Research Article

Ordering Decisions of Supply Chain with Competition and Dual-Fairness Concern

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Received 30 May 2021; Revised 28 December 2021; Accepted 18 January 2022; Published 19 August 2022

Academic Editor: Zeshui Xu

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This study studies a supply chain consisting of one supplier and two retailers and analyzes the optimal decisions of ordering quantity in four types of no fairness concern, horizontal fairness concern, vertical fairness concern, and dual-fairness concern and the impacts of fairness concern on supply chain. The results show that (1) vertical fairness concern can decrease the ordering quantity of the retailer with vertical fairness concern and the wholesale price and improve the ordering quantity of the retailer without fairness concern; (2) horizontal fairness concern can increase the ordering quantity of the retailer with horizontal fairness concern and improve the ordering quantity of the retailer without fairness concern, but does not influence the wholesale price; and (3) dual-fairness concern can decrease the ordering quantity of the retailer with dual-fairness concern and the wholesale price and improve the ordering quantity of the retailer without fairness concern as a whole. The numerical analysis also proves the findings.

1. Introduction

Globalization and technical progress have further intensified market competition from enterprise competition to supply chain competition. Retailers as the closest participant to end consumer compete fiercely; in particular, the development of the Internet has intensified the competition between them. Walmart, Carrefour, Yonghui, and so on often hold commodity promotion activities to compete with each other in retail department stores. Electrical retailers such as Suning, Gome, and JD had price competition in 2012, and they were punished by the Ministry of Industry and Information Technology of China because of unfair competition. The lower price can attract more consumers. However, due to the different sizes of retailers, their own different ordering capabilities may lead to different sale prices, which intensify market competition among retailers. At the same time, the ordering quantity will also affect inventory control; for example, lots of commodity stocks will lead to inventory backlog, which will increase inventory cost and increase inventory risk. Too little commodity stocks will result in out of stocks and loss of market opportunity, which will affect their own earnings. Therefore, the ordering decisions will not only affect their own earnings but also affect market competition. In addition, retailers have different competitive advantages due to different strengths. There are also different competitions between retailers and suppliers under different power structures. The unfair competition will lead to unfair income distribution. When choosing transaction, retailers will consider the influences of ordering quantity on themselves. Therefore, it is necessary to study the influences of ordering strategy on the transaction of retailers and the overall efficiency of supply chain in a competitive environment.

Furthermore, the unfair competition will cause retailers to start paying attention to whether they are treated fairly, which will occur both upstream and downstream of the supply chain. For example, Xuzhou Wanji Trading
Company of China terminated its cooperation with P & G due to unfair price [1], resulting in unfairness concern of retailers. Suppliers will also have fairness concern; for example, Best Buy sells Dell and Lenovo computers at the same time and may adopt different contracts to obtain the greatest benefit. One of them which is not treated unfairly may have unfairness concern [2]. Different fairness concerns will have different effects on their own decision-making. In the study, the vertical fairness concern only exists between the supplier and the retailer, and the horizontal fairness concern only exists between the retailers, that is to say that it only exists between peers. If the vertical fairness concern and the horizontal fairness concern simultaneously exist in the model, we call it a dual-fairness model.

In practice, it has been proved that the stakeholders of supply chain have fairness concern, because they do not want to be treated unfairly and are unwilling to pay for it without a corresponding return. Then, they would rather sacrifice their own interests in exchange for fairness, which affects the efficiency of supply chain. Therefore, the fairness concern has a very important impact on the development and maintenance of stakeholder relationships [3], and it also plays a positive role in promoting the development of the supply chain [4]. However, the different fairness concerns have different impacts on different stakeholders. How to make better use of the positive effects of fairness concern is a problem that needs further research.

The purpose of this study is to find out that (1) the impacts of fairness concern on ordering quantity of supply chain in a competitive environment compared with no fairness concern and (2) how the ordering strategies of competing retailers change under dual-fairness concern. For solving the proposed questions, we have established a two-echelon supply chain composed of a supplier and two retailers and developed utility models of the no fairness concern, the vertical and horizontal fairness concern, and the dual-fairness concern, respectively. We have compared the different ordering strategies of retailers in the four situations to get the influences of fairness concern on supply chain decision-making and management insights.

The new contributions of this study are as follows: firstly, the study develops the models under dual-fairness concern in four types that include the no fairness concern, the vertical fairness concern, the horizontal fairness concern, and the dual-fairness concern. Secondly, the dual-fairness concern is discussed in competitive supply chain, in which the prior works do not involve in all the four games and the influences of dual-fairness concern on supply chain ordering strategies are analyzed in four games. Thirdly, the competition of ordering quantity exists between two retailers and the study discusses that one retailer plays two games—Stackelberg and Nash, which clearly show the relationships between the supplier and the retailer.

The rest of the study is as follows: Section 2 is literature review; Section 3 is the model description, which establishes the different structures of competitive supply chain; Section 4 analyzes the retailers' ordering strategies under the conditions of no fairness concern, vertical fairness concern, horizontal fairness concern, and dual-fairness concern; Section 5 verifies the propositional conclusions through numerical analysis; and Section 6 sums up the conclusions of the study and future research work.

2. Literature Review

The study related to the literature mainly includes competitive supply chain and fairness concern.

