Fairness concerns and extended producer responsibility transmission in a circular supply chain

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Declaration of interest

None.

Acknowledgements

This work was supported by National Natural Science Foundation of China (Grant #: 72001041 and 71801003), Humanities and Social Sciences Foundation of the Ministry of Education of China (Grant #: 18YJC630110 and 20YJC630230) and Natural Science Foundation of Fujian Province (Grant #: 2019J05049). This work was also supported by Research Center of Efficiency and Productivity Fujian College's Research Base of Humanities and Social Science Fujian in China.

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Abstract: Extended producer responsibility (EPR) is an important policy tool that aims to make manufacturers financially and/or physically responsible for recycling and remanufacturing their end-of-life products. To transfer these responsibilities, a number of manufacturers require their retailers to co-finance the additional investment on EPR through wholesale price markup, possibly leading to retailers' fairness concern issues. Along this line, we consider a two-echelon circular supply chain where a manufacturer transfers its recycling and remanufacturing responsibility to a retailer by determining the wholesale price. Thus, the retailer perceives unfairness and makes the corresponding pricing decisions to resist the manufacturer. To analyze the relationship between fairness concerns and the pricing-based responsibility transmission, we establish a leader–follower Stackelberg game model for this supply chain and compare cases with and without fairness concerns. The equilibrium results indicate that the two agents can achieve a win–win situation if the manufacturer considers retailer's fairness concerns when determining the wholesale price and if the retailer sets a relatively lower price to undertake part of upfront investment to fulfill EPR. We further conduct a survey and in-depth interviews as empirical evidences to support these results derived from our models.

Keywords: Circular supply chain; Extended producer responsibility; Fairness concerns; Responsibility transmission

1. Introduction

The alarming increasing in end-of-life (EOL) products has become an important environmental issue (Dissanayake & Sinha, 2015; Yenipazarli, 2016) which can be well addressed by making them re-enter circular supply chain (CSC) through reuse or recycling (Batista et al., 2019; Jia et al., 2020; Nasir et al., 2017). To this end, government is imposing extended producer responsibility (EPR) on manufacturers, which aims to make product manufacturers financially or physically responsible for recycling and remanufacturing of their own EOL products (Jacobs & Subramanian, 2012; Khetriwal et al., 2009; Lindhqvist, 2000). Despite governments' attempts, the investment on EPR has placed a great cost burden on the upstream manufacturer in a CSC (Gui et al., 2016; Ramírez & Morales, 2014; Wang et al., 2018). For instance, a survey examining the reverse logistics cost of 500 auto component manufacturers, shows that their investments on product recovery mostly account for more than 30% of the entire operating cost (Ravi & Shankar, 2015). To alleviate the EPR-related cost pressure, manufacturers may transfer their partial responsibilities to retailers through the wholesale price markup. This behavior of responsibility transmission consequently undermines the original profit distribution mechanism, resulting in inequality from the perspective of the downstream retailer who concerns about the profit distribution fairness (Gu & Wang, 2011; Sharma et al., 2019). There are abundant evidence and examples to show that supply chain firms pay much attention to distribution fairness, i.e., fairness concerns (Cui et al., 2007; Liu et al., 2018; Liu et al., 2021b). In this sense, firms not only are concerned about their self-interest, but also care about their supply chain collaborators' benefits. With fairness concerns, firms may punish their collaborators at the cost of decreasing their own interests if they perceive unfairness (Granot & Yin, 2007; Guan et al., 2020; Wu & Niederhoff, 2014; Zheng et al., 2019b).

It is important to investigate the interaction between manufacturers' responsibility transmission and retailers' fairness concerns in CSC because it implies a complex and intense competition, in which both parties need to treat carefully. On the manufacturers' side, if they set their wholesale prices without considering the retailers' fairness concerns, it may lead to the dissatisfaction of the retailers who would make the corresponding pricing decisions to resist the manufacturers or even terminate the cooperative relationship with their manufacturers (Choi & Messinger, 2016; Wang et al., 2021). On the retailers' side, if they are excessively fairness concerned, their pricing decisions will be far from reasonability, which eventually harm their own interests as well as the overall performance of the supply chain. It can be seen that if the two parties' relationship is not structured and coordinated prudently, the well-intentioned EPR regulations would lead to a lose–lose situation and even have adverse effects on environment. Therefore, our study aims to explore the balance between pricing-based responsibility transmission and fairness concerns. This is an important and interesting question in terms of the game theory. By solving this, we can obtain the trade-off strategies which are not only conductive to EPR fulfilling but also profitable for supply chain members.

