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Interactive impacts of overconfidence and fairness concern on supply chain performance

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A B S T R A C T

For exploring the interactive impacts of overconfidence and fairness concern on optimal decisions of manufacturer and retailer, we establish Stackelberg models with these two behavioural preferences in a two-echelon supply chain, wherein retailer has two behavioural preferences. The optimal equilibrium results are compared in different scenarios, namely the retailer with no behavioural preference, with single-behavioural preference and with the two behavioural preferences. Although previous literatures have proven that overconfidence or fairness concern has a negative influence on retailer, we find that the retailer always benefits from these two behavioural preferences, whether it is retail price, sales effort or utility. This is because when the overconfident degree is within a reasonable range, overconfidence and fairness concern have a positive influence on retailer's decision-making, and when the overconfident degree is high, the fairness concern preference can suppress the adverse effects caused by overconfidence. Compared with the preference of fairness concern, the overconfident preference plays a leading role in supply chain performance, which mainly manifests in retailer's decisions, utility and manufacturer profit. Moreover, the wholesale price and profit of the rational manufacturer may become worsen due to the fairness concern of retailer.

A R T I C L E I N F O

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1. Introduction

Many firms and individuals often show characteristics of bounded rationality in decision-making process, such as overconfidence and fairness concern [1]. The two behavioural preferences are observed anecdotally in practice and coexist in the decision process. Before the onset of Double 11 of 2014, a CEO of Taobao predicts that the return rate of commodity may be in single-digit percentage points, yet the real return rate is 69 %, and the complaint rate is higher than usual, such as Haier complaint rate is 54.2 %[1]. The huge discount induces customers to make irrational shopping, leading to an augment in return orders and complaint rates. Moreover, the prediction of CEO and the high return rate of consumer reveal that many decision makers are overconfident. Consequently, wrong decisions cause profit losses and merchants concern fairness issues about revenue allocation, resulting in a high complaint rate [1]. Moreover, overconfidence and fairness concern simultaneously affect retailer's decisions in supply chain. For instance, in "Dou-

[1]https://www.chinainternetwatch.com/11643/false-prosperity-behind-double-11-refund-rate-increased-to-69/.

ble 11" shopping festival, a retailer believes that he has better marketing capabilities, and thus orders more products from a supplier. Nevertheless, he obtains poor profit due to excessive inventories and marketing expenses. Meanwhile, because of an unfairly disproportionate share of the profit between the retailer and the supplier, he reduces order quantities and increases retail price [2].

Fairness concern is an important factor when the revenue allocation is unfair in a supply chain system [3], and overconfidence is a commonly type of irrational behaviour when retailer overestimates the influence of his sales effort level on market demand. Although the effects of overconfidence and fairness concern on decisions and profits have been extensively studied, the existing studies just consider the overconfidence or the fairness concern in supply chain. But study simultaneously considering the two behaviour preferences for one decision maker is lacking. Many researchers think overconfidence and fairness concern result in self-harm, and are not good for the whole supply chain system [4, 5]. Moreover, social preference, i.e., fairness concern, can be regarded as an important complement to self-regarding preference, i.e., overconfidence [6]. In practice, when a retailer has both the two behavioural preferences, he may benefit from these preferences. Therefore, we attempt to investigate the effects of overconfidence and fairness concern on decisions, profits and utilities in a two-echelon supply chain.

The following study questions should be answered, First, how do the retailer's fairness concern and overconfidence affect the pricing and sales effort for the two-echelon supply chain? Second, what are the impacts of the two behavioural preferences on the profitability and utility of supply chain participants? Third, in the presence of fairness concern and overconfidence, what is the main behavioural preference affecting decision variables and profit?

To investigate these questions, we consider a two-echelon supply chain consisting of a rational manufacturer and a retailer. The assumption that the manufacturer is the leader and the retailer is the follower is proposed, because many manufacturers in the automotive industry or other industries (e.g., Ford, Toyota, Dell and Lenovo) have the power to set the wholesale price, whereas retailers must follow the manufacturer's strategy and accept the price, and then determine a selling price and sales effort level. However, a retailer usually overestimates the effect of sales effort on demand, and pays attention to whether the distribution of profit is fair between participants in a supply chain. Thus, we consider three critical scenarios: (a) retailer with no behavioural preferences, wherein the retailer is rational; (b) retailer with single-behavioural preference, wherein the retailer has a preference, i.e., overconfidence or fairness concern; (c) retailer with two behavioural preferences, wherein the retailer has both overconfidence and fairness concern. Then, we construct three Stackelberg game models in different scenarios, respectively. Specially, we analyse the effect of two behavioural preferences on prices, sales effort, profitability and utility of supply chain members.

The rest of the paper is organized as follows. In section 2, we introduce the literature review. Following that, we describe the basic Stackelberg game model under the retailer with unbounded rationality, and extend the model in which the retailer has the two behavioural preferences; the two models are then solved. In Section 4, we discuss the effect of behavioural preferences in the supply chain under three scenarios. Section 5 presents numerical analysis to examine the theoretical models and propositions. Section 6 concludes and provides direction for future research.

2. Literature review

Two streams of literature research are relevant to the study: overconfidence preference and fairness concern preference in supply chain.

2.1 Overconfidence preference in supply chain

Overconfidence is a common cognitive bias in which decision maker often overestimates his judging ability [7]. This preference is widely existed in behavioural operations management. Ren *et al.* [8] introduce overconfidence in supply chain to study the decisions of overconfident newsvendor, then demonstrate that overconfidence significantly correlates with order bias by introducing the debiasing technique in an experimental study. Kirshner *et al.* [9] think that greater overconfidence typically results in lower margins, higher inventory and pricing. Moreover, Doyle *et al.* [10] assess how the overconfidence affects decision making of grassroots employees in complex supply chain systems. Liu *et al.* [11] examine the effects of the dual-overconfident preferences and changing demand on decisions and utilities. they further develop a two-stage service procurement model in logistics service supply chain, and illustrate that a dynamic pricing mechanism eliminating the negative influence of overconfidence [12]. Li [5] clearly explain overconfidence bias can reduce the double marginalization effect. Furthermore, Xu *et al.* [13] analyse the impact of retailer's overconfidence on optimal pricing, ordering decisions in a duopolistic supply chain. However, the most existing papers only focus on the influence of overconfidence on decision variables, we extend the single-behavioural preference to dual-behavioural preferences in a supply chain system.

2.2 Fairness concern preference in supply chain

Fairness concern is an important social preference, which means that decision-makers not only pay attention to the maximum income of the individual, but also pay attention to whether the distribution of channel income or price is fair [14]. Cui *et al.* [15] incorporate fairness concern into a conventional dyadic supply chain consisting of one manufacturer and one retailer and considered its influence on channel coordination. Caliskan *et al.* [16] further extend the Cui's model to the nonlinear demand environment. Considering the different channel power, Li *et al.* [17] consider a retailer's fairness concern in a dual-channel supply chain model in which the dominant manufacturer has a direct channel, whereas the retailer is a follower. Nie *et al.* [6] further consider whether different contracts can coordinate supply chain performance when retailers show dual-fairness. However, Wang *et al.* [18] introduce the fairness concern of manufacturer into an e-commerce supply chain model. Pan *et al.* [19] explore the effect of fairness concern on decisions of supply chain consisting of a dominant retailer and two manufacturers. Different from the aforementioned papers, we develop a supply chain structure consisting of one rational manufacturer and one retailer with fairness concern and overconfidence.

Contrary to the earlier studies only considering the overconfidence or the fairness concern, we investigate the interactive effects of overconfidence and fairness concern on the supply chain performance. More recently, Zhang *et al.* [1] discuss optimal contract design in the joint effect of overconfidence and fairness concern on order quantity. In comparison, we mainly examine the interactive impacts of behavioural preferences on pricing and utilities in three scenarios, which gradually and clearly describes the interaction between overconfidence and fairness concern. In addition, they assume the market demand is uncertainty, but the market demand in this paper is deterministic to explore the effect of two behavioural preferences on decision variables and profit/utility by exactly mathematical formulas. It is interesting to find that utility of supply chain system may be beneficial to fairness concern when μ is in the range of $\left(\frac{\sqrt{2}-1}{2}, +\infty\right)$, and the wholesale price is not always increasing with overconfidence. More importantly, comparing to fairness concern, overconfidence is the most importantly behavioural preference affecting prices, sales effort and profit.

