Study of the Impact of Fairness Concern on Low Carbon Dual Channel Supply Chain

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Abstract: A supplier-dominated secondary low-carbon dual channel supply chain is used as the object of study, and the expected demand function is constructed when the seller has the advantage of market information in the information asymmetry situation, in order to explore the impact of fairness concern on supply chain decision making. The utility functions in the three scenarios were analyzed and compared, and mathematical simulations were conducted according to market demand information available to the seller and the effort input of decision-making subject. Studies have shown that: Whichever decision-making subject has the fairness concern behavior does not affect the supplier as a higher profit maker; information on market demand also needs to be taken into account when considering the impact of the level of fairness concern on profits of the decision maker. When suppliers misjudge market demand, wholesale price increases are slowed if sellers have equity concerns, and sellers may engage in retaliatory behavior if equity demands are not met. In addition, low carbon demand is profitable for suppliers in supplier-led supply chains regardless of market demand, and low carbon sales efforts are not necessarily profitable for retailers.

Keywords: low-carbon supply chain, fairness concern, dual channels, game theory

1. Introduction

For the past several years, with the growth development of Internet technology, Internet direct marketing channels are prevalent. China's online shopping user base reached 904 million, a year-on-year increase of 2.7%. It can be seen that, with the online and offline consumer system and e-commerce closely integrated, channel competition transparency promotes the fairness of the decision-making body's consciousness; many manufacturing enterprises in the traditional retail channels on the basis of online sales channels, can be seen in the traditional retail industry, the dominant gradually shifted to the supplier. With the rise of the dual-channel sales model, channel competition is also becoming more and more intense, for example, because the benefits are not equitably distributed by e-commerce companies such as Tmall, Jingdong and other suppliers, the supply chain as a whole gradually deviating from the optimal situation. Thus, Focusing on fairness concerns is important to meet the realities of supply chain management. Environmental issues such as the 1.09 degree Celsius increase in global average temperature over the last decade and the increase in carbon emissions were noted by the Sixth Assessment Report of the United Nations Intergovernmental Panel on Climate Change. Low-carbon development has gradually become a consensus for the development of various industries, and consumers' awareness of low-carbon consumption has gradually increased, i.e., product price and carbon emissions have become essential factors influencing consumer behavior. However, carbon reduction behavior is mainly concentrated upstream of the supply chain, and suppliers bear more costs in the process of carbon reduction. With the awakening of a sense of fairness among decision makers, some manufacturing companies have begun to take on negative social responsibility, i.e., to reduce their low-carbon investments. In this context, how companies can set appropriate retail prices and reasonable low-carbon inputs for each of the two channels in the supply chain is an issue that must be addressed, which can contribute to the long-term growth of the supply chain.

2. Literature Review

In the dual-channel supply chain spawned by the Internet, conflicts may be created between two sales channels because product heterogeneity is not reflected. Long X et al. pointed out that the existence of channel conflicts for goods can lead to a decrease in consumer desire to buy them [1]. Guan H et al. mitigate conflicts between decision-making entities by designing synergistic mechanisms to achieve collaborative supply chain development [2]. Liu B et al. have further investigated synergistic mechanisms, mainly at the level of optimal pricing decisions, such as optimized repurchase contracts and revenue sharing contracts [3,4]. All of the above synergistic contracts can reduce channel conflict and an increase in channel profitability under various channel preferences.

