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Research Article

The Impact of Consumers' Peer-Induced Fairness Concerns on Mixed Retail and E-Tail Channels

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With the rapid development of e-commerce, online retailing has become an important part of the market. In order to improve market competitiveness and increase market share, more and more retailers have opened both regular offline channel and online e-tail channel to sell products. Then how to price becomes an urgent problem for upstream manufacturers and dual-channel retailers when there is price competition between regular channel and e-tail channel, especially when consumers have peer-induced fairness concerns. However, linking consumers' behavioral factors such as fairness concerns to pricing decisions of mixed retail and e-tail channels draws little attention in the literature on supply chain management. This paper incorporates "consumers' peer-induced fairness concerns" (CPFC) into pricing decisions in a dyadic supply chain, where dual-channel retailer obtains products from manufacturers and then sells products to consumers through both regular channel and e-tail channel. We use game-theoretic models to analyze the equilibrium pricing strategies under the setting with "symmetry consumers' peer-induced fairness concerns" (SCPFC) and with "asymmetry consumers' peer-induced fairness concerns" (ACPFC), respectively. Detailed comparisons and numerical analysis are further conducted to examine the impacts of different types of CPFC on equilibrium pricing strategies and profits.

1. Introduction

Nowadays, more and more retailers have not only relied on regular channels to sell products which are obtained from manufacturers to consumers but also opened e-tail channels to sell products, such as Suning, Gome, Red Star Macalline, Uniqlo, and other dual-channel retailers. At this time, the pricing of regular channel and e-tail channel has become the first problem dual-channel retailers need to solve. What is more, now consumers can use various price comparison apps, like "Miaomiao Discount," "Compare Price," "Buy Slowly," and so on, to fully understand how much other consumers pay for the same product in other channels of the same dual-channel retailer; CPFC will emerge if there is a price difference between different channels.

As we all know, peer-induced fairness concerns play an important role in the process of consumers' purchasing decisions. Due to peer-induced fairness concerns (Festinger [1]; Fehr and Schmidt [2]), during the process of consumers choosing channel that they purchase from, they are not only concerned about price of a certain channel and utility obtained by themselves but also cared about price of other channels and utility obtained by other consumers (Ho and Su [3]). When retail price of other channels is lower or utility obtained by other consumers is higher, because of suffering from inequity aversion, consumers' own utility will be lost, which will result in decreasing consumers' purchase desire, and consumers will either refuse to purchase from the dual-channel retailer or switch to the channel with lower price to purchase. Therefore, dual-channel retailer should price channel products appropriately to avoid decrease in demand and increase in channel conflict; it can be seen that how to price for dual-channel retailer is crucial especially when facing CPFC.

At the same time, manufacturer, as an upstream company closely related to dual-channel retailer and wholesale price contracts, is still commonly used, whose wholesale price decision also has an impact on retail price decision of dual-channel retailer; in such a case, unreasonably setting wholesale price can also lead to a decrease in demand and an increase in channel conflicts, so we also take manufacturer's decision into consideration in the paper.

In this paper, we consider a dyadic supply chain consisting of a manufacturer and a dual-channel retailer, where a manufacturer sells products to dual-channel retailer through a wholesale price contract, and then dual-channel retailer sells products to consumers through both regular channel and e-tail channel. When consumers find that there is a price difference between different channels of the same dual-channel retailer, consumers will suffer inequity aversion and their desire to purchase from the channel or the dual-channel retailer will be reduced. Under this circumstance, we assume that there are two types of situations: one is that consumers refuse to purchase from the dual-channel retailer, and the other is that consumers transfer to other channels of dual-channel retailer. The former is a more sensitive consumer with a higher sense of unfairness, and the latter has a lower sense of unfairness and will not reject the dual-channel retailer because of the price difference between different channels. This paper refers to the former as ACPFC and the latter as SCPFC, and we will conduct model theoretical analysis on two different types of CPFC.

In our study, we intend to address the following research questions: when considering two different types of CPFC, how should dual-channel retailer price regular and e-tail channels' products and whether two types of CPFC have an impact on upstream manufacturer's wholesale pricing decisions or not? How will the types of CPFC affect profits of dual-channel retailer and manufacturer and product price?

We highlight several findings. In equilibrium, first, whether considering CPFC or not, retail price and demand of regular channel are all higher than those of e-tail channel, but price differences between regular and e-tail channels are different under different models, which is reasonable and in line with reality. Second, after considering CPFC, manufacturer's profit may increase while retailer's profit decreases, and retailer's profits with ACPFC are larger than that with SCPFC. Third, as long as there is CPFC, retailer's price strategy is to adopt a differential pricing strategy which means that price of regular channel is higher than that of e-tail channel. When consumer acceptance of e-tail channel is high, wholesale price with CPFC is higher than that without CPFC and vice versa. Lastly, CPFC decreases price difference between regular channel and e-tail channel, price difference with ACPFC is greater than that with SCPFC, and price difference also decreases with indicator of CPFC.

The rest of the article is organized as follows. Section 2 introduces the model and analyzes equilibrium pricing strategies for three scenarios; the three scenarios are as follows: without CPFC, considering ACPFC, and considering SCPFC. Section 3 compares three scenarios' equilibrium results and analyzes the impacts of ACPFC and SCPFC on equilibrium prices and profits. Section 4 conducts numerical examples to get more insights and conduct sensitivity analysis. Section 5 concludes the paper.

2. Literature Review

This study belongs to two strands of literature: one strand of literature is about supply chain management with fairness concern, and the other strand of literature is about dual-channel supply chain.

2.1. Fairness Concern in Supply Chain Management. In recent years, scholars have done a lot of research on supply chain management with fairness concerns. The growing body of literature that studies the impacts of fairness concerns on supply chain performance and strategic decisions can be composed of the following two distinct aspects.

The first aspect is about the impacts of manufacturer or retailer fairness concern on supply chain performance and coordination, where fairness concern does not affect market demand. Cui et al. [4] studied the impact of retailer distributional fairness concern on coordination of a dyadic supply chain and showed that manufacturer can achieve supply chain coordination by wholesale price contract when retailer has distributional fairness concern. Based on Cui et al. [4], Caliskan-Demirag et al. [5] studied the impact of retailer distributional fairness concern on supply chain coordination under nonlinear demand and found that it is easier to achieve supply chain coordination under nonlinear demand than under linear demand. Yang et al. [6] evaluated how retailer fairness concern influences channel coordination of a two-tier supply chain with a cooperative advertising contract. Under the newsvendor model, Wu and Niederhoff [7] studied the impact of distributional fairness concern on supply chain efficiency in three cases: only retailer distributional fairness concern, only supplier distributional fairness concern, and both retailer and supplier distributional fairness concern. Zhou et al. [8] explored the effect of retailer fairness concern on optimal decisions and coordination in a low-carbon supply chain consisting of a manufacturer and a retailer with the government's energy-saving emission reduction policies and consumer's low-carbon preference. Li [9] showed that manufacturer distributional fairness concern will strengthen double marginal effect and retailer distributional fairness concern weakens double marginal effect; supply chain coordination cannot be achieved by wholesale price contracts in case of manufacturer or retailer with distributional fairness concern. Zheng et al. [10] innovatively applied variable-weighted shapely values to coordinate a closed-loop supply chain with a retailer who has distributional fairness concern. Zheng et al. [11] examined the influence of retailer fairness concern on a three-echelon supply chain coordination. Wang et al. [12] incorporated manufacturer fairness concern and e-commerce platform into decision-making process in an e-commerce supply chain setting to study how fairness affects decision-making and coordination of an e-commerce supply chain. Guan et al. [13] studied how retailer Nash bargaining fairness concern influences a two-tier supply chain coordination, where demand depends on selling price and accumulated goodwill. Pan et al. [14] investigated the effect of both distributional fairness concern and peer-induced fairness concern on a two-echelon supply chain performance with a dominant retailer and two manufacturers.