3. The model

3.1 Fundamental assumption and notation

A two-echelon supply chain where the manufacturer serving as the leader is unboundedly rational and the retailer serving as the follower has three conditions is presented; see Fig. 1. The manufacturer sells products to the retailer selling them to consumers. The manufacturer determines the wholesale price w. The retailer determines the retail price p and sales effort e according to the decision of manufacturer. We assume, without loss of generality, that transaction information between the manufacturer and the retailer is symmetrical, that the manufacturer's productivity can meet the retailer's ordering requirements and that the retailer can increase sales volume by improving the level of sales effort (e.g., advertising, giving gifts, etc.). Referring to study from Karray [20] and Zeng at al. [21], let $c(e) = (1/2)\gamma e^2$,where $c(e)$ denotes the sales effort cost of the retailer and $\gamma(\gamma \geq 1)$ is the sale cost coefficient. The manufacturer and retailer are to maximize their expected profit or utility.

What we need to point out is that in Fig. 1, the single-behavioural preference refers to a retailer with overconfidence or fairness concern, while the two-behavioural preferences refer to a retailer who has both overconfident and fairness concern. We briefly present the notations and parameters used in this paper, as summarized in Table 1.

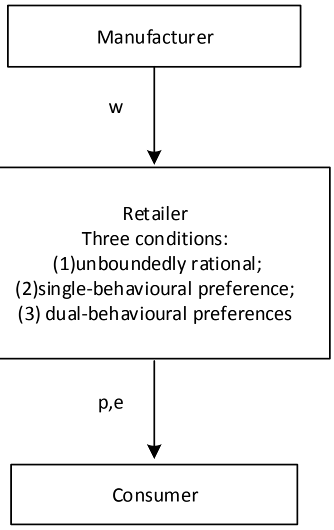

Fig. 1 The two-echelon supply chain structure

Table 1 Summary of parameters

Parameters	Description
a	The basic size of market demand ($a > 0$).
b	The price sensitivity coefficient of demand, i.e., the amount of marginal demand declines or rises when the price rises or falls by one unit($b \geq 1$) .
$c(e)$	The sales effort cost of the retailer, a monotonically increasing and concave function with e.
c_x	$x = m, r$ respectively denote the manufacturer's marginal cost of production and the retailer's marginal cost of selling, such as packaging, transportation, and maintenance fees.
D	The market demand function when the retailer is unboundedly rational.
D_O	The market demand function when the retailer has overconfidence, i.e., the overconfident retailer believes demand to be D_O in the market.
k	Retailer's sales effort output, i.e., the amount of marginal demand increases when the sales effort rises by one unit ($k \geq 1$) .
γ	The sale cost coefficient ($\gamma \geq 1$)
β	The overconfidence parameter of the retailer, which represents the degree of overconfidence,$\beta \in (0,1]$.
μ	The fairness concern parameter of the retailer, which represents the degree of fairness concern,$\mu > 0$.
π_i	$i = m, r, s$ denote the profit of supply chain members and supply chain system, respectively.
U_i	$i = r, s$ denote the utility function of the retailer and the two-echelon supply chain system, respectively.
j	The superscript $j = o, f, of$, respectively, indicates the scenarios of overconfidence, fairness concern and two-behavioural preferences of the retailer.
*	The superscript * indicates the equilibrium solution of variables or profits (utilities)

3.2 Basic model: Retailer with no behavioural preferences

In this section, a setting where there are no behavioural preferences between members is considered in a supply chain. In other words, both the manufacturer and the retailer are unboundedly rational and only interested in their own monetary payoffs. Next, the function of the market demand and the members' profits are built, after which the manufacturer plays a Stackelberg game with the retailer.

Based on the above problem description, the demand function in a two-echelon supply chain is defined as follows

$$D = a - bp + ke \tag{1}$$

The above price- and sales effort-sensitive demand function is a kind of linear model structure and has been systematically proven by many researchers (e.g., Mukhopadhyay *et al.* [22], Zheng *et al.* [23]). The advantages of the deterministic linear function are that it can give rise to explicit results for the optimal solutions in behavioural supply chain and is relatively easy to estimate parameters (i.e., k, b) in next numerical studies. In fact, the demand function is divided into two parts: $a - bp$ and ke.The meaning of these parameters (i.e., a, b and k) is shown in Table 1. When $e = 0$, D is equal to $(a - bp)$, which is the essential demand function and only related to p. We here assume $e > 0$ to study the effect of behavioural preferences on it. Thus, the market demand depends on retail price p as well as sales effort e, where is positively related to the demand but p is negatively correlated with it.

The profit of the manufacturer, the retailer and the whole channel is given below

$$\pi_m = (w - c_m)(a + ke - bp) \tag{2}$$

$$\pi_r = (p - w - c_r)(a + ke - bp) - \frac{1}{2}\gamma e^2 \tag{3}$$

$$\pi_s = (p - c_m - c_r)(a + ke - bp) - \frac{1}{2}\gamma e^2 \tag{4}$$

where the meaning of π_m, π_r, c_m, c_r and γ is described in Table 1. The π_s is the channel profit of the two-echelon supply chain, which is equivalent to the π_m plus π_r. Obviously, it is essential to impose additional inequality constraints on the parameters to guarantee the correct functions. Thus, these constraints are as follows

- $w > c_m, p > c_r$ and $w \leq p$.
- $(p - w - c_r) \geq 0$, there is a reason it may encourage the retailer to participate in order-sale activity; otherwise, if $(p - w - c_r) < 0$, the retailer cannot order products from the manufacturer, and thus the two-echelon supply chain does not exist [24].
- The π_r must be positive, which encourages the retailer to order more quantities from manufacturer and sell more goods to customers by increasing sales effort level.
- The D, π_m must be positive.

To obtain the subgame perfect equilibria for both manufacturer and retailer, the backward induction method is applied. The timeline of events is as follows. In stage 2 of the Stackelberg game, the retailer maximizes himself profit by choosing p and e for each product. According to the Hessian matrix $H(e,p) = \begin{pmatrix} -2b & 0 \\ 0 & -\gamma \end{pmatrix}$ in Eq. 3, we know that there exists unique optimal solution, i.e., e^*, p^*. In stage 1 of the game, according to the retailer's reaction, the manufacturer rationally chooses the optimal price based on c_m. Similarly, based on the first-order condition of π_m, we then obtain the optimal wholesale price w^*. The proof of equilibrium results is given in Appendix A. Lastly, we can derive

$$w^* = \frac{a + b(c_m - c_r)}{2b} \tag{5}$$

$$e^* = \frac{[a - b(c_m + c_r)]k}{2(2b\gamma - k^2)} \tag{6}$$

$$p^* = \frac{(b\gamma - k^2)[a + b(c_r + c_m)] + 2ab\gamma}{2\mathrm{b}(2b\gamma - k^2)} \tag{7}$$

Substituting the above optimal decision variables Eqs. 5, 6 and 7 into Eqs. 2, 3 and 4, respectively, the equilibrium profit of the manufacturer, retailer, and supply chain system is obtained

$$\pi_m^* = \frac{[b(c_r + c_m) - a]^2\gamma}{4(2b\gamma - k^2)} \tag{8}$$

$$\pi_r^* = \frac{[b(c_r + c_m) - a]^2 \gamma}{8(2b\gamma - k^2)} \tag{9}$$

$$\pi_s^* = \frac{3\gamma[b(c_r + c_m) - a]}{8(2b\gamma - k^2)} \tag{10}$$

3.3 Behavioural model: Retailer with both overconfidence and fairness concern

In this section, the basic model is extended by incorporating overconfidence and fairness concern into the two-echelon supply chain. Specifically, we consider a setting where the manufacturer is unboundedly rational, whereas the retailer has both overconfidence and fairness concern in the two-echelon supply chain. Chen *et al.* [25] defined the retailer's overconfidence as an overestimation of the sales effort and market demand. What we convey in this paper is consistent with their idea of overconfidence. Thus, when the retailer is overconfident, the market demand is defined as $D_o = a + (k + \beta)e - bp$. The standard demand function can accurately measure the impact of overconfidence on demand. It is well known that the retailer's overconfidence parameter β is positively related to D_O, and the greater overconfidence degree β is, the greater is the effect of e on D_O. In Eq. 3, we replace D with D_O to obtain the utility function of overconfident retailer.

$$U_r^o = (p - w - c_r)[a + (k + \beta)e - bp] - \frac{1}{2}\gamma e^2 \tag{11}$$

The reference framework for fairness concern is the F-S model [26], and according to Zhang *et al.* [1], the retailer's utility with fairness concern is

$$U_r^f = \pi_r - \mu(\pi_m - \pi_r) = (1 + \mu)\pi_r - \mu\pi_m \tag{12}$$

wherein the μ is the degree of fairness concern, π_m and π_r is the profit of the rational retailer and manufacturer, respectively.