Numerous studies have shown that the degree of importance attached to the fairness of benefit distribution by each decision-making body affects supply chain decision-making. LI Qinghua and LI Bo argued that pricing in the operation process is affected by the fair concern behavior of each decision maker [5], and then the role of fair concern behavior on supply chain utility was further investigated by Shen L et al. [6,7]. Driven by Internet technology, "online and offline" dual-channel sales model is gradually emerging. As the competition for decision-making agents between dual-channel sales models intensifies [8]. Xu Q et al. obtained that in the dual-channel supply chains, consumer online shopping preference and the degree of manufacturer behavior affect the manufacturer's channel choice and pricing decision [9]. SARKAR S et al. characterize the fair concern behavior among multiple competing channel subjects by constructing an equilibrium model to improve supply chain profitability across the board [10]. Yoshihara R et al. analyzed how fair concern behavior coordinates dual-channel supply chains through prices [11]. Most of the above studies are based on information symmetry, but in real life, complete information symmetry is impossible to realize, and most of them will be faced with part of the information lag or asymmetry [12]. Especially in the Internet era, the emergence of dual-channel sales model further exacerbates the fact that communication between supply chain members is hampered by information asymmetry. To optimize supply chains with information asymmetry, Wang T et al. obtained that supply chains can deviate from optimal due to misinformation when supply chain decision makers have asymmetric information [13]. Retailers are more connected to consumers so that they have access to more detailed market information [14]. Kim B et al. obtained that in a two-channel supply chain, as supplier risk aversion decreases, the value of information rises, which leads to more information asymmetry [15].

With the emergence of various environmental problems, consumers have formed a certain low-carbon preference, which also makes enterprises emphasize emission reduction. It is clear from the research that different influencing factors affect dual-channel supply chain decisions differently [16,17]. Jain D et al. obtained a low-carbon emission reduction model applicable to dual-channel supply chains, and constructed a game model to achieve supply chain optimization [18]. Li M W et al. investigated the coordination mechanism of wholesale price contracts and two-way revenue sharing contracts on dual-channel inventory under carbon tax policy [19].

Currently, fairness concerns are mostly researched in relation to a single member while the remaining members remain fairly neutral, and the issue of how pricing is affected by fairness in supply chain decision makers has rarely been studied by scholars. Furthermore, supply chain pricing strategies are mostly studied for single-channel supply chains, dual-channel supply chain is rarely explored by scholars as a research object. This paper builds on previous research and adds consideration of information asymmetry scenarios, compares and contrasts the optimal supply chain decisions in three fair concern scenarios, and puts forward relevant countermeasure suggestions, in order to provide effective recommendations for the long-term growth of dual-channel low-carbon supply chains in various industries.

3. Methodology

3.1. Description of the Problem

In the context of low-carbon consumer preferences, a secondary supply chain is formed by one supplier and one seller. The supply chain contains only one category of low-carbon products, with supplier acting as the bending leader, and the following is the sequence of supply chain decisions: The supplier sets the wholesale price according to the demand given by the seller w_{α}, the seller places the demand order with the supplier, then the supplier judges the market demand based on the order quantity Q_z. Finally, supplier and seller set price for online sales w_{β} and the offline sales price P, respectively.

3.2. Description of Symbols

Table 1: Modeling variables.

Notation	Variable name
Q_i	Market demand $i = \alpha, \beta, t$
a_k	Product market demand $k = u, v$; u represents high market demand, v represents low market demand
P	Retailer sales price
W_{α}	Supplier offline wholesale price
W_{β}	Supplier online sales price
θ	Random distribution of high market demand size $0 < \theta < 1$
ε	Cross price sensitivity coefficient $\varepsilon \in [0,1]$
δ	Consumer sensitivity coefficient to price $\delta \in [0,1]$, $\delta > \varepsilon$
ρ	Sensitivity coefficient of low-carbon emission reduction by units product to value-added cost
μ	Low-carbon emission reductions by units product
σ	Elasticity of consumer demand for low-carbon emission reduction by units product
ω	Supplier fairness concern factor $\omega \in [0,1]$
φ	Seller's fairness concern factor $\varphi \in [0,1]$
z	Sales effort level
γ	Consumer elasticity of demand for level of sales effort
m	Sensitivity factor of sales effort level to value-added cost
x	Consumer preference for online consumption $x \in [0,1]$

