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Research Article

Supply Chain Decisions and Coordination under the Combined Effect of Overconfidence and Fairness Concern

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The purpose of this study was to examine the joint effect of overconfidence and fairness concern on supply chain decisions and design contracts to achieve a win-win situation within the supply chain. For this study, a centralized supply chain model was established without considering the retailers' overconfidence and fairness concern. Furthermore, the retailers' overconfidence and fairness concerns were introduced into the decentralized supply chain, while the Stackelberg game model between the manufacturer and the retailer was built. Furthermore, an innovative supply chain contract, i.e., buyback contract, with promotional cost sharing was designed to achieve supply chain coordination along with overconfidence and fairness concern. Finally, a numerical analysis was also conducted to analyze the effect of overconfidence, fairness concern, and the validity of the contract. The principal findings of the study include the positive correlation between retailers' overconfidence and optimal order quantity, sales effort, expected utility, and profit. Although the order quantity and sales efforts were not affected by the fairness concern of the retailer, the contract achieved coordination with a win-win outcome when the level of overconfidence and fairness concern was moderate.

1. Introduction

In a global supply chain, the manufacturer sells their product to the retailer at a wholesale price set by the manufacturer, and in response, the retailer chooses the order quantity. Retailers sell goods to consumers through various promotional methods. Besides the interaction between manufacturer and retailer, a reasonable wholesale price, appropriate order quantity, and valid promotion are crucial factors for supply chain members. However, players in the supply chain often tend to show characteristics of bounded rationality in complex and uncertain environments, such as overconfidence [1] and fairness concern [2]. These two behavior preferences were observed anecdotally in practice. For example, Eastman Kodak Company overestimated its technical ability and ignored the planning for the future, which led to declined sales and eventually bankruptcy [3]; Gome in March 2016 was concerned about distributional fairness and wanted to capitalize on its dominating power in the retailing industry to extract more profit from the manufacturer [4]. Overconfidence is the most widespread cognitive bias in the decision-making process. Fairness concern is the reflection of sociological emotions, which are related to social preferences in the supply chain. Therefore, overconfidence and fairness concern could affect decision-making profoundly in a wide range of areas, such as ordering, pricing, and sales effort.

In general, the above two behavioral preferences, i.e., overconfidence and fairness concern, coexist in the decision-making process. A typical case can be used to illustrate the phenomenon. During the Chinese shopping festival "Double 11" of 2014, Alibabas' transaction value exceeded RMB 57.1 billion. Before the onset of Double 11, the CEO of Taobao predicted that the refund rate would be in single-digit percentage points. However, the real refund rate was 69%, and the real complaint rate was higher than usual, for example, Haier complaint rate was 54.2% [5]. The significant discount on the activity motivated a large number of end customers with irrational shopping behavior, which resulted in return orders and complaint rate. This case indicated that overconfidence and fairness concern coexisted in the decision-making process. On the one hand, the prediction by the CEO and the high refund rate indicated that a large number of people were overconfident. Consequently, wrong decisions caused losses, which included seller and consumer concern fairness issues that resulted in a high complaint rate. Hence, the coexistence of overconfidence and fairness concern was not occasional but inevitable. In the context of the supply chain, numerous interactions existed between overconfidence and fairness concern. Overconfidence on-demand prediction triggered retailer overordering, while fairness concern had an opposite effect on the retailer's decisions. For instance, in the "Double 11" shopping festival, a retailer of China believed that he possessed better marketing capabilities than others and thus ordered more products from a large manufacturer, e.g., Procter & Gamble (P&G). However, the retailer made lower-than-expected profit due to excessive inventory and marketing expenses. Meanwhile, the retailer reduced order quantity and increased retail price because he felt that P&G was unfairly seizing a disproportionate share of the profit [6]. Therefore, this paper introduces overconfidence and fairness concern into the context of the supply chain. Based on random market demands, we analyzed the retailer's behavioral preferences in decision-making, which affects the decision-making ability, profits, and utility in the supply chain.

The decision makers of the decentralized supply chain are sufficiently rational. However, they suffer when manufacturers charge a wholesale price higher than the production cost so that the amount of order quantity in the decentralized channel is lower in the centralized channel analog [7]. Therefore, coordination is a critical issue in supply chain management. At the same time, the members of the supply chain aim to maximize their profits, which results in the well-known problem of "double marginalization." In order to solve this problem, various coordinating contracts were proposed in different supply chain structures. However, coordinating conditions and the degrees of difficulty during coordination changes depend on behavioral factors [8]. Among many different types of contracts, combined contract, i.e., the combination of two or more contracts, has received widespread attention and proved to be effective in resolving these conflicts [9]. As compared to the centralized supply chain, optimal decisions or profits in a decentralized supply chain are always suboptimal when the retailer has behavioral preferences in the decentralized supply chain.

Based on these challenges, two critical scenarios are considered: (a) the centralized supply chain, wherein the manufacturer and retailer make decisions as a whole to maximize the total expected profit, and (b) the decentralized supply chain consisting of a rational manufacturer and a retailer with overconfidence and fairness concern, wherein members are independent decision makers and aim to maximize their profits. We then assessed the effect of behavioral preferences on the equilibrium outcome for this decentralized supply chain and compared these effects to their centralized channel analogs. We observed that the two cognitive biases could trigger the decision makers of decentralized supply chain members to deviate from their optimal decisions in the centralized supply chain, which reduces the profitability of the decentralized supply chain. Thus, a valid buyback contract with promotional cost sharing was proposed to coordinate the decentralized supply chain with overconfidence and fairness concern. Such a contract is based on two types of conventional contracts: buyback contract and promotional cost-sharing contract. In the buyback contract, the upstream manufacturer commits to buying back unsold goods from the downstream retailer at the end of the selling season in order to encourage the retailer to order more. The latter contract is designed to share the cost of retailers' sales efforts on increasing sales. The buyback contract with promotional cost sharing has been widely applied in various industries, such as procurement of industrial materials [10], medical devices [11], and retailing [12].

The remainder of the paper is organized as follows: the relevant papers are described in Section 2, whereas Section 3 formalizes the problem. The two important models are presented and solved, i.e., (a) the centralized supply chain model wherein the members are both rational and (b) the decentralized supply chain model wherein the retailer has overconfidence and fairness concern. The combined effect of overconfidence and fairness concern on supply chain decisions has also been discussed. In Section 4, the buyback contract with promotional cost sharing is proposed to coordinate supply chain decisions in the presence of cognitive biases. A numerical analysis is conducted to examine the theoretical models and propositions in Section 5. Lastly, the conclusions and directions for future studies are discussed in Section 6.

2. Literature Review

There are three streams of literature related to our paper: overconfidence, fairness concern, and supply chain coordination. In this section, the recent literature on these three topics has been reviewed and summarized.

2.1. Overconfidence. Some studies have investigated overconfidence in supply chain management (SCM). Croson et al. [13] first introduced overconfidence into the supply chain and analyzed the decisions of overconfident newsvendors. Li et al. [14] examined the implications and influences of overconfidence in a competitive newsvendor setting. Similarly, Liu et al. [15] presented a two-period service capacity procurement model and found that a dynamic wholesale price mechanism could eliminate the negative effect of overconfidence. Xu et al. [16] explored the effects of overconfidence on retailers in different games. Li [17] identified that overconfidence could reduce the double marginalization effect in a decentralized supply chain. The papers mentioned above defined the decision makers' overconfidence based on a biased belief that the variance of demand was underestimated. Hence, in this paper, the retailers' overconfidence had the same definition. Besides, we also considered that the overconfident retailer overestimated the mean of market demand and the effects of their own sales effort on demand. Moreover, the most existing papers only focused on the effect of overconfidence on the ordering or pricing; we extended previous research and analyzed the effect of overconfidence on pricing, ordering, and sales effort.

2.2. Fairness Concern. Fairness concern has been studied extensively in SCM. Cui et al. [18] analytically and experimentally evaluated how fairness significantly affected the pricing decisions of the manufacturer and the retailer. Similar issues were considered by Wu et al. [19], who examined the influence of fairness concern on the retailers' profit allocation in the newsvendors' model. A recent paper by Chen et al. [20] also analyzed the interactions between fairness concern and decisions, including pricing and service level in a dual-channel supply chain consisting of a manufacturer and two retailers. Also, Liu et al. [21] investigated the impact of different fairness concerns on order allocation in the logistics service supply chain. Zhang et al. [22] revealed the characteristics of price changes when fairness concern was categorized into unfavorable and favorable disutility, respectively. The above papers mainly studied how fairness concerns affected decision variables in various supply chain structures. Motivated by those papers, we also analyzed the decision-making problems of members in a two-echelon supply chain wherein the retailer had fairness concerns. However, we extended previous studies and analyzed the impact of fairness concern on pricing, ordering, and the sales effort, while other papers ignored sales effort.