When the retailer with behavioural preferences, the rational manufacturer profit function is

$$\pi_m^{of} = (w - c_m)(a + ke - bp) \tag{13}$$

where Eq. 13 is equal to Eq. 2 because the manufacturer is unboundedly rational under the two scenarios.

According to Eqs. 12 and 13, the utility of retailer with the two behavioural preferences is as follows.

$$U_r^{of} = (1 + \mu)\{(p - w - c_r)[a + (k + \beta)e - bp] - \frac{1}{2}\gamma e^2\} - \mu(w - c_m)(a + ke - bp) \tag{14}$$

wherein when the retailer has both behavioural preferences, we can obtain Eq. 14 by replacing D with D_O in Eq. 12. Thus, the utility of the two-echelon supply chain system is equivalent to the manufacturer's profit plus the retailer's utility

The utility of the two-echelon supply chain is

$$U_s^{of} = (1 + \mu)\{(p - w - c_r)[a + (k + \beta)e - bp] - \frac{1}{2}\gamma e^2\} + (1 - \mu)(w - c_m)(a + ke - bp) \tag{15}$$

The Eqs. 14 and 15 can accurately measure the impact of behavioural preferences on utility, respectively.

In this section, the backward induction method is also applied to solve the subgame perfect equilibria for both the manufacturer and retailer. Following the same logic as in Section 3.2, we establish the Stackelberg game model in which the manufacturer maximizes profit and the retailer maximizes expected utility. As proof results in Appendix B, there are equilibrium solutions in the model when the retailer has the two-behavioural preferences.

$$w^{of*} = \frac{b^2 c_m \gamma(3\mu + 1) - bc_m k\beta(5\mu + 1) + (1 + \mu)[\beta(k + \beta)(bc_r - a) + b(a\gamma - b\gamma c_r - c_m\beta^2)]}{2b[b\gamma(2\mu + 1) - k\beta(3\mu + 1) - \beta^2(1 + \mu)]} \tag{16}$$

$$e^{of*} = \frac{[a - b(c_m + c_r)][2b\gamma\mu(k + 2\beta) - 2k\beta(2k + 3\beta) - \beta^3(2\mu + 1) + b\gamma(k + \beta)]}{2[2b\gamma - (k + \beta)^2][b\gamma(2\mu + 1) - k\beta(3\mu + 1) - \beta^2(1 + \mu)]} \tag{17}$$

$$p^{of*}=\frac{b\beta^3[\beta(1+\mu)+\gamma(1-\mu)]+[b\gamma^2(c_m+c_r)(\gamma-1)+ab\gamma(3b\gamma-k^2)+k\beta(ak^2+3bc_m\beta^2)](1+2\mu)}{2b[2b\gamma-(k+\beta)^2][b\gamma(1+2\mu)-\beta^2(1+\mu)-k\beta(1+3\mu)]}$$
$$+\frac{3bk\beta[(c_m+c_r)(b\gamma+k\beta)+c_r\beta^2](1+3\mu)+b\beta(c_m+c_r)(b\gamma\beta+k^3)(1+4\mu)}{2b[2b\gamma-(k+\beta)^2][b\gamma(1+2\mu)-\beta^2(1+\mu)-k\beta(1+3\mu)]} \quad (18)$$

Substituting the above optimal decision variables into Eqs. 13 and 14, respectively, the equilibrium profit of the manufacturer and the equilibrium utility of the retailer are obtained (due to the complexity of the utility function of the supply chain system, there is no display here, but it is equal to π_m^{of*} plus U_r^{of*}).

$$\pi_m^{of*}=\frac{(1+u)[b\gamma-(k+\beta)\beta]^2[a-b(c_m+c_r)]^2}{4b[2b\gamma-(k+\beta)^2][b\gamma(2\mu+1)-k\beta(3\mu+1)-\beta^2(1+\mu)]^2} \quad (19)$$

$$U_r^{of*}=\frac{\alpha(1+u)[a-b(c_m+c_r)]^2}{8b[2b\gamma-(k+\beta)^2][1+b\gamma(2\mu)-k\beta(1+3\mu)-\beta^2(1+\mu)]^2} \quad (20)$$

wherein $\alpha=b\gamma(b^2\gamma^2+k^2\beta^2)(1+2\mu)^2+2(b\beta\gamma)^2(3\mu^2-\mu-1)+2\mu(k\beta)^3(1+4\mu)+6\mu(k\beta^2)^2(1+3\mu)+6k\mu\beta^5(1+2\mu)+2\mu\beta^6(1+\mu)-b\beta\gamma[2bk\gamma(1+2\mu)(1+3\mu)+2k\beta^2(\mu^2-1)]+\beta^3(8\mu^2+4\mu+1)$.

4. Analysis of equilibrium results

In this section, the effects of a retailer's behavioural preference on the decision variables and utility/ profit of members in the two-echelon supply chain are discussed. In fact, the model with the retailer's two-behavioural preferences can reduce back to the model with the retailer's single-behavioural preference, i.e., the retailer has only overconfidence or fairness concern. Therefore, for a clearer explanation, this section is divided into three parts: the retailer with overconfidence only, the retailer with fairness concern only and the retailer with behavioural preferences. Note that all propositions below are proven in Appendix C.

4.1 The retailer with overconfidence only

When the retailer's fairness concern parameter μ is equal to zero, the situation of a retailer with behavioural preferences degenerates into a retailer with overconfidence only. Thus, the following propositions are presented.

Proposition 1. When the retailer is overconfident, the wholesale price of the manufacturer is equivalent to the optimal wholesale price shown in the setting of the retailer's unbounded rationality, i.e., $w^{o*}=w^*$, while the retailer's optimal sales price p^{o*} and sales effort level e^{o*} are both positively correlated with β.

Proposition 1 states that when deciding the wholesale price, the rational manufacturer is not bothered by the retailer's overconfidence, whereas the level of sales effort and the retail price deviate from the optimal value of Section 3.2 where the retailer is rational. In addition, the retailer's overconfidence makes him overestimate his marketing capabilities, which directly motivate the retailer to make a greater sales effort (for example, increasing promotions). On the other hand, recalling Section 3.3, which discusses the theory of a retailer's overconfidence, the retailer's overconfidence parameter β is positively related to the market demand D_O, which means he overestimates the market demand. Thus, the superposition effect of the two aspects allows the retailer to continuously increase the retail price for a non-negative profit.

Proposition 2. When the retailer has overconfidence only, as its degree β increases, the profit of the manufacturer, the utility of the retailer, and the utility of the supply chain system also increase, i.e., π_m^{o*}, U_r^{o*} and U_s^{o*} are positively related to β.

Along with Proposition 1, Proposition 2 indicates that the overconfident retailer overestimates the market demand and sales effort level, and orders more products to meet customer demand as long as the wholesale price is constant, which can form a scale effect to increase profit for the manufacturer. The increase in the retailer's utility is attributed to two aspects: first, overconfident behaviour makes him overestimate the market demand, and thus enhances his sales enthusiasm, which will in turn increase the sales volume of the product in general; second, the rise in the retail price increases the marginal revenue of every product. Thus, the increase in manufacturer profit and retailer utility ultimately leads to an increase in the utility of the supply chain system.

4.2 The retailer with fairness concern only

When the retailer's overconfident parameter β is equal to zero, the scenario of a retailer with behavioural preferences degenerates into the situation of a retailer with fairness concern only. Thus, the series of propositions below are obtained.

Proposition 3. When the retailer only pays attention to the fairness of income distribution in a two-echelon supply chain, the higher the degree of fairness concern μ, the lower is the wholesale price $w^{f*}$of the manufacturer, while the retail price $p^{f*}$and sales effort level $e^{f*}$are constant.

Proposition 3 shows in order to alleviate the retailer's unfair aversion, raise retailer's profitability and keep the competitiveness of the supply chain system, the manufacturer as the leader in the two-echelon supply chain needs to make concession, that is, he must lower the wholesale price, which means that the retailer can boost his bargaining power in the supply chain when he is concerned with the fairness of the relative revenue between the members. Nevertheless, the retailer's optimal decisions are not affected by his own fairness concern behaviour, the possible reason is that in order to maintain market share and improve demand, retailer does not adjust retail price and sales effort level because of fairness concern. The proposition is clearly different from the conclusions in other papers, e.g., Li *et al.* [17], Zheng *et al.* [27], where the retail price is both affected by fairness concern in a two-echelon supply chain.