This paragraph is about the impact of manufacturer or retailer fairness concern on supply chain management decisions. Ho et al. [15] analyzed how retailer distributional fairness concern and retailer peer-induced fairness concern interact and influence economic outcomes in one-supplier and two-retailer supply chain setting. Du et al. [16] used the Nash bargaining solution as a fairness reference point to analyze newsvendor problem when both supplier and retailer exhibit fairness concern. Katok et al. [17] explored the performance of wholesale pricing in a setting where supply chain members' fairness concerns are private information. Cui and Mallucci [18] proved the fairness concern existing in different supply chain members' decisions through experiments and showed that fairness concern has a critical impact on channel pricing. Qin et al. [19] conducted a laboratory work to examine the effect of fairness concern and private production cost information on a dyadic supply chain decision-making under a simple wholesale price contract. Li and Li [20] considered a dual-channel supply chain consisting of a traditional offline retailer with distributional fairness concern, studied value-added service level decision of retailer, and showed that service level is the same as that without fairness concern. Ma et al. [21] incorporated retailer distributional fairness concern into a closed-loop supply chain with a central planner, a manufacturer, a retailer, or a third party, in which manufacturer plays a role as a collector, and examined the chance of supply chain profitability, optimal marketing effort, collection rate, and pricing decisions. Chen et al. [22] incorporated retailer's fairness concern into pricing and ordering issues in a dyadic supply chain with a supplier and a budget-constrained retailer facing stochastic demand. Li et al. [23] used the Nash bargaining solution to investigate the product quality and pricing decisions in a two-echelon supply chain, in which both supplier and retailer have fairness concerns. Shen et al. [24] investigated four models of whether fairness concern is considered by different dominant parties in e-supply chain with one manufacturer and one network platform. Qiu et al. [25] incorporated retailer fairness concern into a green supply chain to analyze how retailer fairness concern interacts with supply chain price and carbon emission reduction decisions. Liu et al. [26] considered a logistics service supply chain with a logistics service integrator and two competing functional logistics service providers, where functional logistic service providers exhibit both peer-induced fairness concern and distributional fairness concern, and investigated the impacts of different fairness concern on order allocation. Zhao et al. [27] explored optimal pricing decisions in a two-tier product and service supply chain considering retailer fairness concern and vertical competition in extended warranty between manufacturer and retailer. Zhen et al. [28] incorporated retailer fairness concern into a dual-channel supply chain, in which both manufacturer and retailer sell products through online and offline channels. Zhang et al. [29] determined the influence of retailer fairness concern and consumer environmental awareness on environmental and price decisions of a green product in a one-manufacturer and one-retailer supply chain. Zang et al. [30] developed four Stackelberg game models aiming to study the impact of fairness concern and subsidy on product green degree, wholesale price, and retail price decisions. Tao et al. [31] considered a three-tier supply chain consisting of multiple suppliers, one manufacturer, and multiple distributors with uncertain supply and demand and focused on the impact of manufacturer aversion to risk and distributional fairness concern on procurement and distribution decisions. Li et al. [32] linked retailer fairness concern to supplier encroachment problem and concluded that encroachment may be detrimental to the supplier when the retailer has strong fairness concern. Niu et al. [33] studied the impacts of channel power and supplier fairness concern on supplier market entry decisions. The above pieces of literature are all about the impact of retailer or manufacturer fairness concern on the supply chain. The following pieces of literature are about the impact of consumers fairness concerns on supply chain decisions or enterprise decisions.

The second aspect is about the impact of consumers fairness concerns on supply chain management, where fairness concern has an impact on market demand. Chen and Cui [34] find that CPFC is the reason why firms adopt uniform pricing for different sizes of the same brand and believed that CPFC can reduce price competition intensity and increase firms' profits. Guo and Jiang [35] studied the impact of heterogeneous consumers with distributional fairness concerns on price and quality decisions of monopolistic firms with different production cost efficiencies and showed that a high degree of consumer distributional fairness concern is not conducive to firms with low production cost efficiency or high production cost efficiency. Yi and Wang et al. [36] studied the impact of consumer distributional fairness concern on manufacturer's distribution channel selection and showed that when consumer distributional fairness concern is strong, manufacturer tends to choose agent selling, while when consumer distributional fairness concern is weak, manufacturer tends to choose direct selling. Harutyunyan et al. [37] found that when the proportion of consumers with distributional fairness concerns is small, consumer distributional fairness concern can alleviate price competition, while consumer distributional fairness concern is detrimental to themselves and beneficial to firm. However, the literature above does not study the impact of CPFC on decision-making of supply chain members in the supply chain environment.

2.2. Dual-Channel Supply Chain. Dual-channel supply chain is a major topic in operation management. With the development of Internet and e-commerce, dual-channel supply chain including an e-tail channel has come into notice in recent years. Dual-channel supply chain structure comprises an e-tail channel added by manufacturer and a traditional retail channel which is the most common in previous studies. For example, He et al. [38] established dual-channel business models considering deterioration property of products in such common structure and studied coordination of dual-channel supply chain with deteriorating products. Ren et al. [39] studied consumer return policies in dual-channel supply chain with price and service competition and designed a new contract to coordinate supply chain. He et al. [40] extended traditional transshipment strategy into dual-channel supply chain structure mentioned above and analyzed the coordination of dual-channel supply chain in two cases of exogenous and endogenous transshipment price. Different from research on manufacturer channel selection, Zhang et al. [41] studied retailer channel selection and found that dual channel is optimal for retailer when customer acceptance rate for online channel is medium. He et al. [42] explored channel selection for manufacturer to sell new products and distribute remanufactured products in a dual-channel closed-loop supply chain considering government subsidy and derived manufacturer's optimal channel structure and equilibrium decisions. Zhang et al. [43] discussed the impacts of preorder-online, pickup-in-store strategy on dual-channel retailer under monopoly case and competition case, respectively, where competition case refers to dual-channel retailer competes with a pure e-retailer. Different from literature about dual-channel supply chain mentioned above, the dual-channel supply chain structure in our paper refers to a regular retail channel and an e-tail channel opened by retailer, that is, consisting of a manufacturer and a dual-channel retailer.

2.3. Literature Summary. In summary, empirical evidence and behavioral research suggest that consumers seek not only base functionalities but also fairness in transactions, which may cause consumers to refuse dual-channel retailer or transfer to channel with a lower price when there is a price difference between the same retailers' regular and e-tail channels, such fairness seeking is called as CPFC, and based on this fact, we consider two types of CPFC: ACPFC and SCPFC; the former will refuse to purchase from dual-channel retailer and the latter will transfer to other channels with lower price because of the price difference. This paper investigates the impact of CPFC on pricing decisions of a dyadic supply chain comprising a manufacturer and a dual-channel retailer, where dual-channel retailer sells products through both regular channel and e-tail channel. However, most of the existing literature is to study the impact of retailer or manufacturer fairness concern on the supply chain performance and decisions, to study the impact of consumer distributional fairness concern on supply chain or firm decisions, or to study the impact of CPFC on firms' strategies. The literature that studies the impact of CPFC on supply chain decisions is rarely seen, while there are many pieces of literature have proved that the existence of CPFC plays an important role in supply chain decisions [44-46]. Therefore, in this paper, considering the two types of CPFC in a dyadic supply chain consisting of a dual-channel retailer and a manufacturer, we study how manufacturer and retailer with mixed channel and e-tail channel should make pricing decisions and analyze the impact of different types of CPFC on supply chain members pricing and profits.

3. Model

In a dyadic supply chain, a manufacturer sells product to a dual-channel retailer with a wholesale price contract, who then sells it to consumers through a single-product retail system mixed with an e-tail distribution channel. Consumers are assumed to be homogeneous and are able to purchase a product either from regular channel or from e-tail channel of dual-channel retailer. However, consumers are informed about the price of regular channel and e-tail channel products; according to Ho and Su [3], consumers will have peer-induced fairness concerns when they find other consumers who purchase the same product from the same dual-channel retailer at a lower price; such inequity aversion brings disutility to consumers. In addition, considering the fact that when finding the price of product in other channels of the same retailer is low, consumers will refuse to purchase from the dual-channel retailer or turn to other channels with a lower price of the dual-channel retailer to purchase product, so we divided CPFC into two types: the former one ACPFC and the latter one SCPFC, which is the focus of this paper.

3.1. Benchmark: Without CPFC. Based on a dyadic supply chain consisting of a manufacturer and a dual-channel retailer with a single-product retail system mixed with an e-tail distribution channel, the manufacturer (m) as a leader of Stackelberg game and the retailer as a follower adopt wholesale price contract; the retailer obtains products from the manufacturer at a wholesale price w and then sells products through both regular channel with a price p_r and e-tail channel with a price p_e. In the case without CPFC denoted by a superscript N, the demand curves of regular and e-tail channels are given as functions of retail price:

$$\begin{aligned} d_r^N &= 1 - p_r + b p_e, \\ d_e^N &= a - p_e + b p_r. \end{aligned} \tag{1}$$

The linear demand functions are common and classical in the economic literature (Tsay and Agrawal [47]; Ho et al. [48]), where a is consumer acceptance of e-tail channel, b is price sensitivity parameter of demand, and $0 < b < a < 1$. And the profit functions of manufacturer and retailer are as follows:

$$\pi_m^N = (w - c)\left(d_e^N + d_r^N\right), \tag{2}$$

$$\pi_r^N = (p_e - w)d_e^N + (p_r - w)d_r^N, \tag{3}$$

where c is the unit production cost of manufacturer; for brevity, we normalize the operation costs of retailer to be zero.

In the benchmark, given the wholesale price w, the retailer will choose a regular channel price p_r and an e-tail channel price p_e to maximize his profit given by equation (3); by using the backward induction solution, the optimal equilibrium decisions are shown in the following Theorem 1.

Theorem 1. *Without considering CPFC, the optimal solutions are as follows, which is denoted by a superscript N^*:*

(1) The optimal retail price and the wholesale price are

$$p_r^{N*} = \frac{5 + a + 2c + (1 + 5a)b - 2b^2c}{8(1 - b^2)},$$

$$p_e^{N*} = \frac{1 + 5a + 2c + (5 + a)b - 2b^2c}{8(1 - b^2)}, \quad (4)$$

$$w^{N*} = \frac{1 + a + 2c - 2bc}{4(1 - b)}.$$

(2) *The optimal profits of manufacturer and retailer are* $\pi_m^{N*} = ((1 + 2bc + a - 2c)^2/16(1 - b))$, $\pi_r^{N*} = \pi_r^N(p_r^{N*}, p_e^{N*}, w^{N*})$.

(3) *The equilibrium demands of regular channel and e-tail channel are* $d_r^{N*} = ((2b - 2)c - a + 3)/(8)$, $d_e^{N*} = ((2b - 2)c + 3a - 1)/(8)$.

For all proofs, see Appendix.

From Theorem 1, we can get Corollary 1.