2.3. Supply Chain Coordination. It can be seen from Sections 2.1 and 2.2 that both overconfidence and fairness concern had a systematic effect on the decision-making and performance in supply chains; they also cause decision-making bias. Therefore, in order to pursue a win-win situation and reduce decision biases, appropriate coordination mechanisms are especially necessary. To date, various contracts have been developed in behavioral supply chain management. For fairness concern, Cui et al. [18] incorporated fairness concern into a conventional supply chain and considered its influence on channel coordination between a manufacturer and a retailer. Cui's model was then extended by Liu et al. [21] to include a nonlinear demand. They further devised a revenue-sharing contract to coordinate a two-echelon CLSC with both members' fairness concerns. Nevertheless, Zheng et al. [4] proposed a cooperative game approach to coordinate a three-echelon closed-loop supply chain with fairness concern. For overconfidence, based on the principal-agent theory, Wang et al. [23] designed an optional contract to achieve a two-echelon supply chain with overconfidence coordination and Pareto improvement. Jiang et al. [24] studied the effect of supplier overconfidence on buyback contracts in a financing supply chain. These studies revealed that fairness concerns and overconfidence could complicate coordination in a supply chain, and existing research along this line is generally confined to a supply chain within a non-cooperative game setting.

Based on these critical features of our model, we tabulated our research in the context of a proper literature review (Table 1). The table revealed that the majority of the literature concentrates on the coordination of different structure supply chains with single-behavioral preference, i.e., overconfidence or fairness concern. However, overconfidence and fairness concern coexist in practice, and this paper extends the depth and breadth of related literature about behavioral preferences. Besides, the two cognitive biases (overconfidence and fairness concern) were simultaneously taken into consideration, and the buyback contract with promotional cost sharing was proposed in this paper. Nevertheless, the focus of our paper was to investigate the impact of retailers' fairness concern and overconfidence on the coordination results of a two-echelon supply chain by employing a Stackelberg game approach. We examined the validity of the contract under conditions that the retailer had cognitive biases, which were aligned with previous research.

3. Assumptions and Models

3.1. Assumptions. A two-echelon supply chain was considered, which included the rational manufacturer as the leader of the supply chain, while the retailer had overconfidence and fairness concern. The manufacturer produced products at unit production cost c and then sold them at unit wholesale price w to the retailer. The retailer then sold those to customers at unit retail price p. The manufacturer and the retailer showed risk neutrality. Let s be the unit salvage value, v be the unit stockout cost, and q be the order quantity of the retailer. According to Ma et al. [25], we assumed that the sales effort cost of the retailer was monotonically increasing as convex function, i.e., $C(e)$ denoted the sales effort cost, where $C(e) = (1/2)\gamma e^2$ $\gamma (\gamma > 0)$ is the sales cost coefficient and $e (e > 0)$ is the retailers' sales effort denoted by the promotional effort level. Without loss of generality, we assumed that $0 < s < c < v < p$, $w > c$, and $q > 0$.

In the two-echelon supply chain, the manufacturer determined the wholesale price w, and the retailer determined the order quantity q and sales effort e, i.e., w, q, and e were decision variables of supply chain members. s, v, and γ were assumed to be exogenous variables. Note that the retail price p was also assumed to be exogenous.

3.2. Centralized Supply Chain Model. In this section, we considered the scenario wherein the manufacturer and the retailer made decisions as individuals. The model with no behavioral preferences was analyzed as a benchmark. Besides, the goal of the coordination contract in Section 4 was to allow supply chain performance to achieve the optimal situation under complete rationality. Hence, the benchmark was kept under complete rationality [8, 26]. However, the only goal was to maximize the overall profitability of the supply chain by determining the optimal order quantity q and sales effort e. Previous studies proved that when decision makers were entirely rational, the equilibrium solutions of

Table 1: Differences between this paper and relevant studies.

Papers	Overconfidence	Fairness concern	Demand function	Coordination
Croson et al. [13]	✓		Stochastic demand	
Li et al. [14]	✓		Deterministic demand	
Liu et al. [15]	✓		Deterministic demand	
Xu et al. [16]	✓		Stochastic demand	
Li [17]	✓		Stochastic demand	
Cui et al. [18]		✓	Deterministic demand	Wholesale price contract
Wu et al. [19]		✓	Stochastic demand	
Chen et al. [20]		✓	Deterministic demand	Revenue sharing contract
Liu et al. [21]		✓	Deterministic demand	Membership-profit share contract
Zhang et al. [22]		✓	Deterministic demand	
Zheng et al. [4]	✓		Deterministic demand	Cooperative game mechanism
Wang et al. [23]	✓		Stochastic demand	Option contract
Jiang et al. [24]	✓		Stochastic demand	Wholesale price contract with buyback
This study	✓	✓	Stochastic demand	Buyback contract with promotion cost sharing

the centralized supply chain were always better than the decentralized behavioral supply chain [27, 28]. In order to explore research problems and compare optimal decision variables to the decentralized supply chain with behavioral preference analogs, we assumed that the decision maker was rational in the centralized supply chain. According to Xu et al. [16], the stochastic demand function is as follows:

$$D = a - bp + e + \theta, \tag{1}$$

where a signifies the market scale, while b is the price sensitivity coefficient of random demand. The above function indicated that sales effort e has a positive influence on demand $D\,(D > 0)$. The sales price p is exogenous; therefore, we assumed that θ denotes the uncertainty of the demand, which was a random variable following a uniform distribution on the interval $[-A, A]$, wherein $A > 0$ denotes the variation range of the random variable. For variable θ, the cumulative distribution function is $F(\theta)$, and the probability density function is $f(\theta)$. According to the assumption, $f(\theta) = (1/2A)$ and $F(\theta) = (\theta - A/2A)$. Also, to avoid trivial cases, we assumed $A < a$ and $a - bp > 0$, which guaranteed that the demand is nonnegative.

Under settings that did not guarantee market demand, we took q to be more than the demand D, i.e., the decision maker faced the situation of overstock. Under such a situation, we assumed $-A < \theta < q - (a - bp + e)$. In contrast, when q was less than D, $q - (a - bp + e) < \theta < A$ was obtained, which indicated that the decision maker faced a situation of stockout. We assumed that $\theta_0 = q - (a - bp + e)$ indicated that order quantity was equal to the actual market demand D. Hence, $f(\theta_0) = (1/2A)$ and $F(\theta_0) = ((c - v)/(s - v))$.

The profit for the centralized supply chain can be expressed as

$$\max_{q,e} \prod^{c} = pE[min\{q, D\}] + E[s(q - D)]^{+} - E[v(D - q)]^{+} - cq - C(e). \tag{2}$$

The first term in equation (2) is the expected revenue of the supply chain, while the second term signifies the expected surplus value if the situation of overstock happened. The third is the expected loss provided the decision makers' order quantity was out of stock. The term cq is the total production cost, and the last term indicated promotion effort, i.e., the cost of sales.

The first-order derivatives of equation (2) with respect to q and e are

$$\begin{cases} \dfrac{\partial E(\prod^{c})}{\partial q} = (s - v)F(\theta_0) + v - c = 0, \\[2ex] \dfrac{\partial E(\prod^{c})}{\partial e} = (p - v) + (v - s)F(\theta_0) - \gamma e = 0. \end{cases} \tag{3}$$

Therefore, the Hessian matrix is

$$H(q, e) = \begin{pmatrix} (s - v)f(\theta_0) & 0 \\ 0 & (s - v)f(\theta_0) - \gamma \end{pmatrix}. \tag{4}$$

Note that $s - v < 0$ and $f(\theta_0) > 0$; thus, the Hessian matrix Π^c is a negative definite for q and e. We can obtain optimal order quantity and sales effort as follows:

$$\begin{cases} q^{c*} = \dfrac{(v - s)[(a - bp)\gamma + (p - c)] + A\gamma(v + s - 2c)}{(v - s)\gamma}, \\[2ex] e^{c*} = \dfrac{(p - c)}{\gamma}. \end{cases} \tag{5}$$

3.3. Decentralized Supply Chain Model. In this section, the overconfidence and fairness concerns were incorporated into the two-echelon supply chain, wherein the manufacturer was reported to be rational, while the retailer had a cognitive bias. We assumed an overconfident retailer who not only underestimated the variance of demand but also overestimated the mean of demand and the effect of sales effort on demand. According to Chen et al. [3], we adopted mean-increasing and variance-reducing transformation of the actual market demand D. Thus, the market demand can be explained as follows:

$$D_O = a - bp + (1+\beta)e + (1-\beta)\theta = a - bp + (1+\beta)e + \theta_1, \tag{6}$$

wherein β indicates the overconfident level $(0<\beta<1)$. Moreover, the continuous random variable θ_1 is equal to $(1-\beta)\theta$, which is a random noisy signal and assumed to be uniformly distributed, i.e., $\theta_1 \sim U(-A, A)$. When $\beta = 0$, the retailer had no overconfidence, whereas for $0<\beta<1$, the mean of D_O increased and the variance of D_O decreased as compared to the mean and variance of D, i.e., $E(D_O) > E(D)$ and $\mathrm{var}(D_O) < \mathrm{var}(D)$. Meanwhile, the impact of the promotion effort $((1+\beta)e > e)$ on market demand was overestimated, i.e., the influence of e on market demand increased as β increased.