Proposition 4. When the retailer has fairness concern only, the best utility of retailer U_r^{f*} grows with increasing degree of fairness concern μ, but the best profit of manufacturer π_m^{f*} falls with increasing μ. If μ is in the range of $(0,(\sqrt{2}-1)/2)$, the U_s^{f*} decreases as μ increases; otherwise, if μ is in the range of $((\sqrt{2}-1)/2,+\infty)$, the U_s^{f*} rises as μ increases.

Combining the change in wholesale price of Proposition 3, we clearly explain why the manufacturer's profit deceases with μ. In particular, Proposition 4 indicates that when μ is in the range of $(0,(\sqrt{2}-1)/2)$, the bargaining power of the retailer is weak, which causes the decline in the manufacturer's profit margin to be higher than the increase in the retailer's utility margin; however, as μ increases, the retailer's bargaining power gradually increases, which causes the decline rate in the manufacturer's profit margin to be lower than the increase rate in the retailer's utility margin, and the supply chain system consists of a manufacturer and a retailer, thus its utility first declines and then rises. Moreover, from $\mu>0$ and the conversion node of bargaining power for the retailer, i.e., $\mu=(\sqrt{2}-1)/2$, it can be found that the retailer's bargaining space is very large.

4.3 The retailer with both overconfidence and fairness concern

When the retailer has both overconfidence and fairness concern, we obtain the following propositions. Due to the complex formula of the utility or profit between supply chain members, this section only analyses the effect of the two behavioural preferences (i.e., overconfidence and fairness concern) on decision variables.

Proposition 5. If other parameters remain unchanged, when the degree of overconfidence β is in the range of $((b\gamma-\sqrt{(b\gamma)^2-2b\gamma k})/2k,(b\gamma+\sqrt{(b\gamma)^2-2b\gamma k})/2k)$, the wholesale price decreases as β increases, and when β is outside the range, the wholesale price increases as β increases.

Unlike those in Proposition 1, Proposition 5 indicates that when the retailer has both overconfidence and fairness concern, if β is in the range of $((b\gamma-\sqrt{(b\gamma)^2-2b\gamma k})/2k,(b\gamma+\sqrt{(b\gamma)^2-2b\gamma k})/2k)$, the retailer's overconfidence will cause the manufacturer upstream of the supply chain to lower the wholesale price to encourage the retailer to order more products, which will ultimately increase the manufacturer's profit. When β is outside the range of $((b\gamma-\sqrt{(b\gamma)^2-2b\gamma k})/2k,(b\gamma+\sqrt{(b\gamma)^2-2b\gamma k})/2k)$, the rational manufacturer may realize that the retailer's degree of overconfidence is unreasonable, and he can raise the wholesale price of the product to maximize his own revenue. This finding also coincides with the situation whereby merchants seek more profit in reality.

Proposition 6. If other parameters remain unchanged, the optimal wholesale price w^{of*}, the optimal retail price p^{of*} and the optimal sales effort e^{of*} are positively or negatively correlated with μ, which depends on the range of the degree of overconfidence β.

Proposition 6 is significantly different from Proposition 3, it shows that the correlation of the optimal decision variables (i.e., $w^{of*}, p^{of*}, e^{of*}$) and μ is determined by the range of β when other parameters are given; in other words, they are positively or negatively correlated with μ as the β changes, and β changes the decision results of members by first affecting the degree of μ in the supply chain. Thus, the above description illustrates that the degree of fairness concern changes according to the degree of overconfidence, and overconfidence is the main factor affecting the decision-making of the supply chain between the two behavioural preferences. Therefore, in actual operation management, when a leading manufacturer analyses or evaluates the effect of the two behavioural preferences of the retailer on business decisions, it is particularly important to pay attention to the retailer's overconfidence degree.

4.4 Comparative analysis of different models

For a clearer understanding of the influence of behavioural factors, optimal equilibrium solutions between basic model and behavioural model are analysed below. At the same time, due to the complexity of decision variables, we only compare the differences in wholesale price and in sales effort in two scenarios, respectively.

Proposition 7. The optimal wholesale price in Section 3.3 is less than that in Section 3.2, i.e. $\Delta w = w^{of*} - w^* < 0$. Nevertheless, the optimal sales effort in Section 3.3 is more than that in Section 3.2, i.e., $\Delta e = e^{of*} - e^* > 0$. In addition, both Δw and Δe increase with the degree of fairness concern μ.

Proposition 7 indicates that compared with the scenario of complete rationality, the two behavioural preferences are unfavourable to wholesale price, but they are conductive to the improvement of sales effort level. Moreover, the fairness concern degree μ can gradually expand the difference of decision variables (i.e., w, e) in different scenarios. Thus, we can show that the two-behavioural preferences are more favourable to retailer decision about sales effort.

5. Numerical analysis

We use numerical experiments to illustrate how the decision variables, profits and utilities change with behavioural preferences in the three scenarios. In this section, some parameter values are gathered by analysing the previous papers. According to [19] and [28], we set $\beta \in [0,1]$ and $\mu = \{0,1,2\}$ to illustrate the retailer's preference degree with regard to overconfidence and fairness concern in this paper. Moreover, we set $a = 100, \gamma = 1, c_m = 6, c_r = 8, b = 5$, and $k = 2$, which the constraint conditions of Stackelberg game models can be satisfied. Then, we can firstly obtain the equilibrium results $w^* = 9, p^* = 19.5, e^* = 5, \pi_m^* = 37.5, \pi_r^* = 18.75, \pi_s^* = 56.25$ in the first scenario.

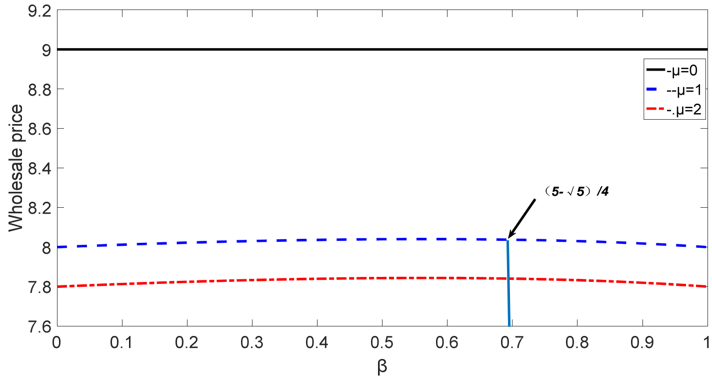

Fig. 2 Wholesale price under three scenarios

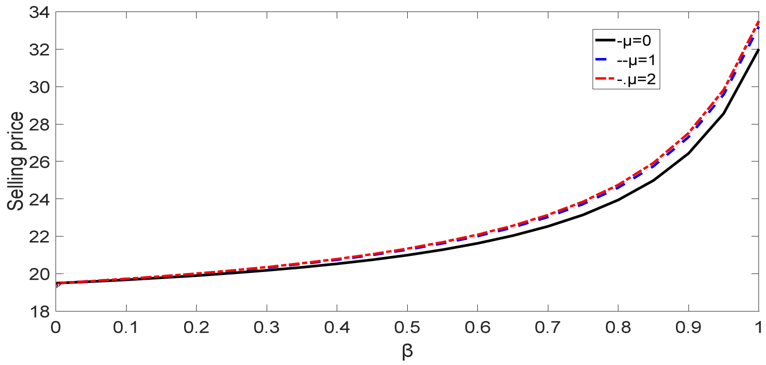

Fig. 3 Retail price under three scenarios

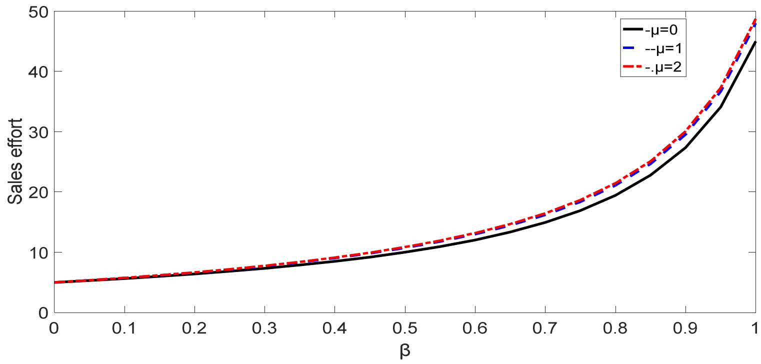

Fig. 4 Sales effort under three scenarios

When the retailer has single-behavioural preference or two-behavioural preferences, the changes in the decision variables, profit/utility and the utility of the two-echelon supply chain system are shown in Fig. 2 to Fig. 7.