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3.3. Basic Assumptions

Asymmetric demand information between suppliers and sellers, when a subject in the supply chain has fairness concerns, it will change its pricing strategy by focusing on the equilibrium of returns in the process. This paper assumed that the wholesale price set through the supplier is less than the selling price set through the seller, that consumers favor low-carbon consumption and have a positive impact on market demand for both online sales channels and offline sales channels, and that the selling effort of the seller positively affects only the offline channel. At the same time, since consumers with low carbon preferences place more emphasis on low carbon volumes when choosing goods, change in demand due to low-carbon emissions by units is more than the change in demand resulting from the seller's low carbon sales efforts, i.e. $\gamma z < \mu\sigma$. Assuming that consumers usually prefer offline sales, but because online demand is usually smaller than offline demand, the supplier can only know the distribution of market demand, based on this design supplier's expected total market demand is

$$Q_z = Q_\alpha + Q_\beta = (a_u - a_v)\theta + a_v, (k = u, v) \tag{1}$$

Since the supplier cannot have access to real market information, market information can only be judged by the volume of orders given by supplier, we assume that the consumer's online purchasing preference is x, and design the supplier's offline expected demand and online expected demand function based on the asymmetry of demand information

$$Q_\alpha = (1 - x)\big((a_u - a_v)\theta + a_v\big) \tag{2}$$

$$Q_\beta = \big((a_u - a_v)\theta + a_v\big)x \tag{3}$$

The seller has the real market situation at this point, so the offline demand for sales is

$$Q_t = (1 - x)a_k \tag{4}$$

which is $0 < x < 1$. Based on the reality that the demand for different products may vary from region to region, and in order to further differentiate between high and low demand markets, this paper assumes that $3a_v \leq a_u$.

In general, the price of product decreases as demand increases; the unit of low carbon emissions and sales effort are both positively proportional to the demand; sellers' sales effort decreases as online demand increases and increases as offline demand increases, so the sales effort of the sellers has a negligible effect on the demand of the suppliers. Based on this, the supplier's forecast offline demand function $D_{z\alpha}$, the online sales channel expected demand function $D_{z\beta}$ and the supplier's actual offline demand function D_t are designed as follows

$$D_{z\alpha} = Q_\alpha - \delta P + \varepsilon W_\beta + \gamma z + \mu\sigma \tag{5}$$

$$D_{z\beta} = Q_\beta + \varepsilon P - \delta W_\beta - \gamma z + \mu\sigma \tag{6}$$

$$D_t = Q_t - \delta P + \varepsilon W_\beta + \gamma z + \mu\sigma \tag{7}$$

According to the degree of influence of demand there is $\sigma < \varepsilon < \delta$, i.e., selling effort, cross-price and price have progressively increasing effects on demand. Among them, there are $\varepsilon < \delta$ and a_k is much larger than γ and σ, i.e., a_k is much larger than $\mu\sigma + \gamma z$, i.e., demand is much larger than the change in demand due to emission reductions and changes in offline service levels.

3.4. Model Establishment and Solution

This paper considers three situations: fairness and neutrality, sellers with fairness concerns, and suppliers with fairness concerns, for modelling low-carbon supply chain decision-making under fairness concerns, and calculate the degree of fairness concerns of different decision-making entities and the optimal solution under emission reductions by units of low-carbon of product, and obtain the relationship between supply chains and fairness concerns and low-carbon emission reductions.

3.4.1. Fairness Neutral Scenario

When both suppliers and sellers are fair neutral, both aim to maximize their own interests. Since low carbon efforts are proportional to demand, the cost of the product's low-carbon emission reductions is $C_z = \frac{\mu^2 \rho}{2}$, and the cost of the product's low-carbon sales effort is $C_t = \frac{z^2 q}{2}$. Therefore, the supplier's expected optimal profit function and seller's profit function in the fairness neutral case are respectively

$$\max_{W_i} \pi_z^n = D_{z\beta} W_\beta + D_{z\alpha} W_\alpha - \frac{\mu^2 \rho}{2} \tag{8}$$

$$\max_{P} \pi_t^n = D_t \mathrm{P} - D_t W_\alpha - \frac{z^2 q}{2} \tag{9}$$

Through the reverse solution method, the optimal decision of the supplier and seller under a fair and neutral situation is

$$W_\alpha^{n^*} = \frac{(Q_\alpha - Q_t)(\delta^2 - \varepsilon^2) + (Q_\alpha + \mu\sigma + \gamma z)\delta^2 + (Q_\beta + \mu\sigma - \gamma z)\delta\varepsilon}{2(\delta^2 - \varepsilon^2)} \tag{10}$$