Similarly, when market demand was uncertain, we considered an order quantity q for the retailer with overconfidence and fairness concern provided q was more than the random demand D_o. Such an arrangement indicated that the retailer faced an overstock situation. In this situation, we have $-A < \theta_1 < q - [a - bp + (1+\beta)e]$. In contrast, if q was less than D_O, $q - [a - bp + (1+\beta)e] < \theta_1 < A$ was obtained, which indicated that the retailer faced a stockout situation, i.e., we assumed that $\theta_2 = q - [a - bp + (1+\beta)e]$. Hence, $F(\theta_2) = (\mu(w-c) + (1+\mu)(w-v)/(s-v)(1+\mu))$. The utility of the overconfident retailer is as follows:

$$\begin{aligned}\max_{q,e} U_r^o = {} & pE[\min\{q, D_o\}] + E[s(q - D_O)^+] \\ & - E[v(D_O - q)]^+ - wq - C(e).\end{aligned} \tag{7}$$

The reference framework for a retailer with fairness concern is the F-S model [29]:

$$U_r^f = \prod_r - \mu\left(\prod_m - \prod_r, 0\right) - \lambda\left(\prod_r - \prod_m, 0\right), \tag{8}$$

where μ is the degree of fairness concern and λ is the coefficient of sympathy, $\mu, \lambda \geq 0$, and $0<\lambda<1$. The first part of equation (12) reflected the retailer's profit, whereas the second part evaluated the utility loss from disadvantageous inequality for the retailer when $\pi_m > \pi_r$, and the third part measured the loss from advantageous inequality for the retailer when $\pi_m < \pi_r$. Note that if the retailer's profit was worse than the manufacturers' profit (i.e., $\pi_m > \pi_r$), the retailer will have negative utility under the condition of unfair aversion. In contrast, if his profit was more significant than the manufacturers', the retailer will also suffer positive utility because of the sympathy. However, Qin et al. [30] demonstrated that the profit of the leader in a supply chain often accounted for more than half of the overall profit when the Stackelberg game was carried out. In this paper, the retailer is a weak follower as compared to the manufacturer who served as the leader. Alongside this, we found out that the profit of the manufacturer was twice that of the retailer when the manufacturer and the retailer were both unboundedly rational. Figures 4 and 5 validate the result in Section 5 when $\mu = 0, \beta = 0$; hence, the retailer had the negative utility of unfair aversion. Therefore, according to equation (8), when the retailer had fairness concern only, his utility function was corrected to

$$U_r^f = \prod_r - \mu\left(\prod_m - \prod_r\right) = (1+\mu)\prod_r - \mu\prod_m, \tag{9}$$

where $\prod_r$ and $\prod_m$ denotes the profit of the rational retailer and the rational manufacturer, respectively. $\mu > 0$ is the degree of fairness concern.

According to the theories of overconfidence and fairness concern, the utility of the retailer with the two behavioral preferences which was replaced by $\prod_r$ in equation (9) with U_r^o in equation (7) is as follows:

$$\max_{q,e} U\left(\prod_r^d\right) = (1+\mu)U_r^o - \mu\prod_m^d. \tag{10}$$

The retailer with behavioral preference orders q from the manufacturer, the rational manufacturer profit function is

$$\max_w \prod_m^d = (w-c)q. \tag{11}$$

The Stackelberg game model, where the manufacturer was serving as the leader and the retailer served as the follower, was established in the decentralized supply chain. The events of the model are described as follows. Firstly, the manufacturer decided the wholesale price w. Then, the retailer made decisions about the order quantity q and the sales effort e based on the decision of the manufacturer and market demand. To solve the subgame perfect equilibrium, the backward induction method was applied. The equilibrium solutions under the Stackelberg game model were considered when the retailer had a cognitive bias. The solutions are as follows. The proof is given in Appendix A.

$$w^{d*} = \frac{(a - bp)(1 + \mu)(v - s)\gamma + (v - s)(1 + \beta)^2[(1 + \mu)p + (1 + 3\mu)c] + A\gamma[(s + v)(1 + \mu) + 2(1 + 3\mu)c]}{2(1 + 2\mu)\left[2A\gamma + (v - s)(1 + \beta)^2\right]}, \tag{12}$$

$$q^{d*} = \frac{(a - bp)(v - s)\gamma + (1 + \beta)^2(v - s)(p - c) + A\gamma(s + v - 2c)}{2(v - s)\gamma}, \tag{13}$$

$$e^{d*} = \frac{(1 + \beta)\left[(a - bp)(s - v)\gamma + (p - c)(v - s)(1 + \beta)^2 + 2A\gamma(2p - c - s - v)\right]}{2\gamma\left[2A\gamma + (1 + \beta)^2(v - s)\right]}. \tag{14}$$

Based on the above equilibrium solutions in the decentralized supply chain, the propositions about the effect of overconfidence and fairness concern (β and μ) on decision variables (q^{d*}, e^{d*}, and w^{d*}) are shown as in the following. Note that the proof of all propositions can be found in Appendix B.

Proposition 1. *When the retailer had both overconfidence and fairness concern, the optimal order quantity q^{d*} and sales effort e^{d*} were both positively correlated with the overconfident level β but had nothing to do with the degree of fairness concern μ. Furthermore, q^{d*} is a strictly convex function with respect to β.*

Proposition 1 indicated that the overconfident drives the retailer to increase order volume and improve sales efforts. The reason is that overconfidence had two main effects. On the one hand, the retailer overestimated the average market demand and exaggerated the effectiveness of sales effort, which directly motivated the retailer to make a more considerable sales effort (for example, increasing promotions). On the other hand, the retailer overestimated that the variance of the "random impact factor θ_1" is smaller than the actual level. In other words, from his point of view, a smaller market demand fluctuation influenced prediction. Thus, the two effects made the retailer order more product quantities and pay more sales effort for more revenue. Meanwhile, it was easy to find that q^{d*} and e^{d*} were only related to β as per equations (13) and (14), which revealed that the retailers' decisions on ordering and sales efforts were not affected by fairness concern.

Proposition 2. *When the retailer has both overconfidence and fairness concern, the optimal wholesale price w^{d*} is positively proportional to the overconfident level β but inversely proportional to the degree of fairness concern μ.*

Proposition 2 illustrated that the cognitive bias of the retailer had an opposite effect on the manufacturers' decision. Firstly, the moment the rational manufacturer realized that the overconfident retailer could increase the order quantity, he raised the wholesale price of the product to maximize the profit, which was consistent with the anecdotes that merchants in real world could take advantage of others' overconfidence to maximize their profit. Besides, when the manufacturer understood the features of the retailers' fairness concern, he lowered the wholesale price to alleviate the retailers' unfair aversion, which implied that the retailer could boost his bargaining power in the supply chain while he was concerned with the fairness. Therefore, the rational manufacturer was required to set a reasonable wholesale price to balance the influence of the two cognitive biases. Next, we compared the equilibrium outcomes in the centralized supply chain model with those in the decentralized supply chain model. There is a proposition as follows.

Proposition 3. *q^{c*} may be more than or less than q^{d*}; e^{c*} may be more than or less than e^{d*}. Interestingly, $\Delta q = q^{d*} - q^{c*}$, and $\Delta e = e^{d*} - e^{c*}$ increases as the overconfidence level β increases, respectively.*

According to Proposition 3, the effect of overconfidence, the optimal order quantity, and sales effort on the decentralized supply chain could deviate from the optimal equilibrium solution in the centralized supply chain, which resulted in a loss of the expected profits, thereby increasing the revenue gap between manufacturer and retailer.