Corollary 1. *In a dyadic supply chain consisting of a dual-channel retailer who sells products through a single-product retail system mixed with an e-tail distribution channel to consumers, the relations of the price and demand for regular channel and e-tail channel are* $p_r^{N*} > p_e^{N*}$, $d_r^{N*} > d_e^{N*}$.

Corollary 1 indicates that in a dyadic supply chain with a mixed retail and e-tail channels, the price of regular channel products is higher than that of e-tail channel products. This is intuitive and coincident with practice, which is because the operating cost of regular channel is higher than that of e-tail channel. But the uncertainty about the quality and availability of the e-tail channel reduces consumer acceptance of e-tail channel; the demand for the regular channel is still higher than that of e-tail channel.

3.2. Model A: With ACPFC. When considering ACPFC, meaning consumer with a high sense of fairness, finding that the price of other channel products is high, consumer will refuse to purchase from the dual-channel retailer. Based on the backgrounds above and according to Chen and Cui [34], in the case with ACPFC denoted by a superscript A, the demand functions in both channels can be described as follows:

$$d_r^A = 1 - (p_r + \theta(p_r - \min(p_e, p_r))) + bp_e, \quad (5)$$

$$d_e^A = a - (p_e + \theta(p_e - \min(p_e, p_r))) + bp_r. \quad (6)$$

The corresponding profit functions are as follows:

$$\pi_m^A = (w - c)(d_e^A + d_r^A), \quad (7)$$

$$\pi_r^A = (p_e - w)d_e^A + (p_r - w)d_r^A, \quad (8)$$

where θ denotes the indicator of CPFC, $0 \le \theta \le 1$, and the larger the value of θ, the stronger the CPFC. when consumers have asymmetry peer-induced fairness concerns, if they find that the price of regular channel is higher than that of e-tail channel, they will refuse to purchase from dual-channel retailer; at this time, the ACPFC will have a negative impact on the demand of regular channel and it is expressed as $-\theta(p_r - \min(p_e, p_r))$, and there is no impact on the demand of e-tail channel. Similarly, $-\theta(p_e - \min(p_e, p_r))$ represents the negative impact on the demand of e-tail channel when consumers find that the price of e-tail channel is higher than that of regular channel, and there is no impact on regular channel.

Here, given the wholesale price w, the retailer will choose a regular channel price p_r and an e-tail channel price p_e to maximize his profit given by equations (5), (6), and (8). In this case, the retailer's profit function is not differentiable everywhere, so we solve the retailer's optimal price decision in two steps. Firstly, obtaining the optimal pricing under three situations: the price of e-tail channel is lower than that of regular channel; the price of e-tail channel is equal to that of regular channel; the price of e-tail channel is higher than that of regular channel; and then the global optimal pricing of retailer is obtained by comparing the three situations.

Similar to Theorem 1, by using the backward induction solution, the optimal decision-making of retailer under the case with ACPFC is given as follows.

Theorem 2. *With ACPFC, the optimal equilibrium decisions of dual-channel retailer and manufacturer are as follows, which is denoted by a superscript* A^*:

(1) *When* $a > 2c(1 - b) - 1$, *then the optimal wholesale price and retail price are* $w_1^{A*} = (a + 1)/(2 - 2b)$, $p_{r1}^{A*} = ((2(ab + w_1^{A*} + 1) - \theta^2 w_1^{A*} + (a + 3w_1^{A*} - 3bw_1^{A*})\theta - 2b^2 w_1^{A*})/(4 + 4(1 - b)\theta - 4b^2 - \theta^2))$, *and* $p_{e1}^{A*} = ((2(a + b + w_1^{A*}) - \theta^2 w_1^{A*} + (1 + 2a + w_1^{A*} - bw_1^{A*})\theta - 2b^2 w_1^{A*})/(4 + 4(1 - b)\theta - 4b^2 - \theta^2))$; *the optimal profits of manufacturer and dual-channel retailer are* $\pi_{m1}^{A*} = \pi_m^A(w_1^{A*}, p_{r1}^{A*}, p_{e1}^{A*})$ *and* $\pi_{r1}^{A*} = \pi_r^A(w_1^{A*}, p_{r1}^{A*}, p_{e1}^{A*})$; *the equilibrium demands of regular channel and e-tail channel are* $d_{r1}^{A*} = d_r^A(w_1^{A*}, p_{r1}^{A*}, p_{e1}^{A*})$ *and* $d_{e1}^{A*} = d_e^A(w_1^{A*}, p_{r1}^{A*}, p_{e1}^{A*})$.

(2) *When* $0 < a \le 2c(1 - b) - 1$, *if* $\theta > 2(b + 1)((2b - 2)c + a + 1)/(4c - 4bc - a - 3)$, *then* $w_2^{A*} = w_1^{A*}$ $p_{r2}^{A*} = p_{r1}^{A*}$, $p_{e2}^{A*} = p_{e1}^{A*}$; *the optimal profits of retailer and manufacturer are* $\pi_{m2}^{A*} = \pi_{m1}^{A*}$ *and* $\pi_{r2}^{A*} = \pi_{r1}^{A*}$; *the equilibrium demands of regular channel and e-tail channel are* $d_{r2}^{A*} = d_{r1}^{A*}$ *and* $d_{e2}^{A*} = d_{e1}^{A*}$. *If* $0 < \theta < 2(b + 1)((2b - 2)c + a + 1)/(4c - 4bc - a - 3)$, *then* $w_3^{A*} = (1 + 3a + 4c - 4bc)\theta + 2(b + 1)(a + 2c + 1 - 2bc)/(8(1 - b)(b + \theta + 1))$, $p_{r3}^{A*} = ((2(ab + w_3^{A*} + 1) - \theta^2 w_3^{A*} + (a + 3w_3^{A*} - 3bw_3^{A*})\theta - 2b^2 w_3^{A*})/(4 + 4(1 - b)\theta - 4b^2 - \theta^2))$, *and* $p_{e3}^{A*} = ((2(a + b + w_3^{A*}) - \theta^2 w_3^{A*} + (1 + 2a + w_3^{A*} - bw_3^{A*})\theta - 2b^2 w_3^{A*})/(4 + 4(1 - b)\theta - 4b^2 - \theta^2))$; *the optimal profits of retailer and manufacturer are* $\pi_{m3}^{A*} = \pi_m^A(w_3^{A*}, p_{r3}^{A*}, p_{e3}^{A*})$ *and* $\pi_{r3}^{A*} = \pi_r^A(w_3^{A*}, p_{r3}^{A*}, p_{e3}^{A*})$; *the equilibrium demands of regular channel and e-tail channel are* $d_{r3}^{A*} = d_r^A(w_3^{A*}, p_{r3}^{A*}, p_{e3}^{A*})$ *and* $d_{e3}^{A*} = d_e^A(w_3^{A*}, p_{r3}^{A*}, p_{e3}^{A*})$.

In Theorem 2, it can be easily gotten that the equilibrium price of regular channel is always higher than that of e-tail channel, which is reasonable and practical because offline operating costs are generally higher than online operating costs. Theorem 2 also shows that the expression of equilibrium retail price regarding wholesale price and indicator of CPFC is the same in the two cases of consumer acceptance of e-tail channel which is high and low, respectively, but the equilibrium wholesale price is different in the two cases. Counter-intuitively and interestingly, Theorem 2 indicates that when consumers have a high acceptance of e-tail channel, ACPFC directly affects retailers' pricing decisions, and when consumer acceptance of e-tail channels is low, the ACPFC can not only directly affect retailer's pricing decisions but also indirectly affect retailer's pricing decisions through influencing wholesale price; that is, ACPFC also affects manufacturer's pricing decisions. In other words, the degree of ACPFC and consumer acceptance of e-tail channel does not affect the mechanism of retailer's pricing decisions because expression of retail price has not changed but affects the level of the equilibrium retail price and the mechanism of manufacturer's wholesale pricing decision.

3.3. Model S: With SCPFC. Considering SCPFC with a low sense of fairness, when consumers find the price of other channels is lower, they will only refuse purchasing from the channel with a higher price but they will not refuse the dual-channel retailer and they will transfer to the channel with lower price. So in the case of SCPFC denoted by a superscript S, according to Chen and Cui [34], the demand of two channels can be described as follows:

$$d_r^S = 1 - (p_r + \theta(p_r - \min(p_e, p_r))) + b(p_e + \theta(p_e - \min(p_e, p_r))), \tag{9}$$

$$d_e^S = a - (p_e + \theta(p_e - \min(p_e, p_r))) + b(p_r + \theta(p_r - \min(p_e, p_r))). \tag{10}$$

The corresponding profit functions are as follows:

$$\pi_m^S = (w - c)\left(d_e^S + d_r^S\right), \tag{11}$$

$$\pi_r^S = (p_e - w)d_e^S + (p_r - w)d_r^S, \tag{12}$$

where θ is the same as model A, $0 \leq \theta \leq 1$, and when consumers have symmetry peer-induced fairness concerns, if they find that the price of one channel is higher than that of the other channel, they will only refuse to purchase from the channel with a higher price but will not refuse the dual-channel retailer, and they will transfer to other channels with lower price. For example, when consumers find the price of regular channel is higher than that of e-tail channel, SCPFC has a negative impact on the demand of regular channel and has a positive impact on the demand of e-tail channel; due to SCPFC, the demand of regular channel will decrease by $\theta(p_r - \min(p_e, p_r))$ and the demand of e-tail channel will increase by $\theta(p_r - \min(p_e, p_r))$. Similarly, $\theta(p_e - \min(p_e, p_r))$ represents the positive impact of SCPFC on regular channel and the negative impact of SCPFC on e-tail channel when consumers find that the price of e-tail channel is higher than that of regular channel.