2.1. Competitive Supply Chain. The aggravation of social competition has also caused different degrees of competition inside and outside the supply chain, and competition exists among suppliers, retailers, and between suppliers and retailers, which has different impacts on the benefit of supply chain. Chakraborty et al. studied the decisions of supply chain consisting of two suppliers and one retailer based on price and quality competition and coordinated the supply chain through wholesale price contract and cost-sharing contract [5]. Wang et al. studied a sustainable supply chain composed of two suppliers and an e-commerce platform and analyzed the impacts of green products and platform deposit on pricing strategies [6]. Zhu et al. studied the impacts of different power structures, different types of green product, and competition on the degree of greenness under three structures of supply chain [7]. Li et al. studied the supply chain composed of offline showrooms and online retailers under asymmetric information and compared and analyzed the cooperation strategies of only one retailer or two online retailers [8]. Wang et al. analyzed the customization dual-channel supply chain based on the price and service competition [9]. Xu et al. studied the two-period supply chain based on cooperative advertising, analyzed the optimal advertising efforts of the supply chain under two competitive retailers, and coordinated through bilateral contract [10]. Yu et al. analyzed the impacts of different information sharing modes and carbon emission reduction in competitive retailers [11]. Choi et al. studied the pricing decision of a mass-customized supply chain based on price competition of retailers under uncertain demand and analyzed the impacts of risk aversion on supply chain decision-making [12]. Mondal et al. studied the optimal decision-making of a green closed-loop supply chain based on retailer competition and cooperation under government intervention and carbon emission policies [13]. Yao et al. studied the impacts of different power structures on service level and retail price under retailer competition and proposed different operation strategies [14]. Pi et al. studied dual-channel supply chain decision-making under disruption of demand and analyzed the optimal service level and pricing strategies under retailer competition and cooperation [15]. Therefore, the different competitions such as competing manufacturers, competing retailers, and channel competition have different impacts on supply chain.

From the above literature, it can be seen that with the deepening of research on competitive supply chain, different competitions have caused participants to have different fairness concerns. Zhao et al. studied the pricing strategy of product and service supply chain based on service competition with extended service period and compared the differences in decision-making under the retailer with
2.2. Fairness Concern. The participants of supply chain have fairness concern due to their interests suffered loss, which will affect their enthusiasm and ultimately affect the performance of supply chain. Zhen et al. studied a dual-channel supply chain in which both supplier and retailer have fairness concerns [19]. Wang et al. studied an e-commerce supply chain of a supplier with fairness concern and an e-commerce platform and coordinated supply chain through mixed contract [20]. Li et al. studied the design strategy of green product of competitive retailers with vertical fairness concern [21]. Shiy analyzed the supplier’s encroachment strategy under the condition that the supplier and the retailer have different fairness concerns [22]. Shu et al. studied the pricing decision of closed-loop supply chain based on the competition and fairness concern of the collector [23]. Guan et al. studied the optimal decision of retailer with fairness concern by the method of differential game and coordinated the supply chain through revenue-sharing and cost-sharing contract [24]. Yan et al. studied the fresh agri-product supply chain under supplier and retailer’s fairness concerns and coordinated through revenue-sharing contract [25], but the literature rarely involves the competition and dual-fairness concern.

It can be known from the existing literature that power structure and competitive advantage will bring different fairness preferences, which leads to different fairness concerns for supply chain participants and will have different effects on the overall performance of supply chain. The differences from the existing literature are shown in Table 1. This study studies the supply chain composed of one supplier and two retailers, considers an inverse demand function and one retailer with fairness concern, and analyzes the optimal decisions in four types of no fairness concern, horizontal fairness concern, vertical fairness concern, and dual-fairness concern.

3. Model Description

This study studies a two-echelon competitive supply chain composed of a risk-neutral supplier and two retailers, the supplier determines the wholesale price of the product, and two retailers compete with each other by ordering the quantity to determine the retail price of the product, and the structures of the competitive supply chain are shown in Figure 1.

The notations used in the study are given in Table 2 (i = 1, 2).

The assumptions are as follows:

(1) To simplify the calculation, the manufacturing cost is assumed to be 0, which does not influence the conclusions of the study,

(2) Retailer 1 has fairness concern and retailer 2 and supplier do not have fairness concern, and

(3) Retailers 1 and 2 compete with each other by ordering quantity under information symmetry.

In the Stackelberg game model, the supplier is the leader, the two retailers are the followers, and the two retailers make ordering decisions simultaneously. In the condition of retailer 1’s fairness concern, when the reference point is the supplier’s profit, it is called vertical fairness concern; when the reference point is retailer 2’s profit, it is called the horizontal fairness concern; when there are vertical fairness concern and horizontal fairness concern simultaneously, it is called the dual-fairness concern. There are different fairness concerns with different power structures and different impacts on supply chain stakeholders.

In the study, the supplier sells the product to retailers 1 and 2 at the same wholesale price \( w \), retailers 1 and 2 sell the product to consumers at the prices \( p_1 \), \( p_2 \), respectively, and the market demands of retailer 2 are \( q_1 \), \( q_2 \), respectively. Assuming that the market demand function is linear, according to the literature of Xiao et al. and Shen [29, 30], the inverse demand function is established as follows:

\[
P_1 = a - q_1 - bq_2, \quad p_2 = a - q_2 - bq_1, \tag{1}\]

where \( a \) is the market potential demand and \( b \) is the substitutability coefficient.

According to the literature of Dai et al. and Zhang [31, 32], the profit functions of the retailers and the supplier can be obtained as follows:

\[
\pi_1 = (p_1 - w)q_1 = (a - q_1 - bq_2 - w)q_1, \tag{2}\]

\[
\pi_2 = (p_2 - w)q_2 = (a - q_2 - bq_1 - w)q_2, \tag{3}\]

\[
\pi_m = w(q_1 + q_2), \tag{4}\]

where \( \pi_1 \) is the profit function of retailer 1, \( \pi_2 \) is the profit function of retailer 2, and \( \pi_m \) is the profit function of the supplier.