4. Buyback Contract with Promotion Cost Sharing

It can be seen from Section 3.3 that due to the cognitive bias of the retailer, his decisions deviated from the optimal decisions in the centralized supply chain, which affected the profit or utility of supply chain members. Thereby, in order to coordinate the profit or utility between the supply chain members and ensure the maximized performance of the two-echelon supply chain, according to Bai et al. [31], the buyback contract with promotional cost sharing was proposed in this section. Here, the manufacturer served as the leader, who buys back the unsold products from the retailer at the buyback price and shared the promotional cost. We denoted this contract factor as (w^{sc}, r, and $1 - \phi$), where w^{sc} is the wholesale price, r is the buyback price, and $1 - \phi$ is the fraction of promotional costs that the rational manufacturer paid, while the retailer undertook ϕ portion of the cost $(0 < \phi < 1)$. In order to avoid retailers' overordering and encourage the retailer to accept the contract, we assumed $0 < s \leq r < w^{sc}$. Based on these descriptions and assumptions above, the manufacturers' profit and retailers' utility are given by the following expression:

$$\prod_{m}^{sc} = (w-c)q + E[(s-r)(q-D_O)]^{+} - (1-\phi)C(e), \tag{15}$$

$$U\left(\prod_{r}^{sc}\right) = (1+\mu)\{p[(a-bp+(1+\beta)e)] + E[r(q-D_O)^{+}] - E[v(D_O-q)^{+}] - wq - \phi C(e)\} - \mu\prod_{m}^{sc}, \tag{16}$$

wherein equation (15) is the profit when the manufacturer buys back the unsold products at buyback price r from the retailer and thus obtained the surplus value of these products. $(1-\phi)C(e)$ is the promotional costs which the manufacturer undertook. $r(q-D_O)^{+}$ in equation (16) is the revenue when the retailer sells the unsold inventory of products to the manufacturer at the end of the selling season. $\phi C(e)$ is the promotional costs which he pay.

According to the first derivations of equation (16) based on q and e, the following expression is obtained:

$$\begin{cases} q^{sc} = \dfrac{2A(1+\mu)(v-w) - \mu(w-c)}{(1+\mu)(v-r) + \mu(s-r)} + a - bp + (1+k)e^{sc} - A, \\ e^{sc} = \dfrac{(1+\beta)[\mu(p+c-2w) + p - w]}{(2\mu\phi - \mu + \phi)\gamma}. \end{cases} \tag{17}$$

In the buyback contract with promotion cost sharing to achieve supply chain coordination, the optimal decisions of the retailer were the same as those under the centralized supply chain model, that is, $q^{sc} = q^{c*}$ and $e^{sc} = e^{c*}$ [25, 26]. Therefore, equation (17) needs to be equal to equation (5) as the contract factors (w^{sc}, r) were obtained:

$$w^{sc*} = \frac{[\beta(1+\mu) + 1 - \phi(1+2\mu)]p + [\beta\mu + (1+2\mu)\phi]c}{(1+2\mu)(1+\beta)}, \tag{18}$$

$$r^{*} = \frac{(v-s)(p-c)(1+\beta)(1+\mu)v\beta + 2A[\gamma\phi(p-c)(1+2\mu) + \beta cv(1+\mu)] - 2A\gamma\{p(v-s)[1+\beta+(2+\beta)\beta\mu] - sv(1+\beta)(1+\mu)\}}{(1+2\mu)(1+\beta)[\beta(p-c)(v-s) + 2A\gamma(c-v)]}. \tag{19}$$

The purpose of the buyback contract with promotion cost sharing was to design a reasonable profit allocation scheme between the rational manufacturer and the retailer with cognitive bias. It should be noted that if the profit of supply chain members became lower, the contract was unacceptable. The contract was acceptable if and only if $\prod_m^{sc} \geq \prod_m^{d*}$ and $U(\prod_r^{sc}) \geq U(\prod_r^{d*})$.

Based on the above equilibrium solutions in the contract, the following propositions were obtained. Due to the sophisticated formula of the buyback price, this section discussed the effect of overconfidence and fairness concern on wholesale price.

Proposition 4. *The optimal wholesale price in the buyback contract with promotion cost sharing was negatively correlated with μ and ϕ. Nevertheless, if $\phi < (\mu/(1+2\mu))$, the wholesale price w^{sc*} is positively correlated with β. In contrast, if $\phi < (\mu/(1+2\mu))$, it is negatively correlated withβ.*

Proposition 4 implied that the contract was adopted, and the negative effect of fairness concern μ on wholesale price w^{sc*} remained consistent with Proposition 2. Besides, as w^{sc} increased, ϕ decreased and $1-\phi$ increased accordingly, which meant that the manufacturer bore more promotional cost when the wholesale price rose, which is in line with the practice. Meanwhile, the values of μ and ϕ determined the impact of β (positive or negative influence) on the wholesale price w^{sc}, which indicated that fairness concern μ and promotional cost portion $1-\phi$ were critical to manufacturer's decisions on the wholesale price w^{sc}. Thus, when the two types of behavioral preferences coexisted in the contract, the effect of overconfidence on the optimal wholesale price depended on the relationship between fairness degree and fraction of promotion cost. Since the utility and profit functions in the supply chain included a large number of unknown parameters under three scenarios (i.e., Sections 3.2, 3.3, and 4), it was difficult to compare and analyze the effects of the cognitive biases. Thus, numerical methods were utilized to conduct further analysis in the next section.

5. Numerical Analysis

In this section, a numerical study approach was adopted to allow a more in-depth insight into the two behavioral preferences. First, a numerical experiment was conducted to show how equilibrium solutions and profit (utility) in the two-echelon supply chain changed along with the levels of overconfidence and fairness concern (i.e., β and μ) and to examine the robustness of propositions. Then, we also determined the effect of overconfidence and fairness concern on the buyback contract with promotional cost sharing.

In our experiments, some parameters were gathered from the existing papers. For the parameters related to overconfidence, Ren et al. [1] set $\beta \in [0,1]$ and $c = \{0.5, 0.6, 0.8, 0.9\}$ to perform their numerical experiments, and Li et al. [7] set $\beta \in (0,1)$ and $c = 5$ to conduct their study. For the parameters related to fairness concern, Zheng et al. [4] set $\mu \geq 0$, $c = 20$, and $a = 100$ to implement their numerical analysis, and Guo et al. [9] set $\mu \geq 0$ to perform their studies. According to the parameters above,

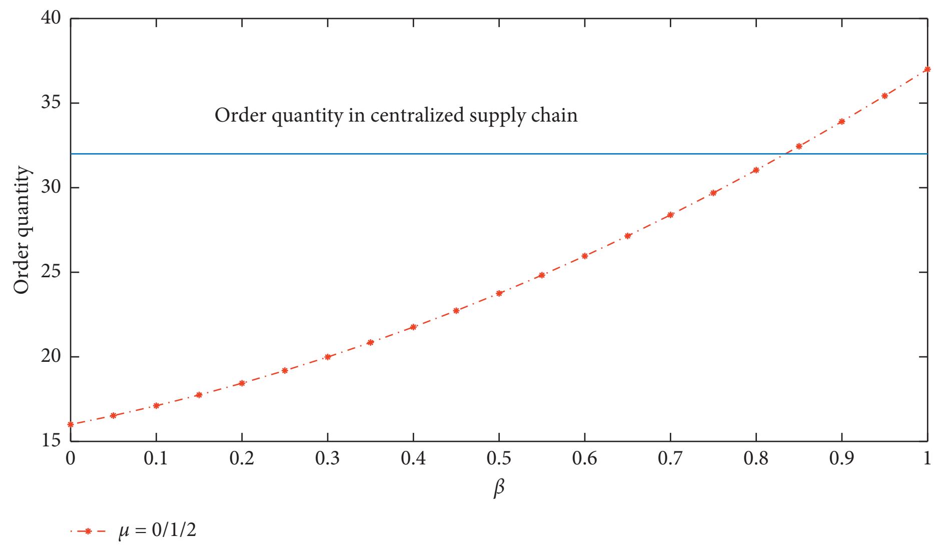

Figure 1: The effect of the cognitive biases on optimal order quantity.

we assumed $\beta \in [0,1)$ and $\mu = \{0,1,2\}$ to reflect the level of overconfidence and fairness concern in this paper. When $\beta = 0$ and $\mu = 0$, the retailer was considered to be rational. Similarly, other fundamental parameter values were set in experiments as follows: $a = 50$, $\theta \sim U(-30,30)$, $c = 4$, $p = 20, v = 7$, $s = 2$, $b = 2$, and $\gamma = 1$. All the parameters satisfied the constraint conditions and assumptions of the three models in Sections 3.2, 3.3, and 4. The parameter values were also in line with the real situation of the market. We could easily obtain $q^{c*} = 32$, $e^{c*} = 16$, and $\prod^c = 252$ in the centralized supply chain.

5.1. Effect of Overconfidence and Fairness Concern on the Supply Chain. The changes in the decision variables (w, q, and e), manufacturer profit, and retailer expected utility when the level of overconfidence and fairness concern (β and μ) changed are shown in Figures 1–5.

As shown in Figures 1 and 2, when the retailer was rational (e.g., $\beta = 0$ and $\mu = 0$) in the decentralized supply chain, both optimal order quantity and sales effort were lower than those under the centralized supply chain. Next, when the retailer had overconfidence and fairness concern simultaneously, overconfidence could only affect the retailer's optimal order quantity and sales effort of the retailer because the optimal order quantity and sales effort were a function of overconfidence in equations (13) and (14). Moreover, the order quantity was monotonically increasing as concave function with respect to β. In comparison, sales effort was monotonically increasing as convex function with respect to it. Furthermore, there existed a threshold ($\beta = 0.83$), when β was less than 0.83, and the two decision variables were both less than the optimal values ($q^{c*} = 32, e^{c*} = 16$) under the centralized decision scenario. Nevertheless, once β was larger than 0.83, the two decision variables were both more than them. The above discussion verified the correctness of Proposition 1. In short, overconfidence was the main factor that affected the retailer's optimal strategies of order quantity and sales effort in the decentralized supply chain. However, the above findings contradicted with the conclusions from a study conducted by Xu et al. [16], which examined the effect of retailer's overconfidence on the supply chain, and the result suggested that a higher level of overconfident resulted in the lower ordering quantity.