The retailer's optimal price decision-making solution process under model S is the same as that of model A, which is not repeated here. The optimal equilibrium decisions of retailer in the case of model S are directly given as in Theorem 3.

Theorem 3. *With SCPFC, the optimal equilibrium decisions of retailer and manufacturer are as follows, which is denoted by a superscript S^*:*

(1) *When $a > 2c(1-b) - 1$, the optimal wholesale price and retail price are $w_1^{S*} = w_1^{A*}$, $p_{r1}^{S*} = (((3w_1^{S*} + a - b^2 w_1^{S*} + (a + 2 - 2w_1^{S*})b)\theta + 2(ab + w_1^{S*} + 1 - b^2 w_1^{S*}) - w_1^{S*}(1-b)^2\theta^2)/((1-b)((4b+4)(\theta+1)t - n(1-b)q\theta^2)))$, and $p_{e1}^{S*} = (((1 + (2w_1^{S*} + 1)b + 2a + w_1^{S*} - 3b^2 w_1^{S*})\theta + 2(a + b + w_1^{S*} - b^2 w_1^{S*}) - w_1^{S*}(1-b)^2\theta^2)/(1-b)((4b+4)(\theta+1) - (1-b)\theta^2))$; the optimal profits of manufacturer and retailer are $\pi_{m1}^{S*} = \pi_m^S(w_1^{S*}, p_{r1}^{S*}, p_{e1}^{S*})$ and $\pi_{r1}^{S*} = \pi_r^S(w_1^{S*}, p_{r1}^{S*}, p_{e1}^{S*})$; the equilibrium demands of regular channel and e-tail channel are $d_{r1}^{S*} = d_r^S(w_1^{S*}, p_{r1}^{S*}, p_{e1}^{S*})$ and $d_{e1}^{S*} = d_e^S(w_1^{S*}, p_{r1}^{S*}, p_{e1}^{S*})$.*

(2) *When $0 < a \leq 2c(1-b) - 1$, if $\theta > 2(b+1)(2cb - 2c + a + 1)/(4c - 4cb^2 - 3ba - b - a - 3)$, then $w_2^{S*} = w_1^{S*}$, $p_{r2}^{S*} = p_{r1}^{S*}$, and $p_{e2}^{S*} = p_{e1}^{S*}$; the optimal profits of manufacturer and retailer are $\pi_{m2}^{S*} = \pi_{m1}^{S*}$ and $\pi_{r2}^{S*} = \pi_{r1}^{S*}$; the equilibrium demands of regular channel and e-tail channel are $d_{r2}^{S*} = d_{r1}^{S*}$ and $d_{e2}^{S*} = d_{e1}^{S*}$. If $0 < \theta < 2(b+1)(2cb - 2c + a + 1)/(4c - 4cb^2 - 3ba - b - a - 3)$, then $w_3^{S*} = (4b^2c - (a+3)b - 3a - 4c - 1)\theta - 2(b+1)(a + 2c + 1 - 2bc)/(8b^2\theta + 8b^2 - 8\theta - 8)$, $p_{r3}^{S*} = ((3w_3^{S*} + a - b^2 w_3^{S*} + (a + 2 - 2w_3^{S*})b)\theta + 2(ab + w_3^{S*} + 1 - b^2 w_3^{S*}) - w_3^{S*}(1-b)^2\theta^2/(1-b)((4b+4)(\theta+1) - (1-b)\theta^2))$, and $p_{e3}^{S*} = ((1 + (2w_3^{S*} + 1)b + 2a + w_3^{S*} - 3b^2 w_3^{S*})\theta + 2(a + b + w_3^{S*} - b^2 w_3^{S*}) - w_3^{S*}(1-b)^2\theta^2/(1-b)((4b+4)(\theta+1) - (1-b)\theta^2))$; the optimal profits of manufacturer and retailer are $\pi_{m3}^{S*} = \pi_m^S(w_3^{S*}, p_{r3}^{S*}, p_{e3}^{S*})$ and $\pi_{r3}^{S*} = \pi_r^S(w_3^{S*}, p_{r3}^{S*}, p_{e3}^{S*})$; the equilibrium demands of regular channel and e-tail channel are $d_{r3}^{S*} = d_r^S(w_3^{S*}, p_{r3}^{S*}, p_{e3}^{S*})$ and $d_{e3}^{S*} = d_e^S(w_3^{S*}, p_{r3}^{S*}, p_{e3}^{S*})$.*

In Theorem 3, the equilibrium price of regular channel is always higher than that of e-tail channel still hold, and it is not difficult to get the other same conclusion from Theorem 3 as Theorem 2. However, by comparing Theorems 2 and 3, we can find that the different types of CPFC have different impacts on the equilibrium. Firstly, the equilibrium prices of supply chain system when considering ACPFC are different from that considering SCPFC, which depends on consumer acceptance of e-tail channel and degree of CPFC; it is interesting and intuitive that CPFC has no impact on wholesale pricing decision when consumer acceptance of e-tail channel is high. Secondly, the interval of different equilibrium states determined by indicator of CPFC is different when considering ACPFC and SCPFC, respectively.

4. Comparative Analysis

4.1. Manufacturer's Decisions. According to Theorems 1–3, we can get the following corollary about manufacturer's optimal wholesale price.

Corollary 2. *At equilibrium, (1)* $w^{N*} < w_1^{A*}$, $w^{N*} > w_2^{A*}$, *and* $w^N > w_3^{A*}$; *(2)* $w^N < w_1^{S*}$, $w^N > w_2^{S*}$, *and* $w^N > w_3^{S*}$; *(3)* $w_1^{A*} = w_1^{S*}$, $w_2^{A*} = w_2^{S*}$, *and* $w_3^{A*} < w_3^{S*}$; *(4)* $(\partial w_1^{A*}/\partial\theta) = (\partial w_1^{S*}/\partial\theta) = (\partial w_2^{A*}/\partial\theta) = (\partial w_2^{S*}/\partial\theta) = 0$, $(\partial w_3^{A*}/\partial\theta) < 0$, *and* $(\partial w_3^{S*}/\partial\theta) < 0$.

Corollary 2 (1) and (2) show that when $a > 2c(1-b) - 1$, wholesale price with ACPFC (or SCPFC) is higher than that without CPFC. And when $0 < a \le 2c(1-b) - 1$, the wholesale price ACPFC (or SCPFC) is lower than that without CPFC. The reason is that consumer with high acceptance of e-tail channel will not choose to leave because of the high price in spite of CPFC; such that manufacturer can raise wholesale price ignoring the CPFC when consumers have high acceptance of e-tail channel. On the contrary, the manufacturer should lower wholesale price due to the CPFC when consumer acceptance of e-tail channel is low.

Corollary 2 (3) shows that when consumer acceptance of e-tail channel is high, the impact of CPFC on supply chain is obscured, so the wholesale price with ACPFC is the same as that with SCPFC. When consumer acceptance of e-tail channel is low and CPFC is stronger, the wholesale price with ACPFC or SCPFC is the same too; we speculate the reason is that stronger SCPFC is similar to ACPFC; the impact of two different types of CPFC on supply chain is almost same. When consumer acceptance of e-tail channel is low and CPFC is weak, the difference between the two types CPFC is great, ACPFC with a high sense of fairness, so the manufacturer should offer a low price to consumers with asymmetry peer-induced fairness concerns compared to that to consumers with symmetry peer-induced fairness concerns.

Corollary 2 (4) shows that only when consumer acceptance of e-tail channel is low and the peer-induced fairness concerns are weak, wholesale price changes with CPFC and decreases with indicator of CPFC. In this case, manufacturer should pay more attention to CPFC.

Previous studies have shown that consumer distributional fairness concerns affect manufacturers' decision-making, and Corollary 2 indicates that CPFC also has an impact on manufacturers' decision-making. This is because two types of CPFC will have an impact on demand functions, and manufacturer's decision-making is closely related to demand functions; CPFC can affect the manufacturer's decision-making by influencing demand functions.

Based on Theorems 1–3, we can get the following corollary about manufacturers' optimal profits.

Corollary 3. *In the case of* $a > 2c(1-b) - 1$, $\pi_m^{N*} > \pi_{m1}^{S*} > \pi_{m1}^{A*}$.

Corollary 3 includes the relative size of manufacturer's equilibrium profits under three models when consumer acceptance of e-tail channel is high. Due to the fact that the expressions of manufacturer's profit are too complex to conduct mathematical analysis when $0 < a \le 2c(1-b) - 1$, Section 5 is conducted to get more meaningful sight.

Corollary 3 indicates that when consumer acceptance of e-tail channel is high, manufacturer's optimal profit without CPFC is higher than that with SCPFC, and the optimal profit with SCPFC is higher than that with ACPFC. This is intuitive because consumers with CPFC are more difficult to accept the price difference between regular channel and e-tail channel, which will induce the demand and profit reduction, and ACPFC with a higher sense of fairness is more difficult to accept the price difference than SCPFC with a low sense of fairness.

4.2. Dual-Channel Retailer's Optimal Decisions. Numerical example analysis will be carried out in the next section because expressions of equilibrium solutions of retailer when $0 < a \le 2c(1-b) - 1$ are too complicated to obtain the meaningful management enlightenment through direct mathematical calculation. Therefore, in this subsection, we only compare and analyze the situation where $a > 2c(1-b) - 1$.