When retailer 1 has fairness concern, the goal is to maximize its own utility and retailer 1 takes the profits of
Table 1: Comparison of related references.

<table>
<thead>
<tr>
<th>Inverse demand function</th>
<th>Competitive retailers</th>
<th>Horizontal fairness concern</th>
<th>Vertical fairness concern</th>
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<td>Yoshihara et al. [17]</td>
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<td>Ho et al. [18]</td>
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<td>Shu et al. [23]</td>
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<td>Ho et al. [26]</td>
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<td>Zhang et al. [2]</td>
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<td>Choi et al. [33]</td>
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<td>Li et al. [12]</td>
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<td>Cui et al. [27]</td>
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<td>Yan et al. [24]</td>
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Figure 1: Competitive supply chain structure. (a) Vertical fairness concern. (b) Horizontal fairness concern.

Table 2: Notations.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Description</th>
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<tbody>
<tr>
<td>w</td>
<td>Wholesale price</td>
</tr>
<tr>
<td>Pi</td>
<td>The retail price of retailer i</td>
</tr>
<tr>
<td>A</td>
<td>The market size</td>
</tr>
<tr>
<td>B</td>
<td>The sensitive coefficient</td>
</tr>
<tr>
<td>Λ</td>
<td>The coefficient of vertical fairness concern</td>
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<td>Φ</td>
<td>The coefficient of horizontal fairness concern</td>
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<td>Decision variables</td>
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<td>qi</td>
<td>The market demand of retailer i</td>
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<td>Profit functions</td>
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</tr>
<tr>
<td>πm</td>
<td>The profit of supplier</td>
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<tr>
<td>πi</td>
<td>The profit of retailer i</td>
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supplier and retailer 2 as the reference point. It is that when the profits of supplier and retailer 2 exceed the profit of retailer 1, the fairness utility of retailer 1 will increase; otherwise, the opposite is true. The difference in income will bring about changes in the utility function. According to Choi et al. and Zhang et al. [2,33], the F-S utility function of retailer 1 is obtained as follows:

\[ u_1 = \pi_1 - \lambda (\pi_m - \pi_1) - \varphi (\pi_2 - \pi_1) \]
\[ = (1 + \lambda + \varphi)\pi_1 - \lambda \pi_m - \varphi \pi_2, \]  
(5)

where \( u_1 \) is the utility function of retailer 1, and \( \lambda, \varphi \) are the coefficients of vertical and horizontal fairness concern, respectively.

4. Analysis of Different Fairness Concerns

4.1. No Fairness Concern of Retailer 1. This section considers that there is no fairness concern in supply chain; that is, \( \lambda = 0, \varphi = 0 \). As the Stackelberg leader, the supplier decides the wholesale price \( w \), retailer 1 and retailer 2 are the Stackelberg followers, and the relationship between the retailers is Nash equilibrium, and they determine their respective ordering quantities \( q_1 \) and \( q_2 \).

From formulas (2) and (3), the first and second derivatives of \( q_1 \) and \( q_2 \) can be obtained as follows:

\[ \frac{\partial \pi_1}{\partial q_1} = a - 2q_1 - b q_2 - w, \]
\[ \frac{\partial \pi_2}{\partial q_2} = a - 2q_2 - b q_1 - w, \]
\[ \frac{\partial^2 \pi_1}{\partial q_1^2} = -2 < 0, \]
\[ \frac{\partial^2 \pi_2}{\partial q_2^2} = -2 < 0. \]  
(6)

It is known that there are the optimal values about \( q_1 \) and \( q_2 \), which are solved as follows:

\[ q_1 = q_2 = \frac{2a - ba + (b - 2)w}{4 - b^2}. \]  
(7)

We put \( q_1, q_2 \) into equation (4), it can be obtained as follows:

\[ \pi_m = w \frac{2a - 2w}{2 + b}. \]  
(8)

Using equation (8), we obtain the derivatives of \( w \):

\[ \frac{\partial \pi_m}{\partial w} = \frac{1}{2 + b} (-4w + 2a), \]  
(9)

\[ \frac{\partial^2 \pi_m}{\partial w^2} = \frac{4}{2 + b} < 0. \]  
(10)

It can be seen that \( w \) has an optimal value, which can be obtained by formula (9):

\[ w = \frac{a}{2}. \]  
(11)

Therefore, there are the optimal values about \( q_1, q_2, \pi_1, \pi_2 \), and \( \pi_m \) when retailer 1 has no fairness concern:

\[ q_1 = q_2 = \frac{a}{2(2 + b)}. \]  
\[ \pi_1 = \pi_2 = \frac{a^2}{4(2 + b)^2}, \]  
(12)

\[ \pi_m = \frac{a^2}{2(2 + b)}. \]

**Proposition 1.** In a competitive condition, when there is no fairness concern, the optimal order quantities of retailers 1 and 2 are equal and their profits are also equal, and the supplier’s profit is \((2+b)\) times the sum of two retailers’ profits.

**Proof.** From the optimal value of \( q_1 \) and \( q_2 \), it is easy to know that \( q_1 \) and \( q_2 \) are equal.

From the profits of retailers 1 and 2, we can get the equation as follows:

\[ (\pi_1 + \pi_2)(2 + b) = \frac{a^2}{2(2 + b)^2} \times (2 + b) = \frac{a^2}{2} = \pi_m. \]

(13)

Proposition 1 is proved.

From Proposition 1, it can be seen that under the competitive condition and the supplier-dominated Stackelberg game, the supplier’s profit is better than the retailer’s, which is the same conclusion as that in the traditional supply chain. That is to say, regardless of whether there is competition between retailers, the supplier obtains more advantages in the supplier-dominated system. The game between the supplier and retailer can reach an equilibrium state only when the ordering quantities of competitive retailers are the same.