To address this question, this paper presents a two-echelon CSC comprising an upstream manufacturer under EPR regulation (i.e., a minimum collection rate is imposed on the manufacturer) and a downstream retailer. Particularly, we consider a leader–follower Stackelberg game between the two agents and construct the following three game models: (1) a fairness-neutral decentralized case (Model ND), (2) the manufacturer considers retailer's fairness concerns (Model NF), and (3) the manufacturer does not consider retailer's fairness concerns (Model NU). Then, based on the equilibrium results derived from the three models, we comparatively analyze the impact of fairness concerns on equilibrium results in three models and obtain the corresponding price transmission mechanism. Finally, we conduct a survey and in-depth interviews to supplement empirical evidences for the analysis results of the mathematical models.

This study contributes to the extant literature in the following ways. First and foremost, this study is the first to investigate the relationship between fairness concerns and pricing-based EPR transmission in a two-echelon CSC according to the authors' best knowledge, which contributes to both the extant behavioral and operational management literatures. Second, we consider and compare the manufacturer's two different attitudes toward retailer's fairness concerns (i.e., models NF and NU) while the existing literature only consider one of them. Third, we derive a robust result not only from the model analysis but also from the empirical study: The CSC can achieve a win–win outcome and environmental benefit if the manufacturer incorporates retailer's fairness preference into his wholesale pricing decisions and the retailer shows moderate fairness concerns with the awareness of undertaking partial EPR responsibility.

The remainder of this paper is organized as follows. In Section 2, we review the relevant literature, and in Section 3, we describe the problems and introduce model assumptions. We formulate three models (i.e., models ND, NF, and NU) to illustrate the manufacturer and retailer's equilibrium decisions and profits in Section 4. In Section 5, we perform model analysis of the optimal results. To supplement supporting evidence, we conduct a survey and in-depth interviews in Section 6. We provide specific conclusions on the theoretical contributions and practical implications, and offer directions for future research in Section 7. All proofs are presented in the Appendices.

2. Literature review

We review the literature related to our work that stems from two streams: EPR transmission in supply chain, and fairness concerns in the CSC. The details are presented in the following sections.

2.1. EPR transmission in supply chain

The literature on EPR transmission in supply chain can be divided into two types: direct transmission and indirect transmission (Atasu & Subramanian, 2012; Cheng et al., 2017; Jacobs & Subramanian, 2012; Wang et al. 2019; Wu, 2013), the details of which are presented below.

(1) Direct transmission: Manufacturers directly outsource their EPR activities to other supply chain collaborators or professional third-party companies, which is called direct transmission. Atasu and Subramanian (2012) suggest that the original equipment manufacturer subject to the Waste Electrical and Electronic and Equipment Directive should directly transfer their EPR responsibility to other supply chain members in order to focus on their core competency of production. Furthermore,

Jacobs and Subramanian (2012) investigate how the direct responsibility transmission improve the overall profit at the supply chain level.

(2) Indirect transmission: Manufacturers undertake EPR activities by themselves, but make their supply chain collaborators co-finance the EPR-related investment through pricing decisions, which is called indirect transmission. Cheng et al. (2017) demonstrate that the original equipment manufacturer (retailer) indeed transfers its remanufacturing (recycling) responsibilities to the retailer (original equipment manufacturer) through the wholesale price (transfer price) of the remanufactured products (the old products) markup. Wang et al. (2019) examine the issue of collection responsibility sharing under the government's reward-penalty mechanism in a multi-tier closed loop supply chain, and their results show that the manufacturer should take full responsibility by charging a relatively lower wholesale price rather than transfer the EPR-related responsibility to the retailer.

Extant literature has demonstrated that EPR transmission is the manufacturers' natural choice when they do have a channel power advantage over the downstream retailers, and indirect responsibility transmission increases the economic burden borne by the downstream members (Atasu et al., 2009; Cheng et al., 2017). However, whether EPR transmission will lead to the retailers' fairness concerns and how the EPR undertakers will react to retailers' fairness concerns have not been investigated in the existing literature, despite these issues are much closer to reality than traditional studies on EPR transmission based on rationality assumptions. The present study aims to remedy this limitation of the existing theory research.