From Theorems 2 and 3, we have the following Corollary about the retailer's optimal decisions.

Corollary 4. *(1) When* $b \le (-\theta^2 - 4\theta + 4)/(2\theta + 12)$, *then* $p_{r1}^{A*} \le p_{r1}^{S*}$; *when* $b > (-\theta^2 - 4\theta + 4)/(2\theta + 12)$, *then* $p_{r1}^{A*} > p_{r1}^{S*}$. *(2)* $p_{e1}^{A*} < p_{e1}^{S*}$. *(3)* $\pi_{r1}^{A*} > \pi_{r1}^{S*}$. *(4)* $p_{r1}^{A*} - p_{e1}^{A*} > p_{r1}^{S*} - p_{e1}^{S*}$.

Corollary 4 (1) shows that, in the case that consumer acceptance of e-tail channel is high, price of regular channel with ACPFC is lower than that with SCPFC when price sensitivity is small and vice versa. Corollary 4 (2) shows that the retail price of e-tail channel with ACPFC is lower than that with SCPFC when consumer acceptance of e-tail channel is high. It can be seen that a high sense of fairness does not always bring lower price to consumers themselves.

Corollary 4 (3) shows that retailer equilibrium profit with ACPFC is higher than that with SCPFC, so we can get that ACPFC does not bring a greater loss to retailer than SCPFC when consumer acceptance of e-tail channel is high; that is to say, ACPFC with a high sense of fairness may be more friendly to retailer than SCPFC with a lower sense of fairness.

Theorems 2 and 3 have shown that price of regular channel is higher than that of e-tail channel, and Corollary 4 (4) shows that when consumer acceptance of e-tail channel is high, price difference between regular channel and e-tail channel with ACPFC is larger than that with SCPFC. Corollary 4 (4) indicates that a high sense of fairness cannot decrease price difference between two channels compared with a low sense of fairness when consumers also have a high acceptance of e-tail channel. The reason is that consumers' acceptable price difference due to the high acceptance of e-tail channel is larger than the price difference that CPFC can mitigate. That is to say, in face of price difference, consumers with strong CPFC will not refuse to purchase form retailer when the consumer acceptance of e-tail channel is large enough, so retailer still increases price difference in spite of ACPFC with a high sense of fairness.

5. Numerical Analysis

So far, we have obtained equilibrium solutions of three models and analyzed equilibrium wholesale prices of three models. In this section, we present numerical examples to focus on comparing the equilibrium profits and retail prices of three models and discuss the impacts of the key parameter θ. We expect to draw some insights that are difficult to draw in the former sections.

Based on equilibrium solutions we derived, we take two sets of values, one is $a = 0.25$, $b = 0.2$, and $c = 0.8$ and the other is $a = 0.5$, $b = 0.2$, and $c = 0.8$; the former is corresponding to the case of $0 < a \leq 2c(1-b) - 1$, in which $\theta_1 = 2(b+1)((2b-2)c + a + 1)/(4c - 4bc - a - 3) \doteq 0.1043$ and $\theta_2 = 2(b+1)(2cb - 2c + a + 1)/(4c - 4cb^2 - 3ba - b - a - 3) \doteq 0.1364$, and the latter is corresponding to the case of $a > 2c(1-b) - 1$.

5.1. The Equilibrium Profits of Retailer and Manufacturer. According to the parameters set above, we can obtain Figures 1 and 2 which represent equilibrium profits of retailer and manufacturer when $\theta \in [0, 1]$ under two sets of values.

From Figures 1 and 2, we have the following observations.

Observation 1. From Figures 1(a) and 2(a), equilibrium profits of retailer with CPFC are always lower than that without CPFC, and equilibrium profits of retailer with SCPFC are always lower than that with ACPFC. From Figure 1(b), when $a = 0.25$, equilibrium profits of manufacturer with CPFC are higher than that without CPFC, and equilibrium profits of manufacturer with ACPFC are higher than that with SCPFC. From Figure 2(b), when $a = 0.5$, equilibrium profits of manufacturer with CPFC are lower than that without CPFC, and equilibrium profits of manufacturer with ACPFC are lower than that with SCPFC.

That is, CPFC is detrimental to retailer, and it is easier to deal with consumers with higher sense of fairness for retailer. However, the impact of CPFC on manufacturer's equilibrium profits depends on consumers' acceptance of e-tail channel; if consumers' acceptance of e-tail channel is low, CPFC is favorable to manufacturer and vice versa.

Observation 2. From Figures 1(a) and 2(a), the equilibrium profits of retailer always decrease with θ. From Figure 1(b), the equilibrium profits of manufacturer increase with θ when $a = 0.25$. From Figure 2(b), the equilibrium profits of manufacturer decrease with indicator of consumers' peer-induced fairness concerns when $a = 0.5$.

That is to say, in the case of considering ACPFC and SCPFC, respectively, the stronger the CPFC, the lower the equilibrium profit of retailer, which is not affected by consumer acceptance of e-tail channel. For manufacturer, when consumer acceptance of e-tail channel is low, the stronger the CPFC, the higher the equilibrium profit of manufacturer. When consumer acceptance of e-tail channel is high, the stronger the CPFC, the lower the equilibrium profit of manufacturer.

5.2. The Equilibrium Retail Prices. In this subsection, we further compare the retail prices of three models and analyze the impacts of the indicator of CPFC on equilibrium retail prices. Based on the parameters set above, we can obtain Figures 3–5, where Figures 3 and 4 represent equilibrium retail price of three models under the two sets of values; Figure 5 represents price differences of three models under the two sets of values.

Form Figures 3 and 4, we obtain Observations 3–5 as follows:

Observation 3. Form Figure 3(a), when $a = 0.25$, retail price of e-tail channel with SCPFC is higher than that without CPFC; as θ increases, firstly retail price of e-tail channel with ACPFC is lower than that without CPFC, then slightly higher than that without CPFC, and finally lower than that without CPFC. Form Figure 4(a), when $a = 0.5$, the retail price of e-tail channel with SCPFC is higher than that with ACPFC, and the retail price of e-tail channel with ACPFC is higher than that without CPFC.

Regardless of the value of a, e-tail channel price with SCPFC is the highest among three equilibrium e-tail channel prices of three models. When consumer acceptance of e-tail channel is high, retail price of e-tail channel with ACPFC is always higher than that without CPFC. That is, SCPFC increases retail price of e-tail channel, and ACPFC can reduce retail price of e-tail channel and can increase retail price of e-tail channel.

Observation 4. Form Figures 3(b) and 4(b), retail price of regular channel with SCPFC is almost the same as that with ACPFC when θ is relatively small, and retail price of regular channel with SCPFC is slightly higher than that with ACPFC when θ is relatively large. Retail price of regular channel without CPFC is higher than that with CPFC when $a = 0.25$, and retail price of regular channel with CPFC is first higher than that without CPFC and then lower than that without CPFC when $a = 0.5$.

In the case of different values, the relative relation of regular channel retail prices under two types of CPFC is the same, and CPFC may lower retail price of regular channel, but it may also increase retail price of regular channel. Combining with Observation 3, it is not difficult to find that CPFC is not always beneficial to consumers themselves.

Observation 5. From Figures 3(a) and 4(a), retail price of e-tail channel with SCPFC increases with θ. When $a = 0.25$, firstly, retail price of e-tail channel with

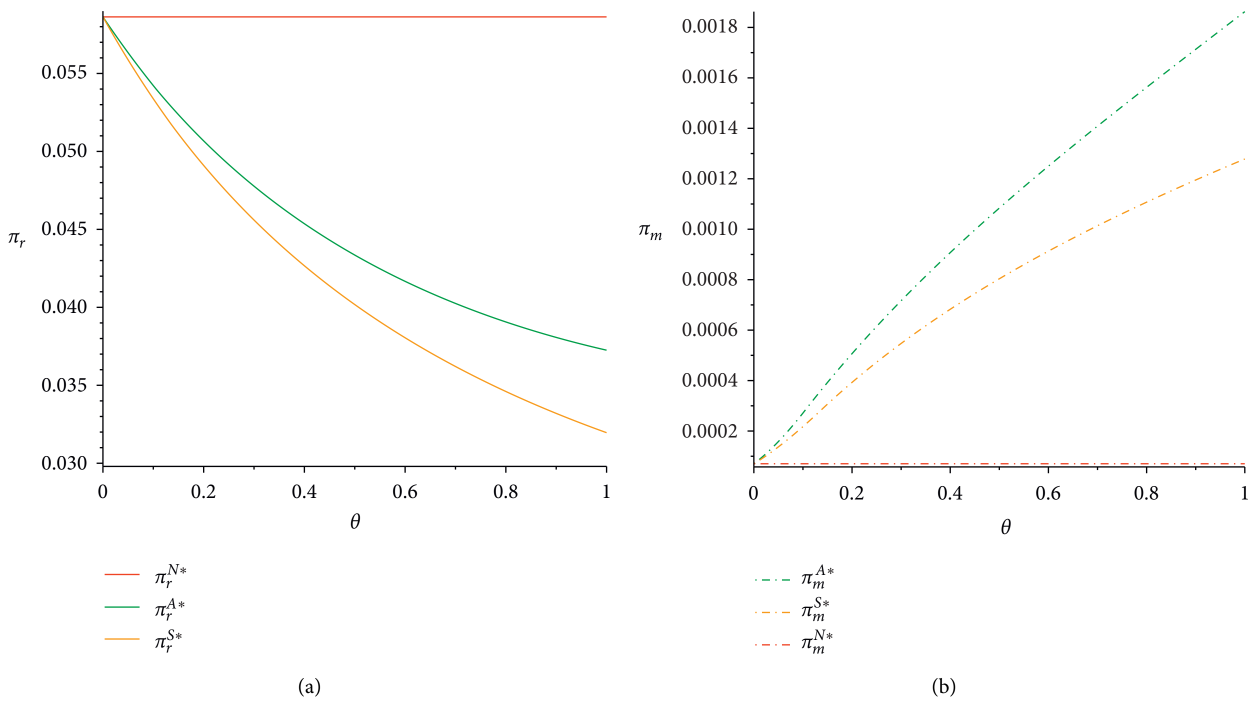

Figure 1: Comparison results of profits versus parameter θ when $a = 0.25$, $b = 0.2$, and $c = 0.8$. (a) Retailer's equilibrium profits under three models. (b) Manufacture's equilibrium profits under three models.