In Figure 3, we observed that the higher overconfident level resulted in the high wholesale price; in contrast, a high degree of fairness concern resulted in low price, which demonstrated that Proposition 2 was robust. This figure implied that when the information for both parties was symmetric, the rational manufacturer knew that the retailer was overconfident, that is, the retailer was optimistic about the market demand and increased the order quantity. As a result, the manufacturer also raised the wholesale price to maximize its revenue. Also, if the overconfident retailer paid attention to the unfairness of profit allocation in the decision-making process, the retailer's bargaining power was enhanced [32]. Hence, for better performance in the supply chain, the leading manufacturer was required to lower wholesale prices to ease the feeling of unfairness by the retailer, which is consistent with the actual economic phenomenon. Furthermore, these findings are consistent with the result concluded by Cui et al. [2], which indicated that a high degree of the retailer's fairness concern could lower the wholesale price. Interestingly, as the levels of the cognitive bias increased, its effect on wholesale price gradually decreased, which highlighted its effect on decreased wholesale prices.

Figure 4 displays the impact of the cognitive bias on the retailer's utility. The graph showed that the retailer expected utility increased gradually with the overconfident level and the degree of fairness concern, which suggested that two cognitive biases were beneficial to the retailer. The reasons for such a phenomenon were that both cognitive biases could increase the optimal order quantity and sales effort, thus enhancing the utility of the retailer.

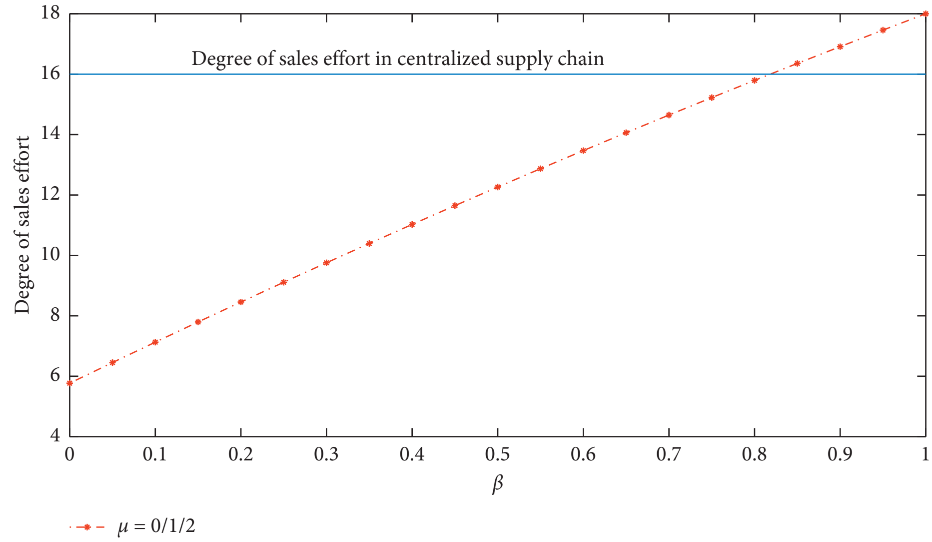

Figure 2: The effect of the cognitive biases on optimal sales effort.

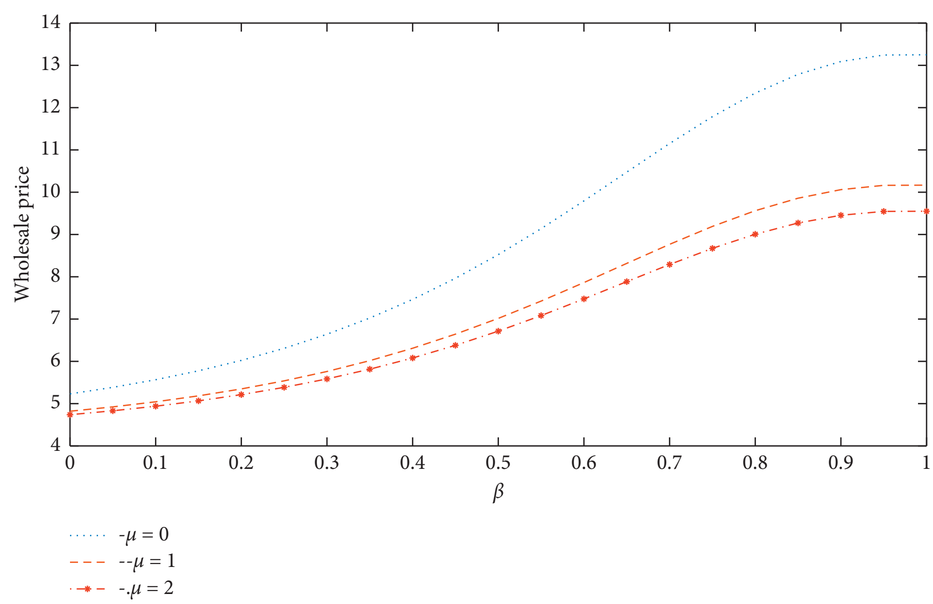

Figure 3: The effect of the cognitive biases on the optimal wholesale price.

Figure 5 illustrates the impact of overconfidence and fairness concern on the manufacturer's profit. That is, the optimal manufacturer's profit is an increasing function of β but a decreasing function of μ. According to Figure 3, the graph of the manufacturer's profit was similar to the graph of the wholesale price, which indicated that the manufacturer's profit was firmly related to wholesale price. Figure 5 also illustrates the effect of the cognitive bias β on the manufacturer's decreasing profit.

5.2. Effect of Overconfidence and Fairness Concern on Supply Chain Coordination. As can be seen from Section 5.1, there exist deviations between the optimal decisions under the benchmark and the decisions in the presence of the retailer's cognitive biases. Therefore, the buyback contract with promotion cost sharing was necessary to coordinate the revenue of supply chain members and optimize the performance of the supply chain.

Here, we discussed the validity of the contract. When the optimal order quantity and sales effort of the retailer under the contract were the same as the optimal decision variables in the centralized supply chain, i.e., $q^{sc} = q^{c*} = 32$ and $e^{sc} = e^{c*} = 16$, the buyback contract with promotion cost sharing achieved supply chain coordination. First, the effect of overconfidence and fairness concern (β and μ) on contract factors w^{sr*}, r^*, and ϕ is shown in Figures 6 and 7 and Table 1. For clearly analyzing the effect of β and μ on w^{sr*}

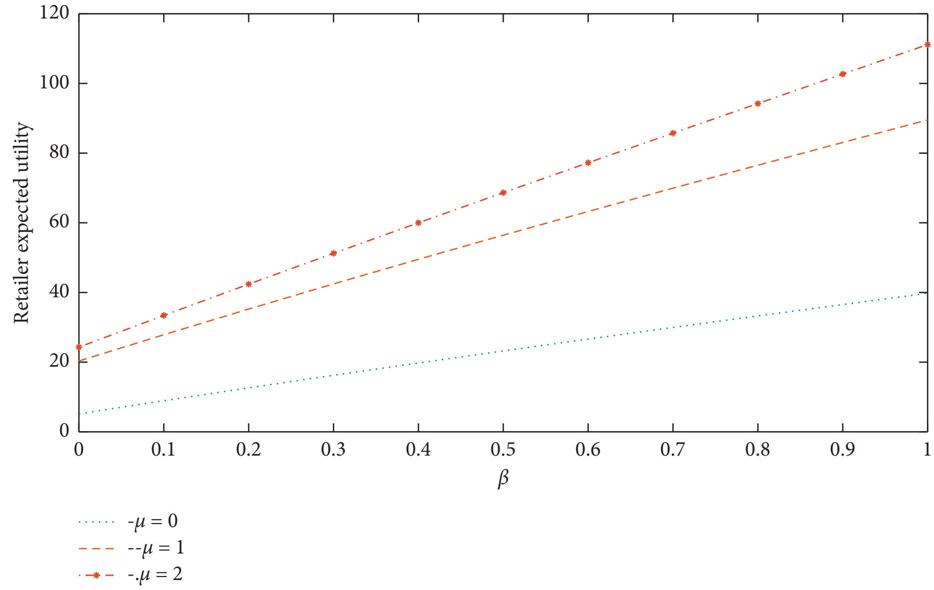

Figure 4: The effect of the cognitive biases on retailer utility.