4.2. Only Vertical Fairness Concern of Retailer 1. In this section, considering that retailer 1 has only vertical fairness concern, that is, \( \lambda > 0 \) and \( \varphi = 0 \), the fairness concern utility function of retailer 1 \( u_{s1} \) is obtained as follows:

\[ u_{s1} = \pi_1 - \lambda (\pi_m - \pi_1) = (1 + \lambda)\pi_1 - \lambda \pi_m, \]  
(14)

and using equation (14) and equation (3), the derivatives of \( q_1, q_2 \) can be obtained, respectively:
\[ \frac{\partial u_{v1}}{\partial q_1} = (1 + \lambda) (a - 2q_1 - bq_2 - w) - \lambda w, \]  
\[ \frac{\partial^2 u_{v1}}{\partial q_1^2} = -2(1 + \lambda) < 0, \]  
\[ \frac{\partial \pi_z}{\partial q_z} = a - 2q_z - bq_z - w, \]  
\[ \frac{\partial^2 \pi_z}{\partial q_z^2} = -2q_z < 0. \]  

It can be seen that there is an optimal value for \( q_1 \) and \( q_2 \), respectively, and the optimal values for \( q_{v1} \) and \( q_{v2} \) can be obtained under vertical fairness concern of retailer 1:

\[ q_{v1} = \frac{(1 + \lambda) (2 - b)a - (2 - b + 4\lambda - b\lambda)w}{(1 + \lambda)(4 - b^2)}, \]  
\[ q_{v2} = \frac{(1 + \lambda) (2 - b)a - (2 - b + 2\lambda - 2b\lambda)w}{(1 + \lambda)(4 - b^2)}. \]  

Putting \( q_{v1} \) and \( q_{v2} \) into equation (4), the supplier’s profit function \( \pi_{vm} \) is obtained under vertical fairness concern as follows:

\[ \pi_{vm} = w \frac{2(1 + \lambda)a - (2 + 3\lambda)w}{(1 + \lambda)(2 + b)}. \]

The first and second derivatives of \( w \) are obtained, respectively:

\[ \frac{\partial \pi_{vm}}{\partial w} = \frac{2(1 + \lambda)a - 2(2 + 3\lambda)w}{(1 + \lambda)(2 + b)}, \]  
\[ \frac{\partial^2 \pi_{vm}}{\partial w^2} = \frac{2(2 + 3\lambda)}{(1 + \lambda)(2 + b)} < 0. \]

It can be seen that there is an optimal value \( w_{v} \), and the first derivative is equal to 0, and the optimal wholesale price \( w_{v} \) under vertical fairness concern is obtained as follows:

\[ w_{v} = \frac{(1 + \lambda)a}{2 + 3\lambda}. \]

Bringing \( w_{v} \) into \( q_{v1}, q_{v2} \) and, the optimal values of \( q_{v1} \) and \( q_{v2} \) are obtained as follows:

\[ q_{v1} = \frac{2 - b + 2\lambda - 2b\lambda}{(2 + 3\lambda)(4 - b^2)} a, \]  
\[ q_{v2} = \frac{2 - b + 4\lambda - b\lambda}{(2 + 3\lambda)(4 - b^2)} a. \]

From this, the profits of retailer 1 (\( \pi_{v1} \)), retailer 2 (\( \pi_{v2} \)), and supplier (\( \pi_{vm} \)) under vertical fairness concern are as follows:

\[ \pi_{v1} = \frac{(2 - b + 2\lambda - 2b\lambda)(2 + 6\lambda - b - \lambda b^2)}{(2 + 3\lambda)^2(4 - b^2)} a^2, \]  
\[ \pi_{v2} = \frac{(2 - b + 4\lambda - b\lambda)^2}{(2 + 3\lambda)^2(4 - b^2)} a^2, \]  
\[ \pi_{vm} = \frac{(1 + \lambda)}{(2 + 3\lambda)(2 + b)} a^2. \]

**Proposition 2.** The wholesale price and the ordering quantity of retailer 1 decrease with the increase in vertical fairness concern, while the ordering quantity of retailer 2 increases with the increase in vertical fairness concern.

**Proof.** Using \( w_{v}, q_{v1}, \) and \( q_{v2} \) to obtain the first derivative of \( \lambda \) results in:

\[ \frac{d\pi_{v1}}{d\lambda} = \frac{a}{(2 + 3\lambda)^2} < 0, \]  
\[ \frac{d\pi_{v2}}{d\lambda} = \frac{(2 - b)a}{(4 - b)(2 + 3\lambda)^2} < 0, \]  
\[ \frac{dq_{v1}}{d\lambda} = \frac{(2 - b)a}{(4 - b)(2 + 3\lambda)^2} > 0. \]

It can be seen that Proposition 2 is proved.

It can be seen from Proposition 2 that when retailer 1 feels more unfair, the ordering quantity will be smaller under vertical fairness concern. At the same time, the supplier lowers the wholesale price to balance retailer 1’s unfair psychology. At this time, retailer 2 increases ordering quantity by free riding to compete with retailer 1, which can improve retailer 2’s competitive edge.