In Fig. 2, when the retailer has overconfidence only(μ=0，0<$\beta \leq 1$), the wholesale price of the manufacturer w^{o*} is equal to w^{*}that the retailer is rational ($\mu = 0, \beta = 0$); when the retailer has fairness concern only($\beta = 0, \mu = \{1,2\}$), the wholesale price w^{f*} is negatively correlated with μ. This finding verifies the correctness of Propositions 1 and 3. Moreover, as β increases, the wholesale price in the two-behavioural preferences ($0 < \beta \leq 1, \mu = \{1,2\}$) slightly increases at the beginning and then decreases afterwards, the turning point being $(5-\sqrt{5})/4$. That is, the w^{of*} is negatively correlated with β in the interval $[(5-\sqrt{5})/4,1]$, and it is positively correlated with β in the interval $(0,(5-\sqrt{5})/4]$. This finding is consistent with the results of Proposition 5. In addition, the wholesale price in the dual-preferences scenario is a decreasing function of μ. In short, the wholesale price in the two-behavioural preferences is less than or equal to that in the single-behavioural preference. Therefore, the interaction of the two behavioural preferences is detrimental to the wholesale price.

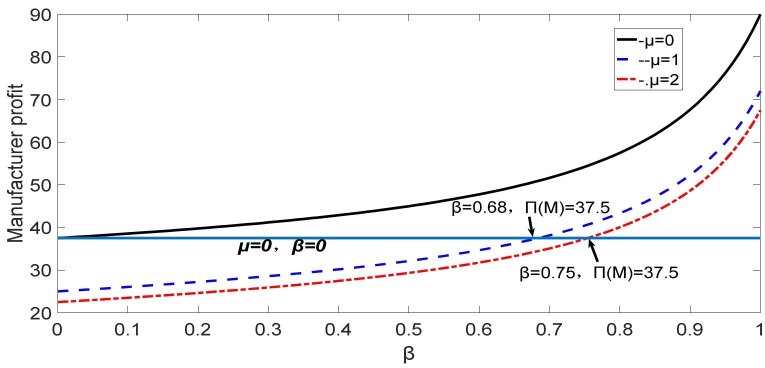

Fig. 5 Manufacturer profit under three scenarios

As shown in Figs. 3 and 4, both the sales price and sales effort are positively correlated with β and μ when retailer has confidence only ($\mu = 0, 0 < \beta \leq 1$) or dual-preferences ($0 < \beta \leq 1, \mu = \{1,2\}$). Although the μ has a slight influence on sales price and sales effort, the two decisions are evidently affected by β. This result is mainly attributed to the fact that the retailer's overconfidence is the overestimation of market demand and sales effort, which prompts the retailer to raise the sale price and make a greater sales effort. In addition, the effects of μ on retail price and on sales effort under the scenario with fairness concern ($\beta = 0, \mu = \{1,2\}$)and with rationality ($\beta = 0, \mu = 0$) are compared. Intuitively, the retailer concerning with the fairness of profit between members must pursue greater profits by improving price and sales effort level. However, as shown in Figs. 3 and 4, the retail price and sales effort remain unchanged. Therefore, this intuition is incorrect. Moreover, when retailer has overconfidence only, the values of both retail price and sales effort are more than these values when supply chain members are rational. In particular, for retailer, the gap of decision variables between the two scenarios is constantly expanding when β increases. In summary, based on the Fig. 3, Fig.4 and analysis, we find that the retailer's overconfidence β is the main factor affecting retailer decision-making; in other words, behavioural preferences are beneficial to retailer's decisions, but are unfavourable to manufacturer's decision.

Fig. 5 illustrates that the optimal manufacturer's profit is an increasing function of β, but a decreasing function of μ in three scenarios. When the retailer is overconfident only, the manufacturer's profit π_m^{o*} is evidently larger than π_m^*, which confirms the result of Proposition 2. Besides, the difference of profit for manufacturer in the two scenarios (i.e., retailer has overconfidence only, retailer is rationality) quickly increases in β, but the difference of profit for manufacturer in the two scenarios (i.e., retailer has fairness concern only, retailer is rationality) gradually enlarges in μ. When the retailer has both overconfidence and fairness concern, the π_m^{of*} is lower than π_m^* at the beginning and then higher than π_m^* afterwards in the situation in which β and μ reach a certain value (i.e., $\beta = 0.68, \mu = 1; \beta = 0.75, \mu = 2$), respectively. In addition, in the three scenarios, the incremental slopes of the profit from the perspective of β is higher than the decrease in the slopes of profit from the perspective of μ, which also highlights that the main factor affecting the profit of the manufacturer is the retailer's overconfidence.

Both β and μ are beneficial to the retailer's utility in three scenarios in Fig. 6. Specially, as β increases, the utility growth rate of the retailer would be higher. The reasons for the above phenomena are the increase in the sales price and sales effort under the influence of the two behavioural preferences. At the same time, the gap of utility for retailer in the two scenarios (i.e., retailer has overconfidence only, retailer is rationality) gently grows in β,but the gap of utility for retailer in the two scenarios (i.e., the retailer has fairness concern only, the retailer is rationality) gradually decreases in μ. Comparing Fig. 6 with Fig. 5, we know that when retailer has overconfidence only the utility of retailer is less than or equal to the profit of manufacturer. However, when retailer has fairness concern only, the utility of retailer is gradually more than the profit of manufacturer. In particular, when retailer has both overconfidence and fairness concern, the utility of retailer is significantly larger than the profit of manufacturer, which may be due to the increase in retail price and sales of products. Therefore, the retailer's two-behavioural preferences are more favourable to his own utility than the manufacturers' profit.

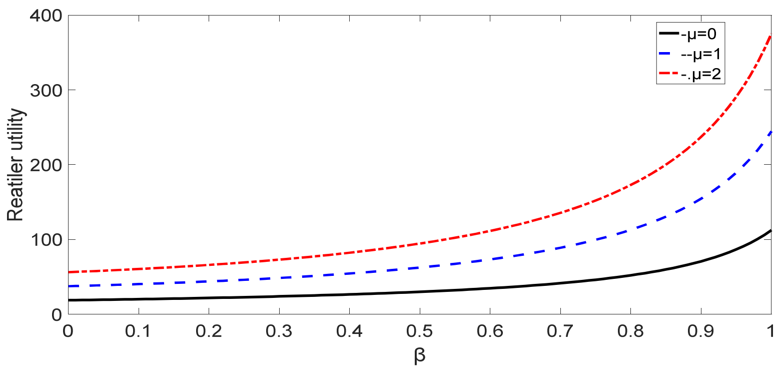

Fig. 6 Retailer's utility under three scenarios

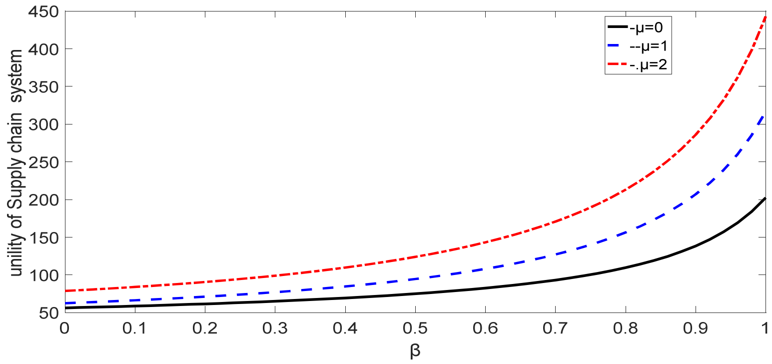

Fig. 7 Utility of the supply chain system under three scenarios

Based on Fig. 7, the utility of the supply chain system is positively correlated with β and μ in three scenarios. Combined with the analysis in Figs. 5 and 6, it is found that the change rate and trend of the utility curve between the retailer and the supply chain system are consistent. As we know, the utility of the supply chain system comprises the manufacturer's profit and the retailer's utility. Hence, the effect of the retailer's utility change on the utility of supply chain system is most obvious, which reflects to the importance of retailers' behavioural preferences in the two-echelon supply chain system.