$$W_\beta^{n^*} = \frac{\varepsilon Q_\alpha + \delta Q_\beta + (\delta + \varepsilon)\mu\sigma + (\varepsilon - \delta)\gamma z}{2(\delta^2 - \varepsilon^2)} \tag{11}$$

$$P^{n^*} = \frac{(Q_\alpha + \mu\sigma + \gamma z)2\delta^2 + (Q_\beta + \mu\sigma - \gamma z)2\delta\varepsilon + (Q_t + \mu\sigma + \gamma z)(\delta^2 - \varepsilon^2)}{4(\delta^2 - \varepsilon^2)} \tag{12}$$

Since γz is the change in consumer demand with respect to sales effort, and the change in demand is less than the online sales demand Q_β, and $P^{n^*} - W_\alpha^{n^*} = \frac{\mu\sigma + \gamma z + 3Q_t - 2Q_\alpha}{4\delta}$, $Q_t - Q_\alpha = (\theta - 1)(x - 1)(a_u - a_v)$, where $(\theta - 1)(x - 1) > 0$, It is obtained that $Q_t - Q_\alpha > 0$, so it can be obtained that $P^{n^*} > W_\alpha^{n^*}$.

3.4.2. The Scenario of Seller Has Fairness Concerns

When the subject decision maker with fairness concerns finds that its own returns are lower than those of the reference party, the decision maker will adopt a price increase strategy to make up for the profits squeezed by the supplier to meet fairness needs. Therefore, the seller's fair utility function can be expressed as

$$\max_{P} \pi_t^{tb} = \pi_t^n - (\pi_z^n - \pi_t^n)\varphi \tag{13}$$

where $(\pi_z^n - \pi_t^n)\varphi$ indicates the fair reference point when the seller has fairness concerns. In this case, the supplier is fair-neutral, so the optimal profitability expected by the supplier is the same as in the fair-neutral scenario

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$$\max_P \pi_z^{tb} = \max_P \pi_z^n \tag{14}$$

It is not difficult to see through calculation that $\max_P \pi_t^{tb}$ and $\max_P \pi_z^{tb}$ are concave functions about P , W_α , W_β . From this, it can be obtained that the optimal decisions made by the supplier and seller when the seller has fairness concerns are respectively

$$W_\alpha^{db^*} = \frac{(Q_t+\mu\sigma+\gamma z)\varphi\varepsilon^2+(1+2\varphi)(Q_\beta+\mu\sigma-\gamma z)\delta\varepsilon}{2\delta(2\varphi+1)(\delta^2-\varepsilon^2)} + \frac{(\varphi\delta^2+\delta^2-\varepsilon^2)(Q_\alpha-Q_\beta)+(1+\varphi)(Q_\alpha+\mu\sigma-\gamma z)\delta^2}{2\delta(2\varphi+1)(\varphi\varepsilon^2+\delta^2-\varepsilon^2)} \tag{15}$$

$$W_\beta^{tb^*} = \frac{(\varepsilon+\delta)\mu\sigma+(\varepsilon-\delta)\gamma z+\varepsilon Q_\alpha+\delta Q_\beta}{2(\delta^2-\varepsilon^2)} \tag{16}$$

According to the above equation, it can be obtained

$$P^{tb^*} - W_\alpha^{tb^*} = \frac{4\varphi(\mu\sigma+\gamma z)+\mu\sigma+\gamma z+3Q_t+4\varphi Q_t-2Q_\alpha}{4\delta(1+2\varphi)} > 0 \tag{17}$$

It is reasonable to obtain the optimal solution when $W_\alpha^{tb^*} < P^{tb^*}$.