4.3. **Only Horizontal Fairness Concern of Retailer 1.** When retailer 1 has only horizontal fairness concern, that is, \( \lambda = 0, \phi > 0 \), retailer 1’s fairness concern utility function \( u_{h1} \) is as follows:

\[ u_{h1} = \pi_1 - \phi (\pi_2 - \pi_1) = (1 + \phi)\pi_1 - \phi \pi_2. \]  

Using equations (24) and (3), the first and second derivatives of \( q_1 \) and \( q_2 \) can be obtained, respectively:
The second derivatives of \( q_1 \) and \( q_2 \) are less than 0, and we know that \( q_1 \) and \( q_2 \) have a maximum value, respectively. In addition, the first derivatives of \( q_1 \) and \( q_2 \) are equal to 0, and \( q_{h1} \) and \( q_{h2} \) can be obtained as follows:

\[
q_{h1} = \frac{(2 - b + 2\varphi)(a - w)}{4(1 + \varphi) - b^2}, \\
q_{h2} = \frac{(1 + \varphi)(2 - b)(a - w)}{4(1 + \varphi) - b^2}.
\]  

Inserting \( q_{h1} \) and \( q_{h2} \) into the supplier’s profit function, we can get the following:

\[
\pi_m = \frac{w(4 - 2b + 4\varphi - b\varphi)(a - w)}{4(1 + \varphi) - b^2}.
\]

We can obtain the first and second derivatives of \( w \), respectively:

\[
\frac{\partial \pi_m}{\partial w} = \frac{(4 - 2b + 4\varphi - b\varphi)(a - 2w)}{4(1 + \varphi) - b^2}, \\
\frac{\partial^2 \pi_m}{\partial w^2} = \frac{-2(4 - 2b + 4\varphi - b\varphi)}{4(1 + \lambda) - b^2} < 0.
\]

It can be seen that the optimal value of the wholesale price \( w_h \) under the horizontal fairness concern is obtained:

\[
w_h = \frac{a}{2}.
\]

Bringing \( w_h \) into \( q_{h1} \) and \( q_{h2} \), we can reach the optimal values:

\[
q_{h1} = \frac{(2 - b + 2\varphi)a}{2[4(1 + \varphi) - b^2]}, \\
q_{h2} = \frac{(1 + \varphi)(2 - b)a}{2[4(1 + \varphi) - b^2]}.
\]

So, the profits of the retailer and the supplier can be obtained:

\[
\pi_{h1} = \frac{(2 - b + 2\varphi)(2 - b + 2\varphi - 2b\varphi + \varphi b^2)}{4[4(1 + \varphi) - b^2]^2}a^2, \\
\pi_{h2} = \frac{(1 + \varphi)^2(2 - b)^2}{4[4(1 + \varphi) - b^2]^2}a^2, \\
\pi_{lm} = \frac{4 - 2b + 4\varphi - \varphi b}{4[4(1 + \varphi) - b^2]^2}a^2.
\]

**Proposition 3.** Under horizontal fairness concern, the wholesale price has nothing to do with horizontal fairness concern. Horizontal fairness concern is positively correlated with ordering quantity of retailer 1 and negatively correlated with ordering quantity of retailer 2.

**Proof.** From equations \( w_h \), \( q_{h1} \), and \( q_{h2} \), respectively, we can obtain the first derivative of:

\[
\frac{dw_h}{d\varphi} = 0,
\]

\[
\frac{dq_{h1}}{d\varphi} = \frac{b(2 - b)}{[4(1 + \varphi) - b^2]^2} > 0, \\
\frac{dq_{h2}}{d\varphi} = \frac{-b^2(2 - b)}{[4(1 + \varphi) - b^2]^2} < 0.
\]

Therefore, Proposition 3 is proved.

Proposition 3 shows that when retailer 1 has horizontal fairness concern, it does not influence the supplier’s decision-making, but it has an incentive effect on retailer 1’s ordering quantity and has an inhibitory effect on retailer 2’s ordering quantity, indicating that retailer 1 increases the ordering quantity to obtain competitive advantage, which makes retailer 1 have more market share. □

**4.4. Dual-Fairness Concern of Retailer 1.** In this part, retailer 1 has vertical and horizontal fairness concerns; that is, \( \lambda > 0 \) and \( \varphi > 0 \), and retailer 1’s fairness utility function \( u_{\lambda\varphi} \) is as follows:

\[
u_1 = \pi_1 - \lambda(\pi_m - \pi_1) - \varphi(\pi_2 - \pi_1) = (1 + \lambda + \varphi)\pi_1 - \lambda\pi_m - \varphi\pi_2.
\]

Using equation (34) and equation (3), it can be obtained the first and second derivatives of \( q_1, q_2 \), respectively:
\[
\frac{\partial u_{d1}}{\partial q_1} = (1 + \lambda + \phi)(a - 2q_1 - bq_2 - w) - \lambda w + \phi bq_2,
\]
\[
\frac{\partial^2 u_{d1}}{\partial q_1^2} = -2(1 + \lambda + \phi) < 0,
\]
\[
\frac{\partial^2 u_{d1}}{\partial q_2^2} = -2 < 0.
\]

It can be seen that there is an optimal value for \(q_1\) and \(q_2\), respectively. Making their first derivatives equal to 0, the optimal values of \(q_{d1}\) and \(q_{d2}\) can be obtained by the simultaneous equations:

\[
\frac{\partial \pi_m}{\partial w} = -[2(2 - b)(2 + 3\lambda + \phi) - 4\phi]w + 2(2 - b)(1 + \lambda + \phi)a + b\phi a,
\]
\[
\frac{\partial^2 \pi_m}{\partial w^2} = -[2(2 - b)(2 + 3\lambda + \phi) + 4\phi].
\]

It can be seen that when \(b < 1\), there is:
\[
\frac{\partial^2 \pi_m}{\partial w^2} < 0.
\]

At this time, \(w\) has an optimal value. We set the first derivative equal to 0 and solve the equation to obtain the optimal value of the wholesale price \(w_d\) under dual-fairness concern:
\[
w_d = \frac{2(1 + \lambda + \phi)(2 - b) + b\phi}{2(2 + 3\lambda + \phi)(2 - b) + 4\phi - a}.
\]