6. Conclusion

In this paper, by establishing Stackelberg game models in which the manufacturer as a leader is unboundedly rational, and the retailer as a follower has two behavioural preferences, we analysed the effect of two behavioural preferences on equilibrium solutions, such as the wholesale price, sales price, sales effort and utility, under three scenarios and compared the equilibrium solutions with the results under the setting of the rational retailer. Based on these propositions and on the results from the numerical analysis, the conclusions and recommends of this paper are summarized as follows:

- When the retailer has a single behavioural preference, the overconfidence can improve the retailer's sales price and sales effort, while also increasing the utility (or profit) of the members and the supply chain system. Although fairness concern does not affect the retailer's sales price and sales effort level, they help improve the utility of the retailer and are not conducive to the manufacturer's pricing and profit, which ultimately cause fluctuation in the utility of the supply chain system. Moreover, the gap about retail price between the scenario of single-behavioural preference and the scenario of rationality is gradually increasing as overconfidence or as fairness concern. The same is true for sales effort.
- When the retailer has both overconfidence and fairness concern, the two behavioural preferences influence both the decision-making and utility (or profit) of the supply chain members. Between the two behavioural preferences, overconfidence is the main preference. Most importantly, the degree of fairness concern changes according to the degree of overconfidence, which can determine if fairness concern has a positive or negative influence on the wholesale price, sales price and sales effort. In addition, the positive effect of overconfidence on decision-making of the members in the supply chain is more pronounced than the retailer's fairness concern.

In practice, when information is transparently shared in the supply chain system, manufacturers, as the leader of the supply chain, can synthetically compare the historical transaction data of retailers with the actual market demand, and then evaluate the degree of the two behavioural preferences of retailers, especially the degree of overconfidence. For retailer, higher levels of overconfidence and fairness concern are needed to pursue more profits or utility. However, manufacturer should adopt reasonable incentives, e.g., contracts (Xiao *et al.* [3]), premiumpenalty mechanism, to guide retailers to control the degree of behaviour preferences, thereby promoting the improvement of profit and utility of the entire supply chain system.

One limitation of this study is that market demand is certain. As we know, the change in market environment and customer preference may induce a variety in market demand. Thus, we will build relevant models to study the effect of uncertainty and fuzziness base on different behavioural preferences, such as the uncertain demand function. In addition, combined with empirical economics, designing experimental studies in which the testers (retailers or manufacturers) are guided to control the degree of behavioural preferences within a reasonable range and reduce the negative effect is also on our research agenda. Finally, the profit distribution mechanism between the members will be designed and examined in the supply chain.

Acknowledgment

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Appendix A

When the members are unboundedly rational in the supply chain, their objectives are to maximize their respective gains. We apply the backward inductive method to model a Stackelberg game and obtain the equilibrium solutions.

In Eq. 3, the first-order and second-order derivative of π_r with respect to the decision variables p and e are the following

$$\begin{cases} \frac{\partial \pi_r}{\partial p} = a + ke - 2bp + b(w + c_r) = 0 \\ \frac{\partial \pi_r}{\partial e} = (p - w - c_r)k - \gamma e = 0 \end{cases} \tag{A1}$$

because $\frac{\partial^2 \pi_r}{\partial^2 p} = -2b < 0, \frac{\partial^2 \pi_r}{\partial^2 e} = -\gamma < 0$.Thus, the retailer has a unique equilibrium solution for retail price and sales effort. Thus, we obtain the following formula of the retail price and sales effort

$$\begin{cases} p = \frac{(b\gamma - k^2)(w + c_r) + a\gamma}{2b\gamma - k^2} \\ e = \frac{[a - b(w + c_r)]k}{2b\gamma - k^2} \end{cases} \tag{A2}$$

Based on the demand function, i.e., $D = a + ke - bp$, then substituting Eq. A2 into D, we can obtain $D = \frac{b\gamma[a - b(c_m + c_r)]}{2b\gamma - k^2}$. Recall that the assumption $D > 0$ holds. Therefore, $2b\gamma - k^2 > 0$, $a - b(c_m + c_r) > 0$.

By substituting Eq. A2 into Eq. 2, we obtain the function $\pi_m(w)$.

$$\pi_m(w) = \frac{b\gamma(w - c_r)[a - b(w + c_r)]}{2b\gamma - k^2} \qquad \text{A3)}$$

In Eq. A3, the first-order and second-order conditions of π_m with respect to the decision variable w are as follows: $\frac{d\pi_m}{dw} = \frac{b\gamma[a - b(2w + c_r - c_m)]}{2b\gamma - k^2} = 0, \frac{d^2 \pi_m}{d^2 w} = \frac{-2\gamma b^2}{2b\gamma - k^2} < 0$.Thus, the manufacturer has a unique equilibrium solution regarding wholesale price. The equilibrium solution of the wholesale price is obtained.

$$w^* = \frac{a + b(c_m - c_r)}{2b} \tag{A4}$$

Substituting Eq. A4 into Eq. A2, we obtain the optimal solution regarding retail price and sales effort.

$$\begin{cases} p^* = \frac{(b\gamma-k^2)[a+b(c_r+c_m)]+2ab\gamma}{2b(2b\gamma-k^2)} \\ e^* = \frac{[a-b(c_m+c_r)]k}{2(2b\gamma-k^2)} \end{cases} \tag{A5}$$

Lastly, we substitute these equilibrium solutions of w^*, e^* and p^* into Eq. 2, Eq. 3 and Eq. 4, and the equilibrium profits of the manufacturer, retailer, and supply chain system are obtained, as shown in Eqs.8, 9, and 10.

Appendix B

First, must to prove that the retailer utility function U_r^{of} has a unique equilibrium solution. The first-order and second-order derivative of U_r^{of} with respect to p and e are as follows

$$\begin{cases} \frac{\partial U_r^{of}}{\partial p} = (1+\mu)[a+(k+\beta)e-bp-(p-w-c_r)]-\mu(w-c_m)(a-bp+ke)=0 \\ \frac{\partial U_r^{of}}{\partial e} = (1+\mu)[(p-w-c_r)(k+\beta)-\gamma e]-\mu k(w-c_m)=0 \end{cases} \tag{B1}$$

because $\frac{\partial^2 U_r^{of}}{\partial^2 p} = -2b(1+\mu) < 0, \frac{\partial^2 U_r^{of}}{\partial^2 e} = -(1+\mu)\gamma < 0$.Thus, the retailer with both overconfidence and fairness concern has a unique equilibrium solution regarding retail price and sales effort. Thus, we obtain the formula of the retail price and sales effort

$$\begin{cases} p^{of} = \frac{-(1+\mu)(k+\beta)^2(w+c_r)+a\gamma(1+\mu)+b\gamma w(1+2\mu)+k\mu(k+\beta)(c_m-w)+b\gamma[(1+\mu)c_r-\mu c_m]}{(1+\mu)[2b\gamma-(k+\beta)^2]} \\ e^{of} = \frac{(k+\beta)[(1+a)\mu-b(w+c_r)+b\mu(c_m-c_r)]+(a-2bw)k\mu}{(1+\mu)[2b\gamma-(k+\beta)^2]} \end{cases} \tag{B2}$$

Substituting Eq. B2 into $D_O = a-bp+(k+\beta)e$, we can obtain

$D_O = \frac{b[\beta\mu(k+\beta)(w-c_m)+(1+\mu)\gamma(a-bc_r)+b\gamma(w(1+2\mu)-\mu c_m]}{(1+\mu)[2b\gamma-(k+\beta)^2]}$. Recall the assumption $D_O > 0$. In addition, the additional inequality constraints in Section 3.2, $w > c_m, p > c_r$, $a - bc_r > 0$. Therefore, $[\beta\mu(k+\beta)(w-c_m)+(1+\mu)\gamma(a-bc_r)+b\gamma(w(1+2\mu)-\mu c_m] > 0$ and $2b\gamma > (k+\beta)^2$, i.e., $0 \le \beta \le \sqrt{2b\gamma}-k$. In addition, substituting Eq. B2 into Eq. 14, we obtain $\pi_m^{of}(w)$.

$$\pi_m^{of}(w) = \frac{(w-c_r)\{\beta(k+\beta)[bc_r\mu-a(1+\mu)]+b\beta w[(1+3\mu)k+\beta(1+\mu)]-b^2\gamma[(1+\mu)c_r+w(1+2\mu)]+bc_m\mu(b\gamma-2k\beta)\}}{(1+\mu)[2b\gamma-(k+\beta)^2]} \tag{B3}$$