2.2. Fairness concerns in the CSC

Since Cui et al. (2007) first introduce the participant's fairness concerns into the supply chain, many researchers extend this study by incorporating fairness concerns into the CSC. Most of them focus on the fairness of income distribution in the CSC and its impact on the decision-making of CSC members, and explore this issue under different supply chain structures using various game theoretic methods (Guan et al., 2020; Jian et al., 2021; Li et al., 2021; Sharma et al., 2019; Zhang & Wang, 2018;

Zheng et al., 2019a). For example, Jian et al. (2021) investigate the effect of manufacturers' fairness concerns on the retailer's sales effort, product green degree, recycling rate and product pricing decisions in a green supply chain and design a profit-sharing contract to coordinate this supply chain. Li et al. (2021) examine distributional fairness in a reverse supply chain by adopting Stackelberg game theory. Sharma et al. (2019) adopt Nash bargaining solutions as the fairness reference to formulate the utility functions of channel members, and investigate the impact of channel members' Nash bargaining fairness concerns in a two-echelon CSC. Similarly, Guan et al. (2020) incorporate players' Nash-bargaining fairness concerns, the supply chain's power structure, and consumer goodwill into an integrated framework to examine the effect of fairness concerns on CSC members' equilibrium decisions. Zhang and Wang (2018) employ a duopoly supply chain game model to examine how a firm's horizontal and vertical fairness concerns influence the three-party supply chain coordination. Zheng et al. (2019a) investigate the optimal decisions and profits under five non-cooperative and cooperative game models in a three-echelon closed-loop supply chain. They also focus on how to allocate maximum profit in a centralized setting, wherein the retailer exhibits distributional fairness concerns. Similar to the first stream of EPR transmission in supply chain, this stream of research in fairness concerns overlooks the issue of EPR transmission in the CSC. This study helps fill this research gap.

In addition, the main motivation of this study is the lack of empirical evidence regarding the issues of EPR transmission and fairness concerns in these two streams (Chen et al., 2021b; Zhang & Wang, 2018; Zheng et al., 2021). In this respect, our work, including both modelling and empirical studies, methodologically contributes to these two streams of research on EPR transmission and fairness concerns in CSC. Table 1 positions our research against existing literature.

Table 1. Literature positioning of this research.

References	Fairness concerns?	EPR?	Price transmission?	Profit distribution?	Empirical research?

Atasu et al. (2009)		●			
Atasu & Subramanian (2012)		●			
Cui et al. (2007)	●				
Chen et al. (2021b)					●
Cheng et al. (2017)		●			
Guan et al. (2020)	●			●	
Jacobs & Subramanian (2012)		●			
Jian et al. (2021)	●				
Li et al. (2021)	●		●	●	
Sharma et al. (2019)	●				
Wang et al. (2019)			●		
Wu (2013)		●			
Zhang & Wang (2018)	●				●
Zheng et al. (2019a)	●			●	
Zheng et al. (2021)					●
This paper	●	●	●	●	●

3. Problem description and model assumptions

3.1. Problem description

We consider a two-echelon CSC consisting of an upstream manufacturer and a downstream retailer, the former is the leader while the latter is the follower. In such setting, this paper establishes a framework for the CSC system's forward and reverse flows with retailer's fairness concerns, as shown in Figure 1. Specifically, the government imposes EPR regulation (i.e., the minimum collection rate for EOL products) on the manufacturer. The manufacturer needs to undertake the investment responsibility for EOL products' recycling and remanufacturing in addition to produce and wholesale new products to its retailer (Chen et al., 2021a). Then the retailer sells new products to consumers, collects and potentially transfers EOL products to the manufacturer for remanufacturing. Wherein, the investment activity aims to advance the sustainability in supply chain resource utilization and management (Koh et al., 2017). Nevertheless, the financially/physically responsibility transmission through wholesale price markup may damage original profit allocation mechanism. Hence, the retailer exhibits fairness concerns for such EPR transmission.