Bringing \(w_d\) into \(q_{d1}\) and \(q_{d2}\), will get the optimal values:

\[
q_{d1} = \frac{(1 + \lambda + \phi)(2 - b) + \phi b}{4(1 + \lambda + \phi) - b^2(1 + \lambda)} \frac{(1 + \lambda + \phi)(2 - b) + b\phi}{2(2 + 3\lambda + \phi)(2 - b) + 4\phi} a,
\]
\[
q_{d2} = \frac{(1 + \lambda + \phi)(2 - b) + \phi b}{4(1 + \lambda + \phi) - b^2(1 + \lambda)} \frac{(1 + \lambda + \phi)(2 - b) + b\phi}{2(2 + 3\lambda + \phi)(2 - b) + 4\phi} a.
\]

The profit of retailer 1 \(\pi_{d1}\), the profit of retailer 2 \(\pi_{d2}\), and the profit of supplier \(\pi_{dm}\) are obtained as follows:

\[
\pi_{d1} = \frac{(1 + \lambda + \phi)(2 - b) + \phi b}{4(1 + \lambda + \phi) - b^2(1 + \lambda)} \frac{(1 + \lambda + \phi)(2 - b) + b\phi}{2(2 + 3\lambda + \phi)(2 - b) + 4\phi} a^2
\]
\[
\pi_{d2} = \frac{(1 + \lambda + \phi)(2 - b) + \phi b}{4(1 + \lambda + \phi) - b^2(1 + \lambda)} \frac{(1 + \lambda + \phi)(2 - b) + b\phi}{2(2 + 3\lambda + \phi)(2 - b) + 4\phi} a^2
\]
\[
\pi_{dm} = \frac{(1 + \lambda + \phi)(2 - b) + \phi b}{4(1 + \lambda + \phi) - b^2(1 + \lambda)} \frac{(1 + \lambda + \phi)(2 - b) + b\phi}{2(2 + 3\lambda + \phi)(2 - b) + 4\phi} a^2
\]
Proposition 4. The wholesale price is affected by horizontal fairness concerns and vertical fairness concerns in opposite trend under dual-fairness concern.

Proof. Using the first derivative of wholesale price of \( w_d \) with respect to \( \lambda \) and \( \varphi \), respectively, we can get the results as follows:

\[
\frac{\partial w_d}{\partial \lambda} = \frac{2(2 - b)[2(2 - b) + (4 - b)\varphi]}{[2(2 + 3\lambda + \varphi)(2 - b) + 4\varphi]^2} < 0, \tag{43}
\]

\[
\frac{\partial w_d}{\partial \varphi} = \frac{2(2 - b)[2(2 - b) + 2\lambda(5 - 2b)]}{[2(2 + 3\lambda + \varphi)(2 - b) + 4\varphi]^2} > 0.
\]

It can be seen that Proposition 4 is proved.

It can be seen from Proposition 4 that when there are both horizontal and vertical fairness concerns, vertical fairness concern can increase the wholesale price, while horizontal fairness concerns will reduce the wholesale price. Compared with Propositions 2 and 3, it can be seen that when there are dual-fairness concerns, the impacts of vertical and horizontal fairness concerns on the wholesale price are different.

To compare all the findings intuitively, the results are shown in Table 3.

It can be seen that the effects of fairness concern are different from Table 3. The horizontal fairness concern does not affect the wholesale price and the vertical and dual-fairness concern can influence the wholesale price obviously, but the ordering quantities of retailers 1 and 2 are affected differently by fairness concern and competition. In addition, the wholesale price and ordering quantity under no fairness concern are less than the ones under fairness concern, which shows that fairness concern can influence supply chain whether there is competition or not. So, the supplier considers not only fairness concern but also competition, which can be funded between the supplier and retailer or between retailers and cause the conflicts between the participants of supply chain. The performance of supply chain will be reduced, and the conflicts will be aggravated under fairness concern and competition; therefore, the behavior and competition of supply chain must be discussed in theory and practice. The managers of supply chain need to pay close attention to different behaviors and competitions and balance the interests of participants by designing the effective contracts and coordinating them to maximize the benefits of supply chain and improve the sustainable development of supply chain.

It is difficult to analyze the effects of dual-fairness concerns on \( q_{d1}, q_{d2}, \pi_{d1}, \pi_{d2}, \) and \( \pi_{dm} \) due to their complex expressions, so we will talk about the effects in Section of Numerical analysis.

5. Numerical Analysis

To find the underlying laws in the model analysis and the conclusions that need to be further verified, this section studies the influences of dual-fairness concern on the optimal decision-making of a competitive supply chain by the way of numerical analysis. Retailer 1 has the same fairness concern on the supplier and retailer 2, and all the conditions and assumptions are met in the study. According to Choi et al. [30], assigning values to the parameters are set as follows: \( \lambda = \varphi = 1, a = 15, \) and \( b = 0.5. \)

5.1. Comparative Analysis. First of all, it can be seen from Table 4 that under four different fairness concerns, the wholesale price and retailer 1’s ordering quantity are the smallest when retailer 1 has vertical fairness concern, while retailer 2’s ordering quantity is the largest. It shows that fair concern has different effects on wholesale price and ordering quantity at this time. Retailer 1’s profit and retailer 2’s profit are also the largest, while the supplier’s profit is the smallest under the vertical fairness concern of retailer 1. This shows that the retailers can obtain greater revenue when retailer 1 has vertical fairness concern.