In Eq. B3, the first-order and second-order conditions of $\pi_m^{of}(w)$ with respect to w is $\frac{d\pi_m}{dw} = 0, \frac{d^2\pi_m}{d^2 w} = \frac{-2b\{[2b\gamma-(k+\beta)^2](1+\mu)+k(k+\beta)+\mu k(k-\beta)]}{(1+\mu)[2b\gamma-(k+\beta)^2]} < 0$, respectively. Thus, the manufacturer has a unique equilibrium solution regarding wholesale price when the retailer has both overconfidence and fairness concern. The equilibrium solution is

$$w^{of*} = \frac{b^2 c_m\gamma(3\mu+1)-bc_m k\beta(5\mu+1)+(1+\mu)[\beta(k+\beta)(bc_r-a)+b(a\gamma-b\gamma c_r-c_m\beta^2)]}{2b[b\gamma(2\mu+1)-k\beta(3\mu+1)-\beta^2(1+\mu)]} \tag{B4}$$

Substituting Eq. B4 into Eq. B2, the optimal solutions regarding retail price and sales effort are obtained.

$$\begin{cases} e^{of*} = \frac{[a-b(c_m+c_r)][2b\gamma\mu(k+2\beta)-2k\beta(2k+3\beta)-\beta^3(2\mu+1)+b\gamma(k+\beta)]}{2[2b\gamma-(k+\beta)^2][b\gamma(2\mu+1)-k\beta(3\mu+1)-\beta^2(1+\mu)]} \\ p^{of*} = \frac{b\beta^4(1+\mu)+b\gamma\beta(1-\mu)+[b\gamma^2(c_m+c_r)(\gamma-1)+ab\gamma(3b\gamma-k^2)+k\beta(ak^2+3bc_m\beta^2)](1+2\mu)+6abk\gamma\beta\mu}{2b[2b\gamma-(k+\beta)^2][b\gamma(1+2\mu)-\beta^2(1+\mu)-k\beta(1+3\mu)]} + \\ \frac{3bk\beta[(c_m+c_r)(b\gamma+k\beta)+c_r\beta^2](1+3\mu)+b\beta(c_m+c_r)(b\gamma\beta+k^3)(1+4\mu)+ak\beta^2(k\mu+\beta)(3+4\mu)-ab\gamma\beta(4+5\mu)(\beta-7k)}{2b[2b\gamma-(k+\beta)^2][b\gamma(1+2\mu)-\beta^2(1+\mu)-k\beta(1+3\mu)]} \end{cases} \tag{B5}$$

Lastly, substituting the equilibrium solutions into Eqs.13 and 14, the equilibrium profit of the manufacturer and retailer are obtained, as shown in Eqs.19 and 20.

Appendix C

Poof of Proposition 1

When the retailer has overconfidence only, we set μ to 0 in Eqs.(16), (17) and (18), and the optimal wholesale price, retail price and sales effort are obtained. It is easy to see that

$$w^{o*} = \frac{a+b(c_m-c_r)}{2b} \tag{C1}$$

$$p^{o*} = \frac{[b\gamma-(k+\beta)^2][a+b(c_r+c_m)]+2ab\gamma}{2b[2b\gamma-(k+\beta)^2]} \tag{C2}$$

$$e^{o^*} = \frac{(k+\beta)[a-b(c_m+c_r)]}{2[2b\gamma-(k+\beta)^2]} \tag{C3}$$

Next, the first-order conditions of w^{o*}, p^{o*}, e^{o*} with respect to $\beta$are as follows. $\Delta w = w^{o*} - w^* = 0$, $\frac{dp^{o*}}{d\beta} = \frac{(k+\beta)\gamma[a-b(c_m+c_r)]}{[2b\gamma-(k+\beta)^2]^2}$, $\frac{de^{o*}}{d\beta} = \frac{[a-b(c_m+c_r)][2b\gamma+(k+\beta)^2]}{2[2b\gamma-(k+\beta)^2]^2}$. According to Appendix A and B, since$a - b(c_m + c_r) > 0, 2b\gamma - (k+\beta)^2 > 0$, hence $\frac{dp^{o^*}}{d\beta} > 0, \frac{de^{o^*}}{d\beta} > 0$.

Proof of Proposition 2

Similar to the proof process for Proposition 1, let $\mu = 0$ in Eqs.19 and 20, the manufacturer's profit, the retailer's utility and the utility of the supply chain when the retailer has overconfidence only are obtained.

$$\pi_m^{o*} = \frac{[a-b(c_m+c_r)]^2[br-\beta(k+\beta)]}{4b[2b\gamma-(k+\beta)]^2} \tag{C4}$$

$$U_r^{o*} = \frac{\gamma[a-b(c_m+c_r)]^2}{8[2b\gamma-(k+\beta)^2]} \tag{C5}$$

$$U_s^{o*} = \pi_m^{o*} + U_r^{o*} = \frac{[a-b(c_m+c_r)]^2[3b\gamma-2\beta(k+\beta)]}{8b[2b\gamma-(k+\beta)^2]} \tag{C6}$$

Thus, $\frac{d\pi_m^{o*}}{d\beta} = -\frac{[a-b(c_m+c_r)]^2[2b\gamma\beta-k(k+\beta)^2]}{4b[2b\gamma-(k+\beta)^2]^2}$, $\frac{dU_r^{o*}}{d\beta} = \frac{(k+\beta)\gamma[a-b(c_m+c_r)]^2}{4[2b\gamma-(k+\beta)^2]^2}$, respectively. According to Appendix B, since $2b\gamma - (k+\beta)^2 > 0$, hence, $\frac{d\pi_m^{o*}}{d\beta} > 0, \frac{dU_r^{o*}}{d\beta} > 0$. Meanwhile, $U_s^{o*} = \pi_m^{o*} + U_r^{o*}$, that is, manufacturer profit and retailer utility together affect the change of utility of the supply chain system. Thus, the U_s^{o*} has same property, i.e., $\frac{dU_s^{o*}}{d\beta} > 0$.

Proof of Proposition 3

When the retailer has fairness concern only, i.e., $\beta = 0, \mu > 0$. Thus, let $\beta = 0$ in Eqs.16, 17 and 18, and the optimal wholesale price, retail price and sales effort for each member in the scenarios are as follows:

$$w^{f*} = \frac{(1+\mu)(a-bc_r)+(3\mu+1)bc_m}{2b(2\mu+1)} \tag{C7}$$

$$p^{f*} = \frac{(b\gamma-k^2)[a+b(c_r+c_m)]+2ab\gamma}{2b(2b\gamma-k^2)} \tag{C8}$$

$$e^{f*} = \frac{[a-b(c_r+c_m)]k}{2(2b\gamma-k^2)} \tag{C9}$$

Then, the first-order conditions of w^{f*}, p^{f*}, e^{f*} with respect to μ is $\frac{dw^{f*}}{d\mu} = -\frac{a-b(c_m+c_r)}{2b(2\mu+1)^2}$, $p^{f*} = p^*, e^{f*} = e^*$. According to Appendix A, $a - b(c_m + c_r) > 0$. Hence, $\frac{dw^{f*}}{d\mu} < 0$. Interestingly, comparing $p^{f*}$and e^{f*} with $p^*$and e^*, the optimal price and sales effort of the retailer with fairness concern are equal to the equilibrium results of the retailer without fairness concern.