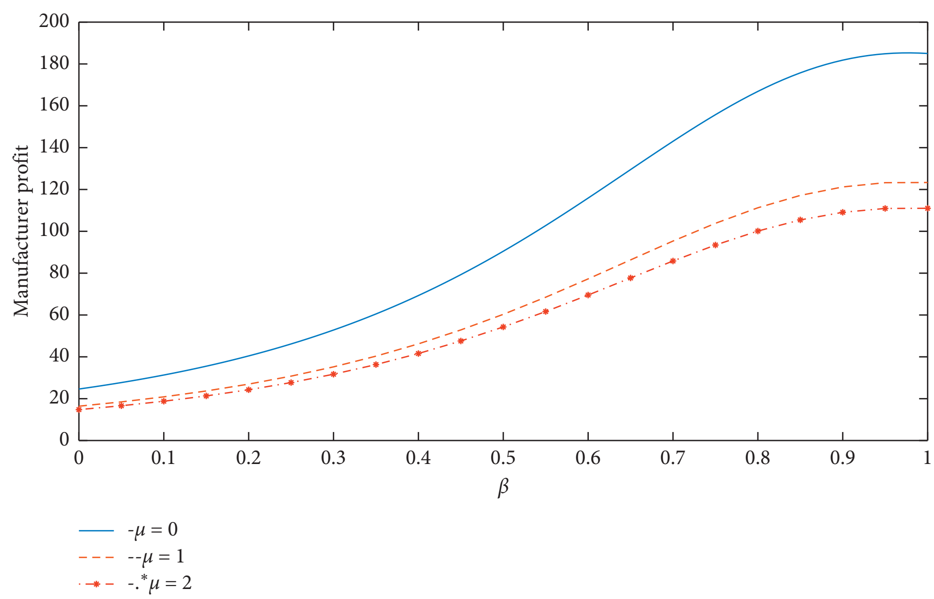

Figure 5: The effect of the cognitive biases on manufacturer profit.

and r^*, we let $\phi = 1$ in equations (18) and (19), which meant that the manufacturer proposed the buyback contract only, and the retailer bore all sales effort costs.

According to Figure 6, it was revealed that the optimal wholesales price is a strictly increasing function of the overconfidence level β but a strictly decreasing function of the degree of fairness concern μ, which confirmed the result of Proposition 4. Similarly, Figure 7 highlights that the optimal buyback price sharply increased with β but decreased with μ. Moreover, in the buyback contract, $w^{sr\,*}$ was always greater than or equal to 4, and r^* was always greater than or equal to 2 in different cognitive bias levels. Hence, the optimal buyback price r^* satisfied the assumption $s = 2 \leq r$. Note that the above characteristics influenced cognitive biases; hence, contract factors $w^{sr\,*}$ and r^* were also correct when ϕ is equal to other values (such as $\phi = 0.3, 0.5, 0.8$) under conditions in which the buyback contract had promotion cost sharing.

However, data from Figure 7 can be compared with the data in Figure 6, which showed $r^{sr\,*}$ is more significant than $w^{sr\,*}$ when β was within a specific range (for example, $0.4 \leq \beta < 1$), which did not match the assumption $r < w^{sr}$. Therefore, the buyback contract did not achieve the coordination of the behavioral supply chain.

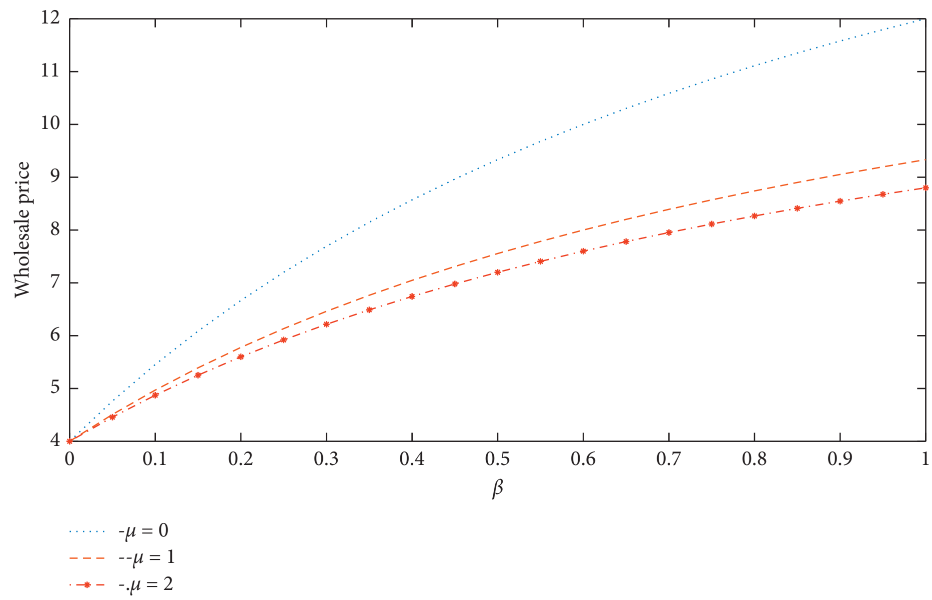

FIGURE 6: The effect of the cognitive biases on wholesale price w^{sr*}.

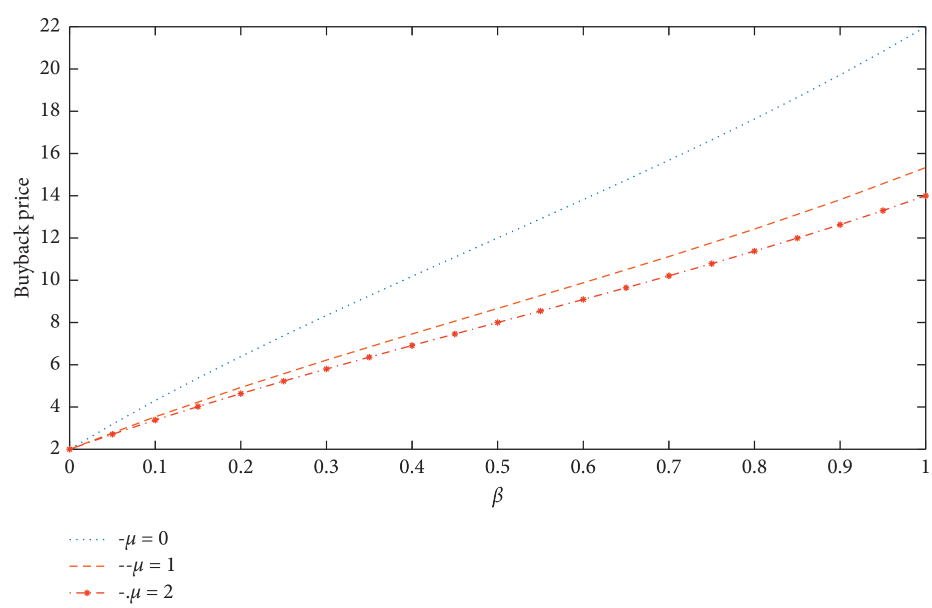

FIGURE 7: The effect of the cognitive biases on buyback price r^*.

As described in Section 4, if the supply chain members accepted the buyback contract with promotion cost sharing, the assumptions $\prod_m^{sc} \geq \max \prod_m^d$ and $U(\prod_r^{sc}) \geq \max U(\prod_r^d)$ had to be satisfied. Also, according to the assumptions, the value ϕ must satisfy $\prod_m^{sc} \geq \max \prod_m^d$ and $U(\prod_r^{sc}) \geq \max U(\prod_r^d)$. Thus, we kept the values of parameters to be the same (i.e., $a = 50$, $\theta \sim U(-30, 30)$, $c = 4$, $p = 20$, $v = 7$, $s = 2$, $b = 2$, and $\gamma = 1$) to capture a likely domain of ϕ.

As can be seen from Table 2, the overconfident level β increased the upper and lower limits of ϕ, which had a clear upward trend. In contrast, the upper and lower limits of ϕ showed a definite declining trend as the degree of fairness concern μ increased. These trends illustrated that in order to coordinate the revenue of both parties and optimize the performance of the supply chain, the manufacturer needs to bear less promotional costs as β increased but bear more promotional costs as μ value increased. Besides, when β and μ increased, the interval of sharing cost portion ϕ shrunk, which indicated that the buyback contract with promotional cost sharing had certain flexibility to coordinate the revenue between supply chain members. However, the flexibility could be weakened with the rise of the cognitive bias level. For supply chain members, the possibility of negotiation or

Table 2: The effect of the cognitive biases on the feasible domain of promotion cost-sharing portion ϕ.

μ	β 0	0.2	0.4	0.6	0.8	0.81
0	[0.2884, 0.4976]	[0.3683, 0.5587]	[0.4528, 0.6199]	[0.6343, 0.7754]	[0.7835, 0.8669]	—
1	[0.2545, 0.4741]	[0.3310, 0.5331]	[0.4167, 0.5908]	[0.6207, 0.7516]	[0.7800, 0.8560]	—
2	[0.2352, 0.4600]	[0.3101, 0.5156]	[0.4034, 0.5719]	[0.6094, 0.7321]	[0.7736, 0.8478]	—

Table 3: The effect of the cognitive biases on the coordination of the supply chain.