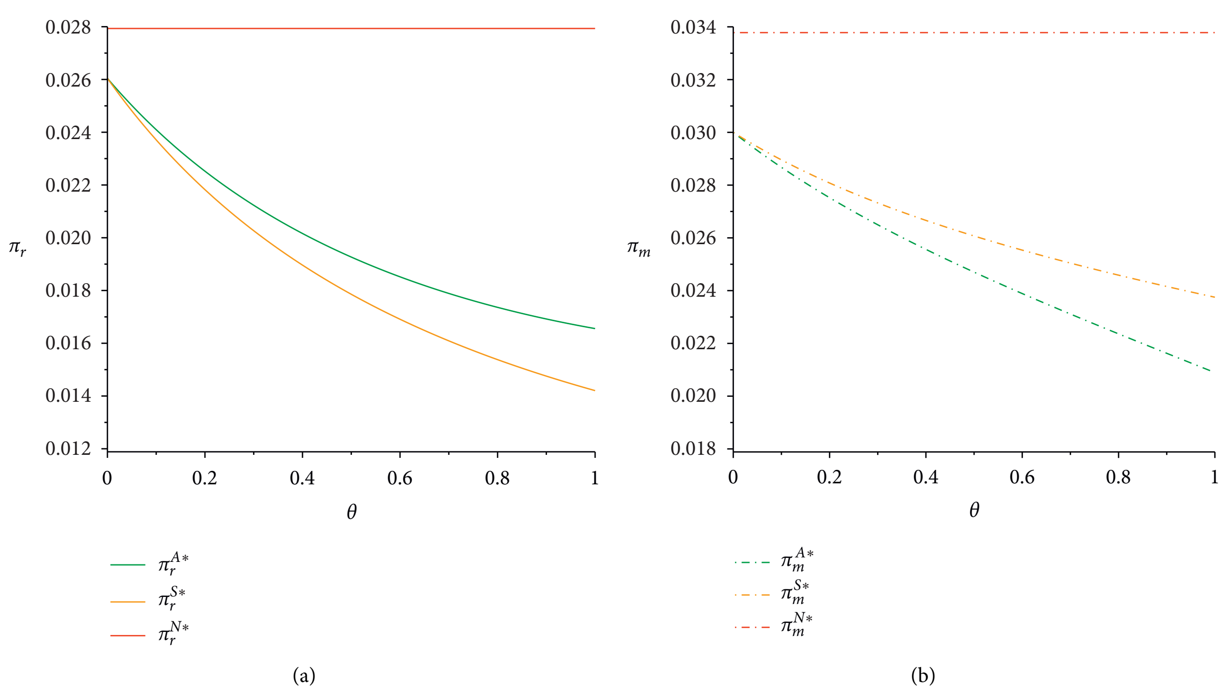

Figure 2: Comparison results of profits versus parameter θ when $a = 0.5$, $b = 0.2$, and $c = 0.8$. (a) Retailer's equilibrium profits under three models. (b) Manufacture's equilibrium profits under three models.

ACPFC decreases with θ, then increases with θ, and finally decreases with θ. When $a = 0.5$, firstly, retail price of e-tail channel with asymmetry consumers peer-induced fairness concern increases with θ and then decreases with θ. From Figures 33(b) and 4 (b), retail price of regular channel always decreases with θ.

Combining with Observations 3 and 4, we can see that SCPFC can always increase retail price of e-tail

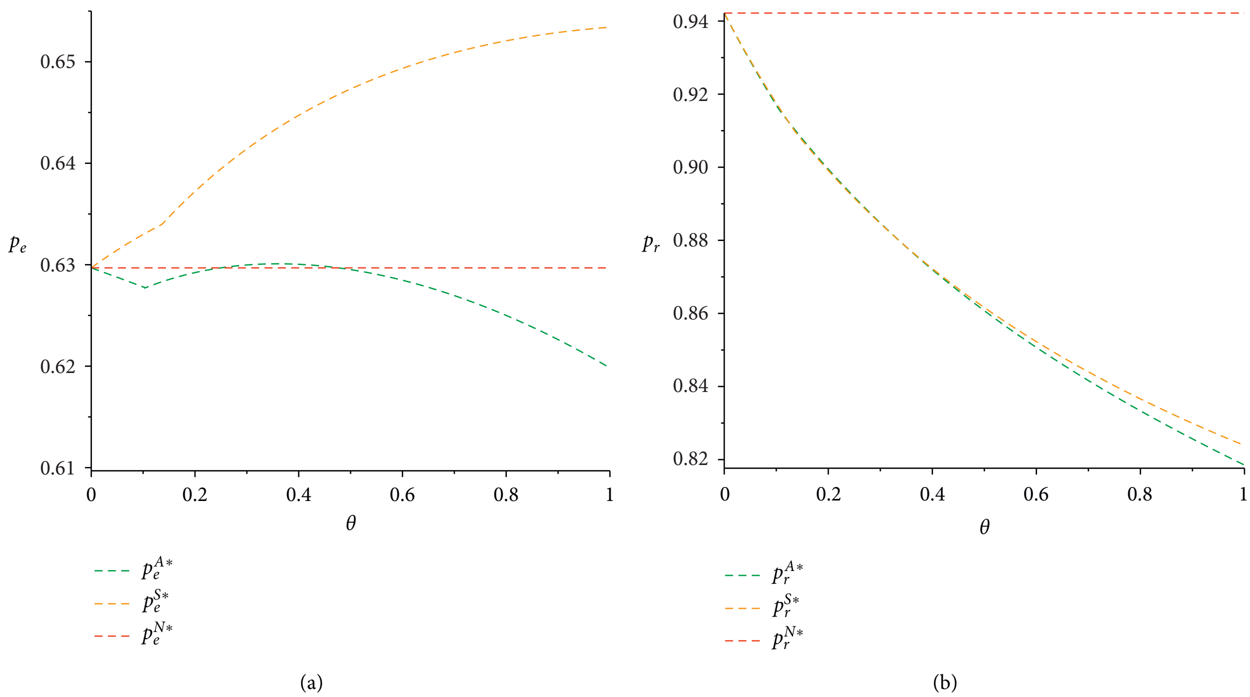

Figure 3: Comparison results of prices versus parameter θ when $a = 0.25$, $b = 0.2$, and $c = 0.8$. (a) Equilibrium prices of e-tail channel under three models. (b) Equilibrium prices of regular channel under three models.

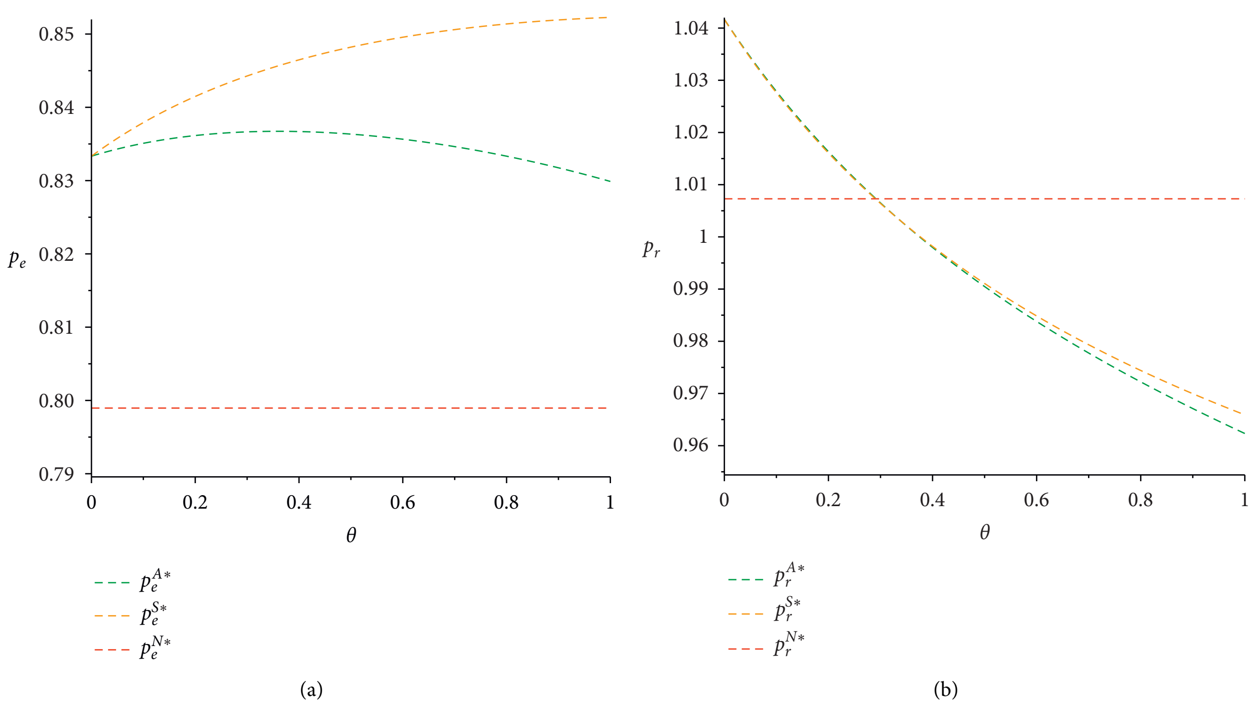

Figure 4: Comparison results of prices versus parameter θ when $a = 0.5$, $b = 0.2$, and $c = 0.8$. (a) Equilibrium prices of e-tail channel under three models. (b) Equilibrium prices of regular channel under three models.

channel, and the stronger the SCPFC, the higher the retail price of e-tail channel. However, the impact of the strength of ACPFC on retail price of e-tail channel depends on consumer acceptance of e-tail channel. Due to the fact that the retail price of regular channel is higher than that of e-tail channel, the stronger the CPFC, the lower the retail price of regular channel.