Although the ordering quantity of retailer 1 is the largest in the four types of fairness concern, the ordering quantity and profit of retailer 2 are the smallest, and the wholesale price and the supplier’s profit are maximized, so the horizontal fairness concern increases competition between retailer 1 and retailer 2, indicating that the fairness concern of retailer 1 has a greater impact on retailer 2. The total profit of the supply chain is greatest when there is dual-fairness concern, which shows that dual-fairness concern coordinates the relationship between the supplier and competitive retailers in the supply chain.

5.2. Sensitivity Analysis

5.2.1. The Vertical Fairness Concern of Retailer 1. Considering retailer 1’s vertical fairness concern, the changes in the decisions of supplier and retailers are analyzed, and the simulation analysis is used by MATLAB. The results are shown in Figures 2–4.

It can be seen from Figure 2 that when retailer 1 has vertical fairness concern, the wholesale price will decrease as vertical fairness concern increases. When the coefficient of fairness concern is zero, the wholesale price has the maximum value, indicating that vertical fairness concern will reduce the wholesale price. This is because the supplier reduces the impact of fairness concern by lowering the wholesale price to relieve the conflict with retailer 1, and then in this case, competing retailer 2 benefits even more due to free riding under vertical fairness concern.
Table 3: Model findings.

<table>
<thead>
<tr>
<th></th>
<th>( W )</th>
<th>( q_1 )</th>
<th>( q_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fairness concern</td>
<td>( \frac{a}{2} )</td>
<td>( \frac{b}{2(2+b)} )</td>
<td>( \frac{a}{2(2+b)} )</td>
</tr>
<tr>
<td>Only vertical fairness concern</td>
<td>( \frac{1+\lambda}{2(2+\lambda)} )</td>
<td>( \frac{2-b+2\lambda-2b\lambda}{(2+2a)^4} )</td>
<td>( \frac{2-b+4\lambda-2b\lambda}{(2+2a)^4} )</td>
</tr>
<tr>
<td>Only horizontal fairness concern</td>
<td>( \frac{a}{2} )</td>
<td>( \frac{(2-b+2\phi)a}{2(2+3\phi)(2-b)} )</td>
<td>( \frac{(1+\phi)(2-b)a}{2(2+3\phi)(2-b)} )</td>
</tr>
<tr>
<td>Dual-fairness concern</td>
<td>( \frac{2(1+\lambda+\phi)(2-b)bq}{2(2+3\lambda+\phi)(2-b)4p} )</td>
<td>( \frac{[(1+\lambda+\phi)(2-b)\phi][2(1+\lambda+\phi)(2-b)-2b\phi b]+2b\phi}{4(1+\lambda+\phi)^2(1+\lambda)[2(2+3\lambda+\phi)(2-b)4p]} )</td>
<td>( \frac{(1+\lambda+\phi)(2-b)[2(1+\phi)(2-b)+4\phi^2 b^2+\lambda b]}{4(1+\lambda+\phi)^2(1+\lambda)[2(2+3\lambda+\phi)(2-b)4p]} )</td>
</tr>
</tbody>
</table>

Table 4: Values of supply chain.

<table>
<thead>
<tr>
<th></th>
<th>( W )</th>
<th>( q_1 )</th>
<th>( q_2 )</th>
<th>( \pi_1 )</th>
<th>( \pi_2 )</th>
<th>( \pi_m )</th>
<th>( \pi_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>No fairness concern</td>
<td>7.5</td>
<td>3</td>
<td>7.5</td>
<td>11.6</td>
<td>9</td>
<td>45</td>
<td>63</td>
</tr>
<tr>
<td>Vertical fairness concern</td>
<td>6</td>
<td>2</td>
<td>4.35</td>
<td>11.6</td>
<td>9</td>
<td>36</td>
<td>63.6</td>
</tr>
<tr>
<td>Horizontal fairness concern</td>
<td>7.5</td>
<td>4</td>
<td>2.9</td>
<td>9.01</td>
<td>11.6</td>
<td>47.18</td>
<td>64.62</td>
</tr>
<tr>
<td>Dual-fairness concern</td>
<td>6.48</td>
<td>2.83</td>
<td>12.62</td>
<td>10.92</td>
<td>42.12</td>
<td>65.66</td>
<td></td>
</tr>
</tbody>
</table>

Figure 2: Impact of vertical fairness concern on the wholesale price.

Figure 3: Impacts of vertical fairness concern on the ordering quantity.
6.2. It can be seen from Figure 3 that the ordering quantity of retailer 1 will decrease with the increase in vertical fairness concern, while the ordering quantity of retailer 2 will increase with the increase in vertical fairness concern. It can be seen from this that retailer 1 is influenced obviously by fairness concern. It means that the more unfair retailer 1 feels, the lower the ordering quantity will be, which causes retailer 2 to increase the ordering quantity to gain the competitive edge.

First of all, it can be seen from Figure 4 that the profits of retailers 1 and 2 both increase with the increase in the degree of fairness concern, while the supplier’s profit is reductive; secondly, the profit of supplier is always greater than the profits of retailers 1 and 2; the profit of retailer 1 is always lower than the profit of retailer 2 due to vertical fairness concern, and the profit of retailer 1 has the maximum value in this range. In the supplier-dominated game model, the supplier’s revenue is dominant due to the influence of power structure, which is the same as the previous research conclusions.

5.2.2. The Horizontal Fairness Concern of Retailer 1. The impacts on the decisions of supplier and retailers are analyzed when there is only horizontal fairness concern, and the results are shown in Figures 5 and 6 by MATLAB.

It can be seen from Proposition 3 that the horizontal fairness concern does not affect wholesale price, so only the impacts on retailer’s ordering quantity and profit of supply chain are analyzed.