$\mu = 1$	β 0	0.2	0.4	0.6	0.8
q^{sc}	32	32	32	32	32
e^{sc}	16	16	16	16	16
ϕ	[0.2545, 0.4741]	[0.3310, 0.5331]	[0.4167, 0.5908]	[0.6207, 0.7516]	[0.7800, 0.8560]
r	[2.100, 3.5363]	[2.8268, 3.9188]	[3.0555, 4.2637]	[3.6209, 4.4215]	[4.0485, 4.9164]
w^{sc}	[4.9205, 5.3687]	[4.9016, 5.3522]	[5.4092, 6.9568]	[6.2513, 7.2626]	[8.0407, 8.7453]
$\prod_m^d$	16.4103	26.9591	46.1996	77.2619	111.2545
$U(\prod_m^{sc})$	[16.8722, 21.7850]	[26.9600, 33.6882]	[46.3175, 50.0938]	[77.2619, 81.4300]	[111.2545, 112.0376]
$\prod_r^d$	20.333	35.2396	49.5161	63.2422	76.5317
$U(\prod_r^{sc})$	[20.333, 24.3043]	[35.2396, 40.0595]	[49.5161, 52.5161]	[63.2422, 65.7581]	[76.5317, 78.4632]

cooperation between manufacturers and retailers also decreased with an increase in retailers' cognitive bias level. When the overconfident level was more than 0.81, the retailer's utility from decentralized decisions was greater than the utility in the contract environment, wherein the two parties could not reach a cooperation agreement. Thus, the supply chain could not achieve coordination as different levels of cognitive bias under the contract had the same influence on decision variables, profit, and utility. Table 2 shows a clear picture wherein μ is equal to 1 and β falls within the range of $(0, 0.8)$ which were used to analyze the effect of the cognitive biases on the coordination of the supply chain.

The results of the numerical simulation in Table 3 indicate that the contract factors, i.e., ϕ, r, wholesale price, the profit, and utility of members existed as flexible intervals when $\beta \in (0, 0.8)$ and $\mu = 1$. Besides, the order quantity q^{sc} and the degree of sales effort e^{sc} under the contract are equal to q^{c*} and e^{c*} in a centralized supply chain, respectively. Meanwhile, the buyback price r was less than the wholesale price w^{sc} and higher than the unit salvage value s, which satisfied the constrains $s \leq r < w^{sc*}$. Thus, the buyback contract with promotion cost could achieve the coordination of the two-echelon supply chain. Also, the buyback price r was positively correlated with the portion ϕ of promotion cost sharing. Notably, the wholesale price w^{sc} dropped as ϕ increased when β was in the range of $(0, 0.2)$ in Table 3. However, the situation reversed when it was in the range of $(0.2, 0.8)$, which was inconsistent since the manufacturer lowered the wholesale price when the retailer paid more promotional costs in the contract. The reason for such an observation was that the wholesale price was not related to ϕ but positively related to the overconfident level β when the degree of fairness concern was moderate. Furthermore, the retailer accepted the contract designed by manufacturers since the term $U(\prod_r^{sc}) \geq \max U(\prod_r^d)$ was guaranteed in Table 3.

6. Conclusions

6.1. Main Conclusions. In this paper, we analyzed the effect of cognitive bias on equilibrium solutions, including the wholesale price, sales price, sales effort, and expected profits under demand uncertainty by introducing both overconfidence and fairness concern into the two-echelon supply chain. The most important conclusion from the study was that, for retailers with the two cognitive biases, overconfidence was positive and the main bias that affected supply chain decisions, and the retailers' utility benefits were not only due to overconfidence but also fairness concern. For manufacturers, overconfidence could increase the wholesale price and profit. However, the fairness concern had a negative effect on them. Furthermore, the decisions of the retailer in the decentralized supply chain deviated from the optimal decisions in the centralized supply chain model. Especially, when the threshold of overconfidence was more than a fixed value, the decision variables under decentralized decision-making were actually higher than the optimal variables under centralized decision-making. Also, the buyback contract with promotional cost sharing achieved behavioral supply chain coordination. In contrast, the promotional cost-sharing portion and buyback price both benefited from overconfidence, but fairness concern had a detrimental effect on them. However, as the retailers' overconfidence level increased and fairness concern was equal to 1, the flexibility of contract coordination was weakened. When the overconfidence level was more than 0.8, the contract became invalid, and members were not able to cooperate.

6.2. Management Insights. This paper provided some interesting managerial insights for decision makers in the decentralized supply chain wherein retailers had two preferences. First, overconfidence was beneficial to them in terms of decision variables, and yet, the fairness concern only damaged the wholesale price. Second, the two behavioral preferences were both conducive to utilities for the retailer but not necessarily beneficial for the manufacturer to receive profit, and overconfidence helped to increase manufacturers' profit, which led to nonoptimal decisions that dragged down the performance of the two-echelon supply chain. Finally, for the two behavioral preferences of the retailer, the manufacturer assessed the degree of overconfidence and fairness concern (especially, the overconfidence) via historical data and the current order quantity or other indicators. In contrast, factual data indicated that two behavioral preferences were in the right range (such as $\beta \in (0, 0.8)$ and $\mu \in (0, 2)$). The manufacturers introduced the buyback contract with promotional cost sharing into the practice of pricing and ordered decentralized supply chains. Furthermore, they designed a reasonable promotional cost-sharing portion and buyback price, thereby achieving an optimized decision and utility. In practice, the manufacturers could analyze whether the sellers had two behavioral preferences based on the historical data by cooperating with downstream enterprises, i.e., if two behavioral preferences existed, they referred to the papers' conclusions to redesign a reasonable contract mechanism.

6.3. Future Research. Since cognitive biases could exist among all members of supply chains, it is necessary to explore the manufacturers' cognitive biases and analyze the supply chain coordination problem in the presence of the two behavior preferences. Besides, the overconfidence and fairness concern considered in our centralized decision are a future research direction.

Appendix

A. Decentralized Supply Chain Model

In a decentralized supply chain consisting of a rational manufacturer and a retailer with cognitive biases, maximum profit or utility is the only goal. The backward inductive method can be applied to solve a Stackelberg game wherein the manufacturer is the leader, and the retailer is a follower. The proof of the equilibrium solutions in equations (12)–(14) is as follows.

The profit of the manufacturer and expected utility of retailers are as follows, respectively:

$$\max_{w} \prod_{m}^{d} = (w - c)q, \tag{A.1}$$

$$\begin{aligned}\max_{q,e} U\left(\prod_{r}^{d}\right) = (1+\mu)\Big\{ & p[a - bp + (1+\beta)e] + s\int_{-A}^{\theta_2} (q - (a - bp + (1+\beta)e + \theta_1) f(\theta_1))\mathrm{d}\theta_1 \\ & -v\int_{\theta_2}^{A} ((a - bp + (1+\beta)e + \theta_1 - q) f(\theta_1))\mathrm{d}\theta_1 - wq - \frac{1}{2}\gamma e^2 \Big\} - \mu(w - c)q.\end{aligned} \tag{A.2}$$

Solving the first-order partial derivatives of the retailer's expected utility concerning q^d and e^d which equal to 0, we obtained the following equations:

$$\frac{\partial U\%\left(\prod_r^d\right)}{\partial q} = (1+\mu)\left[v - w + F(\theta_2)(s - v)\right] - \mu(w - c) = 0, \tag{A.3}$$

$$\frac{\partial U\%\left(\prod_r^d\right)}{\partial e} = (1+\beta)\left[p - v + (v - s)F(\theta_2)\right] - \gamma e = 0. \tag{A.4}$$

Hessian matrix:

$$H(q, e) = \begin{pmatrix} (s - v) f(\theta_2) & (v - s)(1+\beta) f(\theta_2) \\ (v - s) f(\theta_2) & (s - v)(1+\beta) f(\theta_2) - \gamma \end{pmatrix}. \tag{A.5}$$

According to the assumptions, $v > s > 0$, $f(\theta_2) > 0$, and $\beta \in [0, 1)$. Thus, the Hessian matrix of $U\left(\prod_r^d\right)$ is a negative definite for q and e, which meant that the optimal order quantity and sales effort of retailers existed in the decentralized supply chain. Therefore, we obtained the following formula of the retailers' order quantity and sales effort by jointly solving equations (A.3) and (A.4):

$$q^d = \frac{(a - bp)(v - s)(1+\mu)\gamma + (1+\beta)^2 (v - s)[(1+\mu)(p - w) + \mu c] + A\gamma[(s + v)(1+\mu) + 2\mu c - w]}{(v - s)(1+\mu)\gamma}, \tag{A.6}$$

$$e^d = \frac{(1+\beta)[(1+\mu)p + \mu c - (1+2\mu)w]}{(1+\mu)\gamma}. \tag{A.7}$$