3.4.3. The Scenario of Supplier Has Fairness Concerns

Similarly to 3.4.2., the supplier's expected optimal profit function when the supplier has fairness concerns can be expressed as

$$\max_P \pi_z^{zb} = \pi_z^n - (\pi_t^n - \pi_z^n)\omega \tag{18}$$

$(\pi_z^n - \pi_t^n)\omega$ indicates the fair reference point when supplier has fairness concerns. Therefore, the seller's optimal expected profit is the same as when it is fair neutral, i.e., $\max_P \pi_t^{zb} = \max_P \pi_t^n$, and by solving the second-order partial derivatives of $\max_P \pi_t^{zb}$ and $\max_P \pi_z^{zb}$ with regard to W_α, W_β, P and the Hessian matrix test, it can be seen that $\max_P \pi_t^{zb}$ and $\max_P \pi_z^{zb}$ have a unique optimal solution. The optimal decisions made by the supplier and seller when the supplier has fairness concerns are respectively

$$W_\alpha^{zb^*} = \frac{(Q_\alpha+\mu\sigma+\gamma z)\left((2\delta^2-\omega\varepsilon^2+4\omega\delta^2)+\delta\varepsilon(Q_\beta+\mu\sigma-\gamma z)\right)}{2\delta(\delta^2-\varepsilon^2)(2+3\omega)} \tag{19}$$

$$W_\beta^{zb^*} = \frac{\varepsilon Q_\alpha+\delta Q_\beta+(\varepsilon-\delta)\gamma z+(\varepsilon+\delta)\mu\sigma}{2(\delta^2-\varepsilon^2)} \tag{20}$$

According to the above equation, it can be obtained

$$P^{zb^*} - W_\alpha^{zb^*} = \frac{(1+\omega)(\mu\sigma+\gamma z-2Q_\alpha+3Q_t)}{2\delta(2+3\omega)} > 0 \tag{21}$$

That is $W_\alpha^{zb^*} < P^{zb^*}$.

3.5. Correlation Comparison

In order to clearly express the optimal solution, Q_α , Q_β , Q_t are expanded to compare the sensitivity of low-carbon dual-channel supply chains to the fairness concern coefficient, thereby further derivation of supply chain profits as affected by market information asymmetry.

3.5.1. Comparison between Fairness Neutrality and Seller with Fairness Concerns

From the price optimal solution that is fair-neutral and the seller has fairness concerns, it can be obtained that no matter the market is in a high-demand market or a low-demand market, there exists $W_\beta^{n^*} = W_\beta^{tb^*} = W_\beta^{zb^*}$.

When $\mathrm{k} = \mathrm{u}$,if $0 < \theta \leq \frac{(1-x)(a_u-2a_\alpha)-(\mu\sigma+\gamma z)}{2(1-x)(a_u-a_\alpha)}$,and since $(1-x)(a_u-2a_\alpha)-(\mu\sigma+\gamma z)-2(1-x)(a_u-a_\alpha)<0$, it can be seen that $\theta < 1$, satisfies the value condition of θ. Since $3a_v \leq a_u$, the value of θ is small, thus $W_\alpha^{n^*} \leq W_\alpha^{tb^*}$, and $W_\alpha^{tb^*}$ decreases as φ increases, otherwise $W_\alpha^{tb^*} \leq W_\alpha^{n^*}$, and $W_\alpha^{tb^*}$ increases as φ increases. There exists $0 < \theta \leq \theta_\alpha, \pi_t^{n^*} < \pi_t^{tb^*}$, and $\pi_t^{tb^*}$ increases with φ, when $\theta_\alpha < \theta < 0$, $\pi_t^{tb^*} \leq \pi_t^{n^*}$ and $\pi_t^{tb^*}$ decreases with φ.

When $\mathrm{k} = \mathrm{v}$, $W_\alpha^{n^*} - W_\alpha^{tb^*} = \frac{((1-x)a_v+2\theta(1-x)(a_u-a_v)+\mu\sigma+\gamma z)\theta}{2\delta(1+2\varphi)} > 0$, $W_\alpha^{tb^*} < W_\alpha^{n^*}$ and $W_\alpha^{tb^*}$decreases as φ increases. No matter what value θ takes , $\pi_t^{tb^*}$ decreases as φ increases.