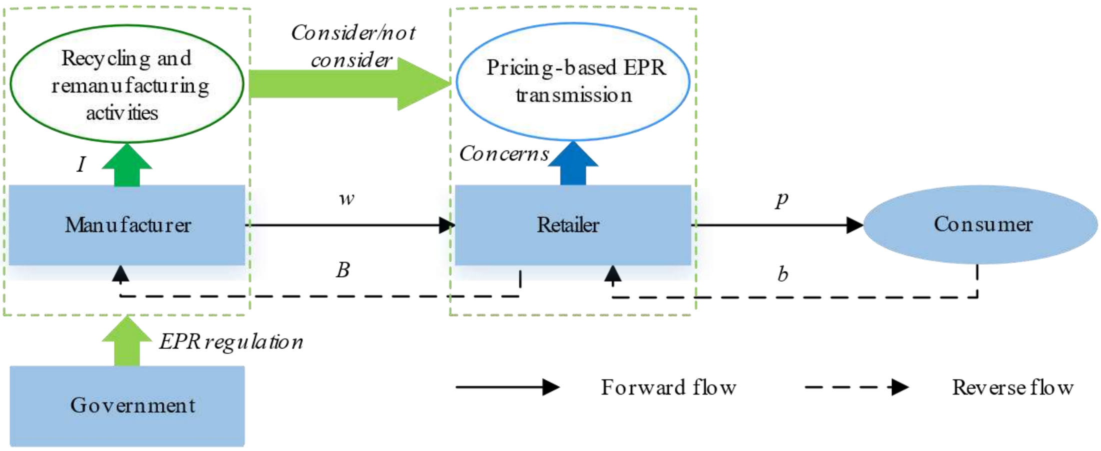

Figure 1. The framework of the CSC system.

Based on the above description, this study considers retailer's fairness concerns. To comparatively analyze the impact of retailer's fairness concerns on the two-echelon CSC's equilibrium decisions and profits, as well as the adaptable price transmission mechanism with fairness concerns, we carry out model analysis according to the following procedures. First, we establish a two-echelon CSC benchmark model for the retailer without fairness concerns (Model ND). Under this condition, the retailer is fairness-neutral and does not consider the fair utility goal. Then we study two decision-making cases with retailer's fairness concerns in a two-echelon CSC. The first is the complete information condition, in which the manufacturer considers retailer's fairness concerns (Model NF). These concerns represent 'information' that the manufacturer can observe, thus the retailer's decision-making process relies on its utility target, and then its fairness perceptions are also considered in the manufacturer's decision-making process. The second is the incomplete information condition, where the manufacturer does not consider retailer's fairness concerns (Model NU). As these concerns represent 'information' that the manufacturer cannot observe or does not care to, its decision-making process only relies on the retailer's profit target, rather than the utility target.

3.2. Model assumptions

To ensure the reasonability of models and that the analysis is tractable, we make the following assumptions.

Assumption 1. We assume that remanufactured and new products can exhibit equal quality levels and the potential market size Q is uniformly distributed in $[0, Q]$ (Liu et al., 2019; Zhang et al., 2021b). For simplicity, Q is normalized to 1 (Debo et al., 2005; Liu et al., 2021a). The retail price is a linear function of the retailer's sales volume: $p(q) = 1 - q$ (Atasu et al., 2008; Yenipazarli, 2016).

Assumption 2. As the undertaker of the investment in EOL products' recycling and remanufacturing the manufacturer's collection rate decision variable is $\sqrt{I}$, where $I \in [0,1]$. We assume that the unit marginal cost savings from remanufacturing EOL products is Δ and the unit production cost of new products is c_n, the average unit cost of manufacturing is given by $c_n - \Delta\sqrt{I}$ (Savaskan et al., 2004). The retailer collects EOL products from consumers at the unit price b and then transfers them to the manufacturer at the unit price B, where $0 < b < B < \Delta < 1$ (Cheng et al., 2017; Hong et al., 2021).

Assumption 3. The manufacturer's collection rate is subject to two constraints. That is, $t_0 \le \sqrt{I} \le t_1$, where t_0 is the minimum collection rate specified by the government for EOL products, including electronic and electrical equipment waste (Atasu et al., 2009; Liu et al., 2021a), and t_1 is the maximum collection rate (Esenduran et al., 2017). $t_0 < \sqrt{I} < t_1$ refers to the partial collection rate for EOL products.