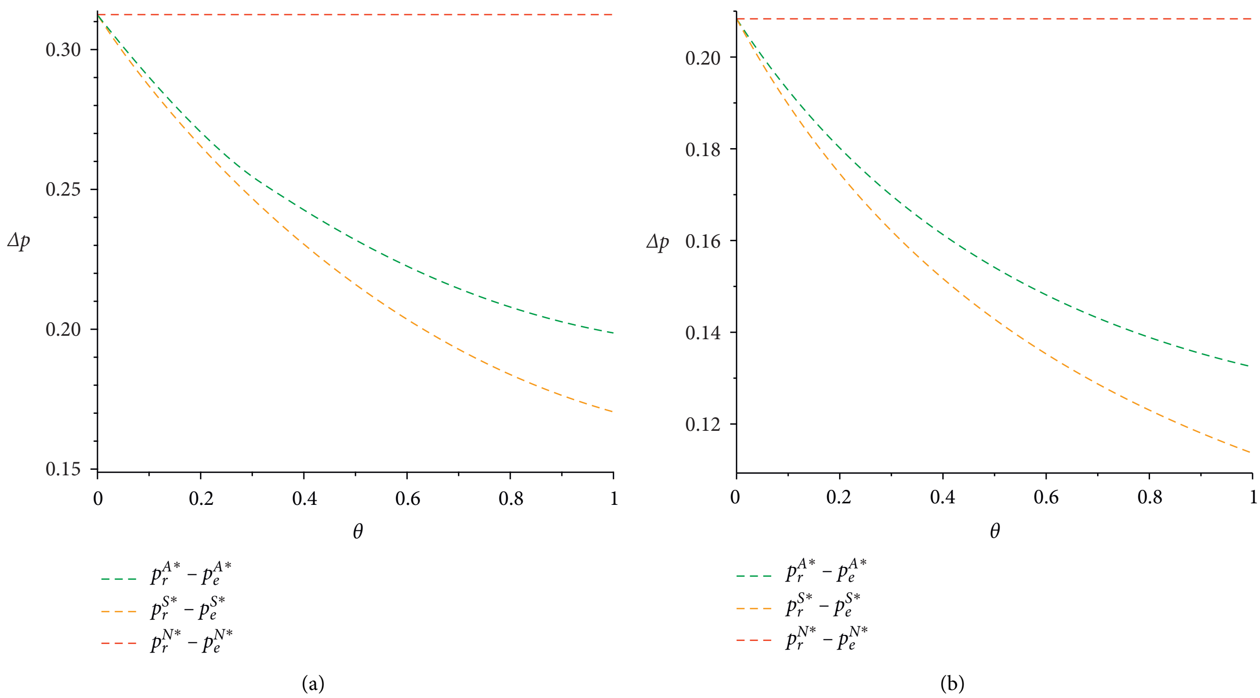

Figure 5: Price differences under three models (a) when $a = 0.25, b = 0.2, c = 0.8$ and (b) when $a = 0.5, b = 0.2, c = 0.8$.

Table 1: Parameter description.

Notations	Descriptions
p_r, p_e	Price of the regular channel and the e-tail channel per unit
d_r, d_e	Demand of the regular channel and the e-tail channel
b	Price sensitivity parameter of the demand
a	Consumer acceptance of the e-tail channel
π_i	$i = m, r$ denote the manufacturer's profit and the retailer profit
w	Wholesale price of the manufacturer to the retailer per unit
c	The unit production cost of manufacturer
θ	Indicator of the consumer's peer-induced fairness concerns

From Figure 5, Observations 6–7 are obtained as follows:

Observation 6. The price differences with SCPFC are smaller than that with ACPFC, and the price differences with ACPFC are smaller than that without CPFC.

Intuitively, CPFC can narrow the price difference between regular channel and e-tail channel due to consumer fairness seeking. What is unexpected and interesting is that SCPFC with a low sense of fairness can more effectively narrow the price difference than ACPFC with a high sense of fairness.

Observation 7. The price differences decrease with θ.

No matter what type of CPFC is, the stronger the CPFC, the smaller the price difference between regular channel and e-tail channel, which is a reasonable observation.

6. Conclusion

In this study, we consider a setting where consumers purchase decisions are affected by both their own monetary payoff and their peer-induced fairness concerns about others' monetary payoff; we divided CPFC into two types: one is ACPFC and the other is SCPFC. Then we unravel how such peer-induced fairness-seeking behavior interacts with supply chain member pricing decisions under a two-level supply chain including a dual-channel retailer selling products to consumers through both the regular channel and the e-tail channel. In this paper, the decision-making models under the scenarios without CPFC, the scenarios with ACPFC, and the scenarios with SCPFC are constructed, respectively, and optimal price decisions and optimal profits for dual-channel retailer and manufacturer are solved, respectively. Through comparative analysis and numerical analysis, the main conclusions are as follows:

(1) No matter whether there is CPFC or not, retailer's equilibrium price of regular channel product is higher than that of e-tail channel product, which is in line with reality. However, CPFC can reduce the price difference between regular channel and e-tail channel, and the stronger the CPFC, the smaller the price difference.

(2) CPFC may affect the manufacturers pricing decisions by affecting the market demand, and the CPFC is beneficial for the manufacturer; the stronger the CPFC, the higher the manufacturer equilibrium profit. But CPFC is harmful to the retailer; the stronger the CPFC, the lower the retailer equilibrium profit.
(3) The type and strength of CPFC do not necessarily affect manufacturers' pricing decisions; only when both consumer acceptance of e-tail channel and CPFC are small, the type and strength of CPFC can affect the manufacturers' pricing decision.
(4) The type and strength of CPFC will affect the retailers' pricing decisions. The equilibrium price of e-tail channel products with SCPFC is higher than that of ACPFC, and the equilibrium price of regular channel products under both types of CPFC decreases with indicator of CPFC.

However, in this paper, ACPFC and SCPFC are discussed separately as two cases. There is no discussion about some consumers who have ACPFC and the others who have SCPFC, or even there are consumers who are fairness-neutral. Therefore, when there are different proportions of different types of CPFC in the consumer group, how to make pricing decision in supply chain is also a worthy problem to discuss.

6.1. Notations. The notations used in this paper are as shown in Table 1.

Appendix

Proof of Theorem 1

Given the wholesale price w, the retailer will choose a regular channel price and an e-tail channel to maximize his profit. Computing the first-order conditions of the retailer's profit functions given by equation (3) yields the following equations:

$$\frac{\partial \pi_r^N}{\partial p_r} = (-w + 2p_e)b + w - 2p_r + 1,$$
$$\frac{\partial \pi_r^N}{\partial p_e} = (-w + 2p_r)b + a + w - 2p_e. \quad \text{(A.1)}$$

And then the authors obtain the retailer equilibrium prices by solving the first-order condition $(\partial \pi_{\mathrm{r}}^N/\partial \mathrm{p}_{\mathrm{r}}) = 0$ as follows:

$$p_r = \frac{1 + ab + w - b^2 w}{2 - 2b^2},$$
$$p_e = \frac{a + b + w - b^2 w}{2 - 2b^2}. \quad \text{(A.2)}$$

These are optimal because the Hessian matrix is negative definite:$|H| = \begin{vmatrix} -2 & 2b \\ 2b & -2 \end{vmatrix} = 4 - 4b^2 > 0$. Then, we plug the retailer's equilibrium prices into the manufacturers' profit function:

$$\pi_m^N = -\frac{1}{2}(-w + c)((2b - 2)w + a + 1). \quad \text{(A.3)}$$

Solving the first-order condition $(\partial \pi_m^N/\partial w) = 0$ yields $w^N = (1 + a + 2c - 2bc/4(1 - b))$; it is optimal because $(\partial^2 \pi_m^N/\partial w^2) = 2b - 2 < 0$.