3.5.2. Comparison between Fairness Neutrality and Supplier with Fairness Concerns

The optimal solution for prices follows from fairness neutrality and the fact that suppliers have fair concerns:

When $\mathrm{k} = \mathrm{u}$, then there is $P^{n^*} \leq P^{zb^*}$, $W_\alpha^{n^*} \leq W_\alpha^{zb^*}$, and both P^{zb^*} and $W_\alpha^{zb^*}$ are positively correlated with ω. There exists $\omega \in (0,1)$, such that $\pi_z^{n^*} < \pi_z^{zb^*}$, when $\{0, \theta_2\} < \theta < 1$, at this point $\pi_z^{zb^*}$ increases as ω increases. when $0 < \theta < \theta_2$, $\pi_z^{zb^*}$ decreases as ω increases.

When $\mathrm{k} = \mathrm{v}$, when $0 < \theta \leq \frac{\mu\sigma+\gamma z+(1-x)a_v}{2(1-x)(a_u-a_\alpha)}$, where as a_v is much larger than $\mu\sigma + \gamma z$, then there is $\theta < 1$, at this time $P^{n^*} \leq P^{zb^*}$, $W_\alpha^{n^*} \leq W_\alpha^{zb^*}$, and$P^{zb^*}$ and $W_\alpha^{zb^*}$ are both positively correlated with ω; otherwise $P^{zb^*} < P^{n^*}$, $W_\alpha^{zb^*} < W_\alpha^{n^*}$, and P^{zb^*} and $W_\alpha^{zb^*}$ are both negatively correlated with ω. The presence of $\omega \in (0,1)$, makes $\pi_z^{n^*} < \pi_z^{zb^*}$, and $\pi_z^{zb^*}$ increases as ω increases.

4. Results

Different results are obtained by modelling the low-carbon supply chain decision in the three fairness concern scenarios.

Firstly, the supply chain is fair-neutral, with the seller's selling price increasing as the low-carbon sales effort, per unit of emission reduction, increases. Suppliers' online selling prices decrease as low-carbon selling efforts increase and are positively correlated with emission reductions per unit of product. Suppliers' wholesale prices are positively correlated with sales efforts and unit emission reductions.

Secondly, when sellers have fairness concerns, both offline and online selling prices are independent of the fairness concern coefficient, and supplier offline wholesale prices are inversely proportional to the fairness concern coefficient. Online sales prices, offline wholesale prices, and sales prices all increase with more low-carbon emission reduction by units product. Offline wholesale and sales prices increase with low carbon sales efforts, and online sales prices decrease. Supplier online sales channels are only relevant to the seller's low carbon sales efforts and low carbon emission

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reductions per unit of product. When high market demand is present, if the probability of the distribution of the high demand market is small, supplier's optimal wholesale price under fairness neutrality is less than seller's optimal wholesale price under fairness concerns, and the optimal wholesale price is inversely proportional to the degree of fairness concerns of sellers. When the probability of the distribution of the high demand market is large, the opposite is true. When market demand is low, supplier's optimal wholesale price under fairness neutrality is always smaller than seller's optimal wholesale price with fairness concerns. At this point, both seller and supplier profits are threatened.

Thirdly, when suppliers have fairness concerns, online sales prices do not vary with the fairness concern coefficient, while offline wholesale prices of suppliers and sales prices of sellers increase with the fairness concern coefficient. The online sales price is inversely related to low-carbon sales efforts and positively related to low-carbon emission reduction by units product. Offline wholesale and sales prices are directly proportional to both. Offline wholesale prices are highest when suppliers have fairness concerns, followed by online wholesale prices under fairness neutrality, and offline wholesale prices are lowest when retailers have fairness concerns. When in a low-demand market, suppliers' optimal selling prices and wholesale prices are both greater than fairness-neutral pricing, and pricing increases with the level of fairness concerns; when in a high-demand market, suppliers' wholesale and selling prices with fairness concerns are always greater than fairness-neutral, and increase with the level of fairness concerns. In this case, regardless of whether the seller is in a high or low demand market, the seller's optimal profit in fairness neutrality is always greater than the optimal profit when the supplier has fairness concerns.