Substituting equations (A.6) into (A.1), we attained

$$\max_{w}\prod_{m}^{d}=\frac{(w-c)\left\{(a-bp)(v-s)(1+\mu)\gamma+(1+\beta)^{2}(v-s)[(1+\mu)p+\mu c]+A\gamma[(s+v)(1+\mu)+2\mu c]-(1+2\mu)w\left[2A\gamma+(1+\beta)^{2}(v-s)\right]\right\}}{(v-s)(1+\mu)\gamma}. \tag{A.8}$$

Taking into account the first-order condition of equation (A.7) with respect to w rounded off to 0, we obtained`

$$\frac{\partial\prod_{m}^{d}}{\partial e}=\frac{(a-bp)(v-s)(1+\mu)\gamma+(1+\beta)^{2}(v-s)[(1+\mu)p+\mu c]+A\gamma[(s+v)(1+\mu)+2\mu c]-(2w-c)(1+2\mu)\left[2A\gamma+(1+\beta)^{2}(v-s)\right]}{(v-s)(1+\mu)\gamma}. \tag{A.9}$$

Solving equation (A.8), we found that the optimal wholesale price of the manufacturer is as follows:

$$w^{d\,*}=\frac{(a-bp)(1+\mu)(v-s)\gamma+(v-s)(1+\beta)^{2}[(1+\mu)p+(1+3\mu)c]+A\gamma[(s+v)(1+\mu)+2(1+3\mu)c]}{2(1+2\mu)\left[2A\gamma+(v-s)(1+\beta)^{2}\right]}. \tag{A.10}$$

By substituting equation (A.9) into equations (A.6) and (A.7), we attained the optimal order quantity and sales effort, which are displayed in equations (13) and (14).

B. Propositions

Proof of Proposition 1. We solved the first derivatives of optimal order quantity $q^{d\,*}$ and sales effort $e^{d\,*}$ with respect to β in equations (13) and (14), respectively. Meanwhile, taking the second-order derivative of $q^{d\,*}$ with respect to β, we obtained

$$\frac{\partial q^{d\,*}}{\partial\beta}=\frac{(1+\beta)(p-c)}{\gamma},\quad \frac{\partial^{2}q^{d\,*}}{\partial\beta^{2}}=\frac{p-c}{\gamma}, \tag{B.1}$$

$$\frac{\partial e^{d\,*}}{\partial\beta}=\frac{4(p-c)(v-s)^{2}\beta\left(\beta^{3}+4\beta^{2}+6\beta+4\right)+(a-bp)\gamma(1+\beta)^{2}(v-s)^{2}+A\gamma(v-s)(1+\beta)^{2}\left[(2(p-c)+v+s)+2(A\gamma)^{2}(4p-c-s-v)\right]}{2\gamma\left[(1+\beta)^{2}(v-s)+2A\gamma\right]^{2}}. \tag{B.2}$$

Since the second derivative of $e^{d\,*}$ with respect to β was very complicated, there was no need to solve it. According to the assumptions $p>v>c>s>0$, $\beta\in(0,1)$, $a-bp>0$, and $\gamma>0$, so $(\partial q^{d\,*}/\partial\beta)>0$, $(\partial^{2}q^{d\,*}/\partial\beta^{2})>0$, and $(\partial e^{d\,*}/\partial\beta)>0$.

Proof of Proposition 2. Based on the process above, we took the first-order and second-order partial derivatives of optimal wholesale price $w^{d\,*}$ with respect to β and μ in equation (12), respectively:

$$\frac{\partial w^{d\,*}}{\partial\beta}=\frac{\gamma(v-s)(1+\mu)(1+\beta)[(a-bp)(v-s)+A(2p-s-v)]}{(1+2\mu)\left[(1+\beta)^{2}(v-s)+2A\gamma\right]^{2}}, \tag{B.3}$$

$$\frac{\partial w^{d\,*}}{\partial\mu}=-\frac{\left[(a-bp)(v-s)\gamma+(p-c)(v-s)(1+\beta)^{2}+A\gamma(s+v-2c)\right]}{2(1+2\mu)^{2}\left[(v-s)(1+\beta)^{2}+2A\gamma\right]}. \tag{B.4}$$

According to the optimal result of order quantity in equation (13) and the assumption $q > 0$, the condition $s + v - 2c > 0$ is found. According to the assumptions we had, $(\partial w^{d*}/\partial\beta) > 0$ and $(\partial w^{d*}/\partial\mu) < 0$.

Proof of Proposition 3. The gap between q^{d*} and q^{c*}, denoted by Δq, is as follows:

$$\Delta q = q^{d*} - q^{c*} = \frac{(p-c)(v-s)\left[(1+\beta)^2 - 2\right] - A\gamma(s+v-2c) - (a-bp)(v-s)\gamma}{2\gamma(v-s)}. \tag{B.5}$$

If $(p-c)(v-s)[(1+\beta)^2-2]$ is more than $A\gamma(s+v-2c) + (a-bp)(v-s)\gamma$, we have $\Delta q > 0$, i.e., $q^{d*} > q^{c*}$. In contrast, if $(p-c)(v-s)[(1+\beta)^2-2]$ is less than $A\gamma(s+v-2c) + (a-bp)(v-s)\gamma$, $\Delta q < 0$, i.e., $q^{d*} < q^{c*}$.

The gap between e^{d*} and e^{c*}, denoted by Δe, is as follows:

$$\Delta e = e^{d*} - e^{c*} = \frac{A\beta\gamma(4p-2c-s-v) - A\gamma(s+v-2c) - (v-s)(1+\beta)\left[(a-bp)\gamma + \left(1-\beta^2\right)(p-c)\right]}{2\gamma\left[2A\gamma + (1+\beta)^2(v-s)\right]}. \tag{B.6}$$

Similarly, if $A\beta\gamma(4p-2c-s-v) > A\gamma(s+v-2c) + (v-s)(1+\beta)[(a-bp)\gamma + (1-\beta^2)(p-c)]$, we have $\Delta e = e^{d*} - e^{c*} > 0$. In contrast, if $A\beta\gamma(4p-2c-s-v) < A\gamma(s+v-2c) + (v-s)(1+\beta)[(a-bp)\gamma + (1-\beta^2)(p-c)]$, we have $\Delta e = e^{d*} - e^{c*} < 0$.

Upon solving the first-order derivative of Δq and Δe with respect to β, respectively, we obtained

$$\frac{\partial\Delta q}{\partial\beta} = \frac{(1+\beta)(p-c)}{\gamma}, \tag{B.7}$$

$$\frac{\partial\Delta e}{\partial\beta} = \frac{4(p-c)(v-s)^2\left(\beta^3 + 4\beta^2 + 6\beta + 4\right)\beta + (a-bp)\gamma(1+\beta)^2(v-s)^2 + A\gamma(v-s)(1+\beta)^2\left[2(p-c) + v + s) + 2(A\gamma)^2(4p-c-s-v)\right]}{2\gamma\left[(1+\beta)^2(v-s) + 2A\gamma\right]^2}. \tag{B.8}$$

According to the assumptions $p > v > c > s > 0, \beta \in (0,1)$, $\gamma > 0$, and $a - bp > 0$, $(\partial\Delta q/\partial\beta) > 0$ and $(\partial\Delta e/\partial\beta) > 0$ can be proved. Hence, the gaps increased as a function with respect to β.

Proof of Proposition 4. The proof for Proposition 4 is similar to Proposition 2. Herein, we took first-order and second-order partial derivatives of optimal wholesale price w^{sc*} with respect to β, μ, and ϕ in equation (18), respectively. The solving results are as follows:

$$\begin{aligned}
\frac{\partial w^{sc*}}{\partial\beta} &= \frac{[(1+2\mu)\phi - \mu](p-c)}{(1+2\mu)(1+\beta)^2},\\
\frac{\partial w^{sc*}}{\partial\mu} &= -\frac{(p-c)\beta}{(1+\beta)(1+2\mu)^2},\\
\frac{\partial w^{sc*}}{\partial\phi} &= -\frac{p-c}{1+\beta},
\end{aligned} \tag{B.9}$$

$(\partial w^{sc*}/\partial\beta)$, if $\phi > (\mu/(1+2\mu))$ is more than 0; otherwise, $\phi > (\mu/(1+2\mu))$ is less than 0. Thus, w^{sc} could be increasing with respect to β, nevertheless, decreasing with respect to β. Besides, according to the assumptions, $p > v > c > s > 0$, $\beta \in (0,1)$, $\gamma > 0$, and $a - bp > 0$, it can be evidently found that $(\partial w^{sc*}/\partial\mu) > 0$ and $(\partial w^{sc*}/\partial\phi) > 0$.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

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