Assumption 4. Due to fairness concerns, the retailer maximizes fairness utility as the decision-making goal, while the manufacturer takes maximum profit as the decision-making goal. The model of fairness concerns involves both aversion to advantageous inequity and aversion to disadvantageous inequity (Charness & Rabin, 2002; Cui et al., 2007; Katok et al., 2014). As the latter is more common in practice, many existing studies adopt utility functions similar to those of disadvantageous inequity (Chen et al., 2017; Liu et al., 2018; Nie & Du, 2017; Pan et al., 2020; Yoshihara & Matsubayashi, 2021). Therefore, our study follows this line of research by assuming that retailer's fairness concerns are unidirectional, that is $u_R = \pi_R - \lambda\pi_M$ (Chen et al., 2020; Qian et al., 2020; Zhang et al., 2021a), where $\lambda \geq 0$ is the fairness concerns coefficient, u_R is the retailer's utility function, and π_M (π_R) is the manufacturer's (retailer's) profit function. When the retailer is fairness-neutral ($\lambda = 0$), the retailer's utility equals to its profit. When the retailer has extreme fairness concerns ($\lambda \to \infty$), the retailer is willing to pay a great cost to ensure fairness.

Assumption 5. The investment in recycling and remanufacturing activities is I, and k is a scaling parameter of the investment in EOL products' recycling and remanufacturing (Savaskan et al., 2004). Wherein, such investment can be considered as the expenditure for fulfilling EPR regulation (the minimum collection rate) undertaken by the manufacturer (Atasu et al., 2009). Considering the optimal solution exists in the model and the equilibrium solutions is larger than 0, thus we assume that $4k - (\Delta - b)^2 > 0$ is valid.

Specifically, we summarize parameters and decision variables in Table 2. For a more concise description of equilibrium solutions, we denote $C = 1 - c_n > 0$, $v_1 = \Delta - B > 0$ and $v_2 = B - b > 0$, where C is used as a notation instead of $1 - c_n$ to simplify the calculation results, v_1 is the marginal revenue of EOL products collected by the manufacturer from the retailer and v_2 is the marginal revenue of EOL products collected by the retailer from the consumers.

Table 2. Parameters and decision variables.

Symbol	Definition
Parameters	

p	Unit retail price of new products
c_n	Unit production cost of new products
λ	Fairness concerns coefficient
u_R	Utility function of retailer's fairness concerns
k	Scaling parameter of investment in EOL products' recycling and remanufacturing
I	Investment in EOL products' recycling and remanufacturing, where $I \in [0,1]$
b	Direct collecting price of EOL products paid to the consumer
B	Collecting transfer price of EOL products paid from the manufacturer to the retailer
Δ	Marginal cost savings from remanufacturing EOL products
Decision variables	
w	Unit wholesale price of the new products
$\sqrt{I}$	Collection rate of EOL products, $t_0 \le \sqrt{I} \le t_1$, where t_0 is the minimum collection rate specified by the government and t_1 is maximum collection rate
q	Sales volume of new products
Other notations	
π_h^j	Profit of member h under model j, where $j \in \{ND, NF, NU\}$, $h \in \{M, R, T\}$, representing the manufacturer, retailer, and two-echelon CSC, respectively

4. Model formation

4.1. Model ND: Fairness-neutral decentralized

In the model without fairness concerns, k is the scale parameter of investment in recycling and remanufacturing, I is the investment in EOL products' recycling and remanufacturing, and the goal of decision-makers is to maximize their own profit. The manufacturer is the leader, who first determines the wholesale price w and the collection rate $\sqrt{I}$. The retailer is the follower, who then determines the sales volume q.

The manufacturer profit function is:

$$\max_{\{w,\sqrt{I}\}} \pi_M^{ND} = q(w-(c_n-\Delta\sqrt{I}))-B\sqrt{I}q-kI \quad (1)$$

$$s.t.\ t_0 \le \sqrt{I} \le t_1$$

The retailer profit function is:

$$\max_{\{q\}} \pi_R^{ND} = q(1-q-w+(B-b)\sqrt{I}) \quad (2)$$

We apply the KKT optimization condition method and backward induction method to solve the decision variables w, $\sqrt{I}$, and q. Table 3 lists the equilibrium solutions for the manufacturer and retailer, where $\Delta^{ND+} = b+\frac{\sqrt{C^2+32kt_1^{\,2}}-C}{2t_1}$ and $\Delta^{ND-} = b+\frac{\sqrt{C^2+32kt_0^{\,2}}-C}{2t_0}$ are the upper and lower thresholds for marginal cost savings, respectively.