5. Discussion

The above results indicate that under information asymmetry, fair concern behavior does not affect pricing decisions in online sales channels. When the seller's fairness concerns are too high, it will result in a reduction of its own interests. In different demand scenarios, the different levels of information superiority of sellers make the subject's decision-making differentiated. Appropriate increases in emission reductions will enhance the profitability of both suppliers and vendors. However, in low market demand scenarios where vendors have fairness concerns, increasing emission reductions will result in behavior that satisfies fairness at the expense of self-interest. When the market is in low demand, the overall profitability of the supply chain is optimal if suppliers have fair concerns. When high market demand, if the supplier has accurate information and fairness concerns, the supply chain profit decrease and then increase as fairness concerns increase. Supply chain profitability decreases with increasing equity concerns when sellers have equity concerns, regardless of whether real market demand is high or low.

Firstly, since there is only one supplier in the simple secondary supply chain, the seller can only squeeze the interests of the consumers to ensure the profit while the wholesale price rises, thus increasing the selling price. In the absence of fairness concerns behavior of managers, decision makers place more importance on competition in the distribution channel. Secondly, due to the seller's fairness concern, the seller will improve its bargaining power, the offline wholesale price will be reduced as the seller's fairness concerns grows, the supply chain prioritizes suppliers to set online and offline wholesale prices as a decision-making sequence. Therefore, when a seller has equity concerns, the level of equity concerns cannot directly influence the supplier's decision. Sellers will not only focus on channel competition, but also on distributing profits more equitably. Finally, supplier ownership of the supply chain as a result of fairness concerns of suppliers, the retailer has little say in setting wholesale prices. Therefore, when suppliers focus more on fairness concerns, sellers will increase pricing to maintain profits. Consumers favor offline consumption channels with higher service perceptions when sellers increase low-carbon service levels.

Based on the above discussion, when market demand information is asymmetric, the following suggestions are provided for the decision-making management of suppliers and sellers with fairness concerns in low-carbon dual-channel supply chains:

Firstly, suppliers can establish a supply chain information network to maximize information sharing with sellers in supply chain management. Suppliers should try their best to understand the fairness concerns of sellers and reduce wholesale price increases while making profits for themselves. In addition to improving the accuracy of market judgment, suppliers can also invest in more online services to increase value, such as conducting online live broadcasts and focusing on improving online after-sales services.

Secondly, sellers need to strengthen ties with suppliers, especially in low-demand markets, and should establish strong trust relationships with suppliers. When suppliers have fairness concerns, sellers should increase their bargaining power in high-demand markets and increase marginal profits. When suppliers have both online and offline sales channels, sellers can strengthen their sales efforts and improve service quality, such as providing door-to-door services, optimizing after-sales services, and strengthening sales promotions to attract consumers to purchase offline.

Thirdly, when considering low-carbon emission reduction of products, suppliers should consider market demand and sellers' fairness concerns to formulate emission reduction strategies and wholesale prices to optimize supply chain profits. At the same time, sellers also need to invest moderately in low-carbon. Especially in low-demand scenarios, sellers should consider reducing sales efforts to ensure their profitability.

6. Conclusion

This study considers the relationship between dual-channel low-carbon supply chains pricing decisions and supplier and seller profitability and low carbon emission reductions per unit, low carbon sales effort, and equity concerns under market demand uncertainty, and proposes relevant countermeasures. In markets with low carbon preferences, a secondary supply chain containing one supplier and one seller is constructed. Design a game model between supply chain decision makers with three specific scenarios: fairness neutrality, seller with fairness concerns, and supplier with fairness concerns. First of all, the optimal pricing decision under three scenarios is derived by backward solving, and the impacts of low-carbon emission reductions by units, low carbon sales efforts of sellers, and the fairness concern factor on pricing are investigated under different market demand distributions. Numerical analyses are conducted to study the impact of the degree of fairness concerns on profits, and to compare the impacts of low-carbon emission reductions by units product, low-carbon efforts of sellers, and fairness concern behaviors on pricing changes in different fairness concern scenarios under different market demand distributions.

However, this paper does not discuss the change of revenue when each decision maker has fair concern behavior at the same time, in real life, suppliers will serve multiple sellers, so future research can discuss the synergistic strategy of supply chain members with fair concern behavior from the perspective of multi-channel.

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