Proof of Proposition 4

Similar to the proof process for Proposition 3, let $\beta = 0$ in Eqs.19 and 20, the equilibrium manufacturer's profit, the retailer's utility and utility of supply chain when the retailer has fairness concern only are obtained.

$$\pi_m^{f*} = \frac{(1+\mu)\gamma[a-b(c_m+c_r)]^2}{4(1+2\mu)(2b\gamma-k^2)} \tag{C10}$$

$$U_r^{f*} = \frac{(1+\mu)\gamma[a-b(c_m+c_r)]^2}{8(2b\gamma-k^2)} \tag{C11}$$

$$U_s^{f*} = \pi_m^{f*} + U_r^{f*} = \frac{(1+\mu)(2\mu+3)\gamma[a-b(c_m+c_r)]^2}{8(2\mu+1)(2b\gamma-k^2)} \tag{C12}$$

and $\frac{d\pi_m^{f*}}{d\mu} = -\frac{\gamma[a-b(c_m+c_r)]^2}{4(1+2\mu)^2(2b\gamma-k^2)} < 0$; $\frac{dU\pi_r^{f*}}{d\mu} = \frac{\gamma[a-b(c_m+c_r)]^2}{8(2b\gamma-k^2)} > 0$; $\frac{dU\pi_s^{f*}}{d\mu} = \frac{[a-b(c_m+c_r)]^2(4\mu^2+4\mu-1)\gamma}{8(2\mu+1)^2(2b\gamma-k^2)}$. According to Appendix A, $2b\gamma - k^2 > 0$, thus, $\frac{d\pi_m^{f*}}{d\mu} > 0$and $\frac{dU\pi_r^{f*}}{d\mu} > 0$ .For the function $\frac{dU\pi_s^{f*}}{d\mu}$, let$(4\mu^2 + 4\mu - 1) = 0$, $\mu_1 = \frac{1-\sqrt{2}}{2}$ and $\mu_2 = \frac{-1+\sqrt{2}}{2}$ are obtained. Since $\mu > 0$, thus, μ_1 is omitted; Given the $\mu \in (0, \mu_2)$, the $(4\mu^2 + 4\mu - 1)$ is less than zero by calculating; then the $\frac{dU(\pi^f)}{d\mu} < 0$ can be observed. Whereas given the $\in (\mu_2, +\infty)$, we can receive the $\frac{d\pi^f}{d\mu} > 0$.

Proof of Proposition 5

When the retailer has dual-preferences, the first-order partial derivative of w^{of*} with respect to β is as follows:

$$\frac{\partial w^{of*}}{\partial \beta} = \frac{\mu(1+\mu)[a-b(c_m+c_r)][b\gamma+2\beta(k\beta-b\gamma)]}{2b[b\gamma(1+2\mu)-k\beta(1+3\mu)-\beta^2(1+\mu)]^2} \tag{C13}$$

According to Appendix A, $a - b(c_m + c_r) > 0$, and $b > 0, \mu > 0, \mu(1 + \mu) > 0$, and the denominator of $\frac{\partial w^{of*}}{\partial \beta}$ is positive. Thus, it is easy to see that $\frac{\partial w^{of*}}{\partial \beta}$ is less than zero or more than zero depending on the degree of $b\gamma + 2\beta(k\beta - b\gamma)$.

Let $b\gamma + 2\beta(k\beta - b\gamma) = 0$, we can easily obtain the $\beta_1 = \frac{b\gamma-\sqrt{(b\gamma)^2-2b\gamma k}}{2k}$ and $\beta_2 = \frac{b\gamma+\sqrt{(b\gamma)^2-2b\gamma k}}{2k}$. According to Appendix B, $2b\gamma > (k + \beta)^2$, and β is in the interval (0,1]. Thus, we obtain $(b\gamma)^2 - 2b\gamma k \in (0, b\gamma)$ and $0 < \beta_1 < \beta_2 < 2k$. Therefore, $\frac{\partial w^{of*}}{\partial \beta} > 0$ only when$\beta \in (0, \beta_1)$ or $\beta \in (\beta_2, 1]$; $\frac{\partial w^{of*}}{\partial \beta} < 0$ only when $\beta \in (\beta_1, \beta_2)$. Note that the partial derivatives of p^{of*}, e^{of*} with respect to β are more complex. There is no analysis listed here, but their analysis will be carried out through numerical analysis.

Proof of Proposition 6

When the retailer has dual-preferences, the first-order derivative of w^{of*},$e^{of*}$and p^{of*} with respect to μ are as follows:

$$\frac{\partial w^{of*}}{\partial \mu} = \frac{(b\gamma-2k\beta)[br-\beta(k+\beta)][a-b(c_m+c_r)]}{2b[b\gamma(2\mu+1)-k\beta(3\mu+1)-\beta^2(1+\mu)]^2} \tag{C14}$$

$$\frac{\partial e^{of*}}{\partial \mu} = \frac{[a-b(c_m+c_r)][b\gamma-\beta(k+\beta)]}{2[b\gamma(2\mu+1)-k\beta(3\mu+1)-\beta^2(1+\mu)]^2} \tag{C15}$$

$$\frac{\partial p^{of*}}{\partial \mu} = \frac{k\beta[br-\beta(k+\beta)][a-b(c_m+c_r)]}{2b[b\gamma(1+2\mu)-(1+\mu)\beta^2-(1+3\mu)k\beta]^2} \tag{C16}$$

Since $(b\gamma - 2k\beta)$ may be greater than zero or less than zero, we assume $2k\beta > b\gamma$ or $2k\beta < b\gamma$. Let $b\gamma - \beta(k + \beta) = 0$; it is easily to obtain $\beta_3 = \frac{k-\sqrt{k^2+4b}}{-2}$ and $\beta_4 = \frac{k+\sqrt{k^2+4b}}{-2}$. Recall that $\beta \in (0,1]$, and $0 < k < \sqrt{k^2+4b} < 2$ can be easily observed. Hence, the β_4 is omitted, and β_3 is reserved. The β_3 has two intervals (0,1) or [1, +∞). Here, we only analyse the interval (0,1), because it is easily observed that the relationship between optimal wholesale price and μ when β_3 is in the range of [1, +∞).

We first present the relationship between $w^{of*}$and μ when $2k\beta > b\gamma$. It can be easily verified that the denominator of $\frac{\partial w^{of*}}{\partial \mu}$is positive and that $a - b(c_m + c_r)$ and b are positive. Therefore, $\frac{\partial w^{of*}}{\partial \mu} < 0$ only when$\beta \in (0, \beta_3)$, and $\frac{\partial w^{of*}}{\partial \mu} > 0$ only when $\beta \in (\beta_3, 1]$. Next, we present the relationship between $w^{of*}$and μ when $2k\beta < b\gamma$; in the same condition, we obtain where $\frac{\partial w^{of*}}{\partial \mu} > 0$ only when $\beta \in (0, \beta_3)$, and $\frac{\partial w^{of*}}{\partial \mu} < 0$ only when $\beta \in (\beta_3, 1]$.The proofs for $\frac{\partial e^{of*}}{\partial \mu} > 0, \frac{\partial p^{of*}}{\partial \mu} > 0$ or $\frac{\partial e^{of*}}{\partial \mu} < 0, \frac{\partial p^{of*}}{\partial \mu} < 0$ are similar.

Proof of Proposition 7

Comparing the optimal wholesale price and sales effort under basic model and behavioural model, we get the solutions:

$$\Delta w = w^{of*} - w^* = -\frac{(a-b(c_m+c_r))(2k\beta+b\gamma)\mu}{2b\big(b\gamma(1+2\mu)+\beta((1+\mu)\beta+(1+3\mu)k)\big)} \quad \text{(C17)}$$

$$\Delta e = e^{of*} - e^* = \frac{k(a-b(c_m+c_r))(k+2\beta)}{2(2b\gamma-k^2)(b\gamma(1+2\mu)-k\beta(1+3\mu)-\beta^2(1+\mu))} \quad \text{(C18)}$$

Since $\beta \in (0,1]$,$a - b(c_m + c_r) > 0$and $2br - (k + \beta)^2 > 0$,in addition, the optimal sales effort must be greater than 0, thus $(b\gamma(1 + 2\mu) > k\beta(1 + 3\mu) + \beta^2(1 + \mu))$. Therefore $\Delta w < 0$ and $\Delta e > 0$.

$$\frac{\partial \Delta w}{\partial \mu} = \frac{\beta(a-b(c_m+c_r))(2k\beta+b\gamma)(\beta+k)}{2b\big(b\gamma(1+2\mu)+\beta((1+\mu)\beta+(1+3\mu)k)\big)^2} \quad \text{(C19)}$$

$$\frac{\partial \Delta e}{\partial \mu} = \frac{k(a-b(c_m+c_r))(k+2\beta)\big(2b\gamma-\beta^2-3k\beta\big)}{4(2b\gamma-k^2)(b\gamma(1+2\mu)-\beta^2(1+\mu)-\beta k(1+3\mu))^2} \quad \text{(C20)}$$

According to $a - b(c_m + c_r) > 0$, obviously, $\frac{\partial \Delta w}{\partial \mu} > 0$. In addition, since$\beta \in (0,1]$, $b \geq 1, \gamma \geq 1$, $2b\gamma > \beta^2 + 3k\beta$,and $2b\gamma > \beta^2 + 3k\beta$, thus, $\frac{\partial \Delta e}{\partial \mu} > 0$.