Then, we plug them into the retailer's equilibrium prices:

$$p_r^N$$
$$p_e^N = \frac{1 + 5a + 2c + (5 + a)b - 2b^2 c}{8(1 - b^2)}. \quad \text{(A.4)}$$

Proof of Theorem 2

Given any wholesale price w, the retailer will choose a group of retail prices p_r and p_e to maximize his profit given by equations (5), (6), and (8). As the retailers' profit function is not differentiable everywhere, we drive the retailer's optimal decisions in two steps. First, we drive the retailers' optimal decision which is conditional on the price of e-tail channel which is lower than that of regular channel, conditional on the price of e-tail channel which is equal to that of regular channel, or conditional on the price of e-tail channel which is higher than that of regular channel. In the former case, $d_r^A = 1 - (p_r + \theta(p_r - p_e)) + bp_e$ and $d_e^A = a - p_e + bp_r$. In the middle case, $d_r^A = 1 - p_r + bp_e$, $d_e^A = a - p_e + bp_r$, and $p_r = p_e$. In the last case, $d_r^A = 1 - p_r + bp_e$, $d_e^A = a - (p_e + \theta(p_e - p_r)) + bp_r$. Second, the optimal solutions from three cases are compared to determine the retailer's global optimal solution, and then the following solution method for the retailer is the same as Theorem 1.

It can be shown that when $4 + 4(1 - b)\theta - 4b^2 - \theta^2 > 0$, the Hessian matrix is negative, and the optimal pricing under the situations that the price of e-tail channel is lower than that of regular channel is as follows: when $a + 1 + (2b - 2)w > 0$ and $0 < \theta < (2(b - 1)(a - 1)/a + 1 + (2b - 2)w)$ or $a + 1 + (2b - 2)w < 0$ and $\theta > (2(b - 1)(a - 1)/a + 1 + (2b - 2)w)$, the optimal profit and price of regular channel and e-tail channel of the retailer are

$$p_r^L = \frac{2(ab + w + 1) - \theta^2 w + (a + 3w - 3bw)\theta - 2b^2 w}{4 + 4(1 - b)\theta - 4b^2 - \theta^2}, \quad \text{(A.5)}$$

$$p_e^L = \frac{2(a + b + w) - \theta^2 w + (1 + 2a + w - bw)\theta - 2b^2 w}{4 + 4(1 - b)\theta - 4b^2 - \theta^2}, \quad \text{(A.6)}$$

$$\Pi_r^L = \frac{1+2(1-b)^2(b+\theta+1)w^2+a^2+2ab+\left(a^2+a\right)\theta-((3a+1)\theta+2(b+1)(a+1))(1-b)w}{4+4(1-b)\theta-4b^2-\theta^2}. \quad (A.7)$$

When the price of e-tail channel is equal to that of regular channel, it is easy to obtain that the retailer's profit function is a concave function of price, and the optimal price and profit of retailer are, respectively,

$$p_e^* = p_r^* = p^U = \frac{1+a+2w-2bw}{4(1-b)}, \quad (A.8)$$

$$\pi_r^U = \frac{(1+a+2bw-2w)^2}{8(1-b)}. \quad (A.9)$$

It can be shown that when $4+4(1-b)\theta-4b^2-\theta^2>0$, the Hessian matrix is negative; the optimal pricing under the situations that the price of e-tail channel is higher than that of regular channel is as follows: when $a+1+(2b-2)w<0$ and $\theta>(2(1-b)(a-1)/a+1+(2b-2)w)$, the optimal profit and price of regular channel and e-tail channel of the retailer are

$$p_r^H = \frac{2(ab+w+1)-\theta^2 w+(2+a+w-bw)\theta-2b^2w}{4+4(1-b)\theta-4b^2-\theta^2}, \quad (A.10)$$

$$p_e^H = \frac{2(a+b+w)-\theta^2 w+(1+3w-3bw)\theta-2b^2w}{4+4(1-b)\theta-4b^2-\theta^2}, \quad (A.11)$$

$$\pi_r^H = \frac{2(1-b)^2(b+\theta+1)w^2-((a+3)\theta+2(b+1)(a+1))(1-b)w+(a+1)\theta+a^2+2ab+1}{4+4(1-b)\theta-4b^2-\theta^2}. \quad (A.12)$$

By comparing equations (A.7), (A.9), and (A.12), we can get the optimal equilibrium decisions of retailer as shown in Theorem 2. Given the retailers' optimal decision, the manufacturer's decision problem can be described as follows:

$$\text{s.t.} \begin{cases} p_e = p_e^L \\ w > \dfrac{a+1}{2-2b} \\ w > \dfrac{(a+1)\theta+2(1-b)(a-1)}{2(1-b)\theta} \\ p_r = p_r^L. \end{cases} \quad (A.13)$$

Then using the K.T. conditions to solve equation (A.12) can easily get manufacturer's optimal decisions.

Proof of Theorem 3

Similar to the solution of Theorems 1 and 2, given any wholesale price, the retailer will choose a group of retail prices and maximize his profit given by equations (9), (10), and (12). As the retailers' profit function is not differentiable everywhere, we drive the retailer's optimal decisions in two steps. First, we drive the retailers' optimal decision which is conditional on the price of e-tail channel which is lower than that of regular channel, conditional on the price of e-tail channel which is equal to that of regular channel, or conditional on the price of e-tail channel which is higher than that of regular channel. In the former case, $d_r^S = 1-(p_r+\theta(p_r-p_e))+bp_e$ and $d_e^S = a-p_e+b(p_r+\theta(p_r-p_e))$. In the middle case, $d_r^S = 1-p_r+bp_e$, $d_e^S = a-p_e+bp_r$, and $p_r = p_e$. In the last case, $d_r^S = 1-p_r+b(p_e+\theta(p_e-p_r))$ and $d_e^S = a-(p_e+\theta(p_e-p_r))+bp_r$. Second, the optimal solutions from three cases are compared to determine the retailer's global optimal solution. And then the following solution method is the same as that in Theorems 1 and 2 and will not be repeated here.

Proof of Corollary 1

$$\begin{aligned} p_r^N - p_e^N &= \frac{1-a}{2b+2} > 0, \\ d_r^N - d_e^N &= \frac{1}{2} - \frac{1}{2}a > 0. \end{aligned} \quad (A.14)$$

Proof of Corollary 2

(1) $w^{N*} - w_1^{A*} = (2bc+a-2c+1/4b-4) < 0$, $w^{N*} - w_2^{A*} = (2bc+a-2c+1/4b-4) > 0$, and $w^N - w_3^{A*} = (1/8)(\theta(a-1)/(b-1)(b+\theta+1)) > 0$.

(2) $w^N - w_1^{S*} = (2bc+a-2c+1/4b-4) < 0$, $w^N - w_2^{S*} = (2bc+a-2c+1/4b-4) > 0$, and $w^N - w_3^{S*} = -(1/8)(\theta(a-1)/(b-1)(b+\theta+1)) > 0$.

(3) $w_3^{A*} - w_3^{S*} = -(1/8)(\theta(a-1)b(2\theta+1+b)/(b+\theta+1)(\theta+1)(b-1)(b+1)) < 0.$

(4) $(\partial w_3^{A*}/\partial\theta) = -(1/8)((b+1)(a-1)/(b-1)(b+\theta+1)^2) < 0$ and $(\partial w_3^{S*}/\partial\theta) = (1/8)(a-1/(\theta+1)^2(b+1)) < 0.$

Proof of Corollary 3

$$\pi_m^{N*} - \pi_{m1}^{S*} = \frac{1}{16}\frac{(2bc+a-2c+1)\left((2bc+a-2c+1)\left((1/4)\theta^2+(b-1)\theta+b^2-1\right)+(b-1)(2-2a)\theta\right)}{\left((1/4)\theta^2+(b-1)\theta+b^2-1\right)(1-b)} > 0,$$

$$\pi_{m1}^{S*} - \pi_{m1}^{A*} = -\frac{1}{2}\frac{\theta(a-1)\left((1/4)\theta^2+b+2\theta+1\right)(2bc+a-2c+1)b}{\left((1/4)\theta^2+(b-1)\theta+b^2-1\right)\left((b-1)\theta^2+(4b+4)\theta+4b+4\right)} < 0. \tag{A.15}$$

Proof of Corollary 4

(1) $p_{r1}^{A*} - p_{r1}^{S*} = -(1/8)((2b\theta+\theta^2+12b+4\theta-4)(a-1)b\theta/((b-1)\theta^2+(4b+4)\theta+4b+4)((1/4)\theta^2+(b-1)\theta+b^2-1))$; when $b < (-\theta^2-4\theta+4/2\theta+12)$, $p_{r1}^{A*} < p_{r1}^{S*}$; when $b > (-\theta^2-4\theta+4/2\theta+12)$, $p_{r1}^{A*} > p_{r1}^{S*}$.

(2) $p_{e1}^{A*} - p_{e1}^{S*} = (1/4)((-(1/2)\theta^2+(b-6)\theta+2b-6)\theta(a-1)b/((1/4)\theta^2+(b-1)\theta+b^2-1)((b-1)\theta^2+(4b+4)\theta+4b+4)) < 0.$

(3) $\pi_{r1}^{A*} - \pi_{r1}^{S*} = (1/8)(\theta((b-2)\theta+4b-4)(a-1)^2b/((b-1)\theta^2+(4b+4)\theta+4b+4)((1/4)\theta^2+(b-1)\theta+b^2-1)) > 0.$

(4) $(p_{r1}^{A*} - p_{e1}^{A*}) - (p_{r1}^{S*} - p_{e1}^{S*}) = -(1/2)(b((b-2)\theta+4b-4)\theta(a-1)/((1/4)\theta^2+(b-1)\theta+b^2-1)((b-1)\theta^2+(4b+4)\theta+4b+4)) > 0.$

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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