It can be seen from Figure 5 that the horizontal fairness concern can improve the ordering quantity of retailer 1 but decrease the ordering quantity of retailer 2. In addition, it can also be seen from Figure 5 that the impact of horizontal fairness concern on the ordering quantity of retailer 1 is more significant. With the increase in degree of fairness concern, the ordering quantity has increased relatively quickly, indicating that the more retailer 1 feels unfair, the larger the ordering quantity will be, and this is because that retailer 1 wants to obtain the competitive edge by increasing the ordering quantity and having a bigger market share.

It can be seen from Figure 6 that when retailer 1 has horizontal fairness concern, the supplier’s profit increases with the increase in degree of fairness concern, while the profits of retailers 1 and 2 decrease, that is to say, retail 1’s horizontal fairness concern can increase the supplier’s profit and reduce the retailers’ profit. At the same time, under the supplier-dominated system, the profit gap between the supplier and the retailers has been increased, and this is because the wholesale price is maximum and the total ordering quantity of supply chain is maximum. In addition, the profit of retailer 1 has always been greater than the profit of retailer 2, which shows that in a competitive environment, the horizontal fairness concern is beneficial to retailer 1 and brings the competitive edge to retailer 1.

5.2.3. Changes in Supply Chain Decision-Making under Dual-Fairness Concern. Considering both vertical and horizontal fairness concerns, the influences of retailer 1’s dual-fairness concern on the supply chain decision-making are discussed. The simulation results are shown in Figures 7–9 using MATLAB 2014.

Figure 7 shows that the wholesale price decreases in general under dual-fairness concern; while vertical fairness concern will reduce wholesale price, horizontal fairness concern will increase wholesale price. Therefore, the dual-fairness concern can balance the impacts on wholesale price between the horizontal fairness concern and vertical fairness concern.

Figure 8 shows that the ordering quantity of retailer 1 decreases generally under dual-fairness concern. Horizontal concern can increase the ordering quantity of retailer 1, while vertical fairness concern will reduce retailer 1’s ordering quantity, which shows that the ordering quantity of retailer 1 is more affected by vertical fairness concern, and it
is because the effects of both power structure and fairness concern are more obvious.

It can be seen from Figure 9 that the ordering quantity of retailer 2 shows an overall upward trend under dual-fairness concern; the ordering quantity of retailer 2 decreases as horizontal fairness concern decreases, while vertical fairness concern increases retail 2’s ordering quantity.

Comparing Figure 8, it can be seen that the ordering quantities of retailers 1 and 2 are affected by dual-fairness concern in the opposite way. When there is only horizontal or vertical fairness concern, the ordering quantities of the two are also affected differently. At the same time, in a competitive environment, dual-fairness concern can abate the competition between retailers 1 and 2, so the total profit of supply chain can achieve the maximum.
It can be seen from the above analysis that horizontal fairness concern, vertical fairness concern, and dual-fairness concern have different impacts on supply chain stakeholders and the competition among stakeholders can also affect the decisions of supply chain. Therefore, supply chain managers should pay attention to the impacts of participant behavior and competition on the supply chain to avoid the negative effects, so it is necessary to develop a fairer cooperation mechanism to enhance the stability and sustainable development of supply chain. In real life, competition is normal but should be fair, which is useful for social development.

6. Conclusions

This study studies the supply chain composed of a supplier and two retailers and analyzes the influences of horizontal fairness concern, vertical fairness concerns, and dual-fairness concern on ordering quantity of supply chain. The specific conclusions are as follows:

(1) The wholesale price is affected differently by fairness concern: when there is only horizontal fairness concern, the wholesale price is a fixed value and is not affected. When there are vertical and dual-fairness concerns, the wholesale price will be reduced.

(2) Retailer 1’s ordering quantity decreases with the increase in vertical fairness concern and dual-fairness concern and increases with the increase in horizontal fairness concern, while retailer 2’s ordering quantity is reversed.

(3) Supplier’s profit and retailer 2’s profit are affected conversely by vertical fairness concern and horizontal fairness concern. However, retailer 1’s profit has a maximum value within a certain range under vertical fairness concern, while under horizontal fairness concern, it shows a downward trend.

It can be seen from the research conclusions that dual-fairness concern has different impacts on retailers’ ordering strategies under competitive conditions, and they also have a significant impact on the overall operation of supply chain. Managers should consider the impacts of fairness concern, competition factor, and power structure on stakeholders in the supply chain to avoid negative effects and maximize the overall benefits of supply chain, which can better promote the development of supply chain and society.

However, there are certain limitations in the study; that is, crisis management of demand fluctuation is not considered, because the market demand is uncertain and random [34, 35]; in particular, the disasters such as COVID-19 pandemic crisis, flood and waterlogging disasters, and earthquake, can influence the sustainable development of supply chain. Although ordering quantity can influence the competition, it also influences inventory of goods, which leads to lots of cost and risks. At the same time, the research conclusions show that the interests of various participants are not balanced, and the study does not coordinate the interests of supply chain. We will develop the models of random variable, inventory and green technology, and so on and coordinate supply chain by different contracts for the long-term development of supply chain in the future.

Data Availability

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

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgments

This research was supported by the National Natural Science Foundation of China (Grant nos. 72074110 and 71771055), Anhui Planning Office of Philosophy and Social Science Project (Grant no. AHSKQ2020D49), Research Project Innovation and Development of Anhui (Grant no. 2020CX057), Talent Project of Fuyang Normal University (Grant nos. rcxm202012 and 2020KYQD0008), Key Project of Humanities and Social Sciences of Anhui (Grant no. SK2021A0393), and Postgraduate Project of Fuyang Normal University (Grant no. 2021SKY19).

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