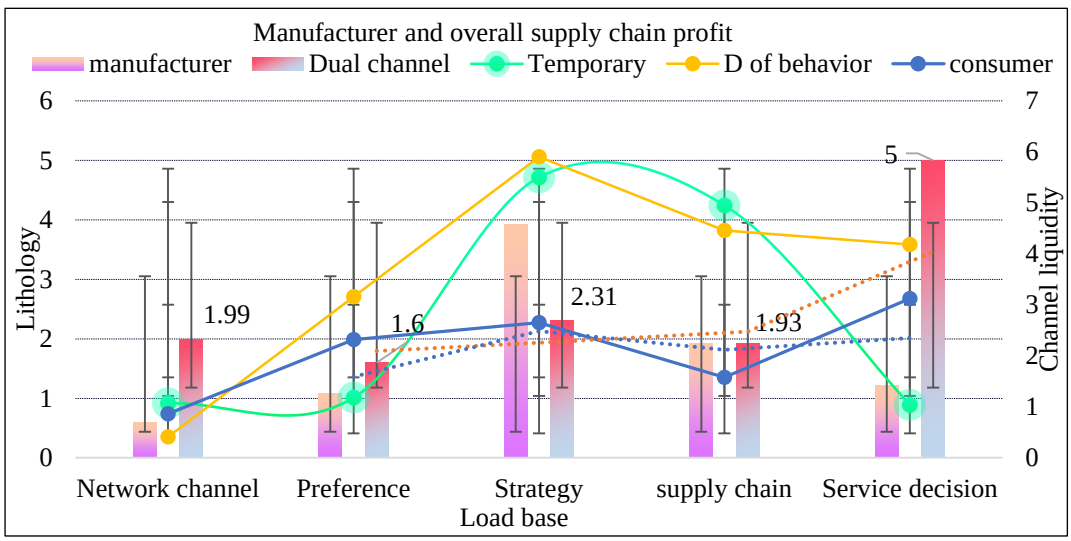

Figure 9: Manufacturer and overall supply chain profit

As shown in Figure 9, when both sides of the supply chain of a dual supply chain manufacturer do not invest in supply chain integration, the profits of the manufacturer and the whole supply chain will increase with the increase of the degree of mutual substitutability between the dual supply chains and the compatibility of goods with online sales. This means that manufacturers and the whole supply chain can benefit from the increasing competition between online and offline supply chains. At the same time, the retailer's profit will decrease with the increase of the compatibility of online sales, but it is not affected by the degree of substitutability between manufacturers' dual supply chains. The former is easier to understand. When both sides of the supply chain have no supply chain cost, the more the goods adapt to online sales, the more unfavorable to the retailer's offline supply chain. The reason for the latter is that when both sides reach the game equilibrium, the retailer's offline supply chain sales and marginal revenue per unit of goods are not affected by the degree of substitutability between the two supply chains.

5. Conclusions

By comparing the pricing decisions of two kinds of dual supply chain mode, it is found that the traditional retail supply chain and network supply chain should set higher sales price in the dual supply chain mode of network distribution compared with the dual supply chain mode of network direct selling. The setting of wholesale price is related to the preference degree of consumers' network supply chain, that is, when the preference degree of consumers' network supply chain is less than a certain threshold, the manufacturer should set a higher wholesale price in the dual supply chain mode of network direct selling; when the preference degree of consumers' network supply chain is greater than a certain threshold, the manufacturer should set a higher wholesale price in the dual supply chain mode of network distribution .

By comparing the service levels of different modes, it is found that compared with the dual supply chain mode of online direct selling, the traditional retailers will provide better service under the dual supply chain mode of online distribution. However, manufacturers should increase the selling price of network supply chain under the mode of network direct selling and dual supply chain. When the retailer integrates the supply chain, the manufacturer's profit is positively correlated with the substitutability coefficient, the direct influence coefficient and the indirect spillover coefficient of the retailer's advertisement, regardless of whether the manufacturer is willing to share the advertising expenses. Only when the compatibility coefficient of the online sales of goods is greater than a certain threshold, the manufacturer's profit is positively correlated, otherwise, there will be negative correlation, and the retailer's profit will always be negative correlation, but its monotonicity will be affected by whether the manufacturer participates in the cooperative supply chain.

By comparing the pricing strategies of network direct selling dual supply chain and network distribution dual supply chain, it is found that the sales price of traditional supply chain and network supply chain under network distribution dual supply chain mode should be higher than that under network direct selling supply chain mode. But the setting of wholesale price is related to the degree of temporary cooperation, that is, when the degree of temporary cooperation is less than a certain threshold, the manufacturer should set a higher wholesale price in the network distribution dual supply chain mode. When the degree of temporary cooperation is greater than a certain threshold, the manufacturer should set a higher wholesale price.

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