Table 3. Model ND's equilibrium solutions.

	$\Delta<\Delta^{ND-}$	$\Delta^{ND-}\le\Delta\le\Delta^{ND+}$	$\Delta>\Delta^{ND+}$
w_M^{ND*}	$\frac{2-C-t_0(v_1-v_2)}{2}$	$\frac{4k(2-C)+(v_2C-(\Delta-b))(\Delta-b)}{8k-(\Delta-b)^2}$	$\frac{2-C-t_1(v_1-v_2)}{2}$
$\sqrt{I}_M^{ND*}$	t_0	$\frac{C(\Delta-b)}{8k-(\Delta-b)^2}$	t_1
q_R^{ND*}	$\frac{C+t_0(\Delta-b)}{4}$	$\frac{2kC}{8k-(\Delta-b)^2}$	$\frac{C+t_1(\Delta-b)}{4}$
π_M^{ND*}	$\frac{(C+t_0(\Delta-b))^2}{8}-kt_0^{\,2}$	$\frac{kC^2}{8k-(\Delta-b)^2}$	$\frac{(C+t_1(\Delta-b))^2}{8}-kt_1^{\,2}$
π_R^{ND*}	$\frac{(C+t_0(\Delta-b))^2}{16}$	$\frac{4k^2C^2}{(8k-(\Delta-b)^2)^2}$	$\frac{(C+t_1(\Delta-b))^2}{16}$

Proof. Appendix A provides the derivation process of the equilibrium solutions in Model ND.

4.2. Model NF: The manufacturer considers retailer's fairness concerns

In Model NF, the retailer is fairness-minded, and the manufacturer is aware of and willing to address these fairness concerns. In this context, the manufacturer, as the leader, first determines the wholesale price w and collection rate $\sqrt{I}$ to maximize its profit. Then, the retailer determines the sales volume q to maximize its fairness utility. Substituting Eq. (1) and Eq. (2) into the retailer's utility function, we obtain:

$$u_R = q(1-q-w+(B-b)\sqrt{I}) - \lambda(q(w-(c_n-\Delta\sqrt{I})) - B\sqrt{I}q - kI) \tag{3}$$

We again use the KKT optimization condition and backward induction method to solve the decision variables w, $\sqrt{I}$, and q. Table 4 lists the equilibrium solutions for the manufacturer and retailer, where $\Delta^{NF+} = b + \frac{\sqrt{C^2 + 32kt_1^{\,2}(1+\lambda)} - C}{2t_1}$ and $\Delta^{NF-} = b + \frac{\sqrt{C^2 + 32kt_0^{\,2}(1+\lambda)} - C}{2t_0}$ are the upper and lower thresholds for marginal cost savings, respectively.

Table 4. Model NF's equilibrium solutions.

	$\Delta < \Delta^{NF-}$	$\Delta^{NF-} \le \Delta \le \Delta^{NF+}$	$\Delta > \Delta^{NF+}$
w_M^{NF*}	$1 - C - t_0 v_1 + \frac{C + t_0(\Delta - b)}{2(1+\lambda)}$	$\frac{4k(2 - C + 2\lambda(1-C))}{8k(1+\lambda) - (\Delta-b)^2} - \frac{(\Delta-b)(v_1 + v_2(1-C))}{8k(1+\lambda) - (\Delta-b)^2}$	$1 - C - t_1 v_1 + \frac{C + t_1(\Delta - b)}{2(1+\lambda)}$
$\sqrt{I}_M^{NF*}$	t_0	$\frac{C(\Delta-b)}{8k(1+\lambda) - (\Delta-b)^2}$	t_1
q_R^{NF*}	$\frac{C + t_0(\Delta-b)}{4}$	$\frac{2Ck(1+\lambda)}{8k(1+\lambda) - (\Delta-b)^2}$	$\frac{C + t_1(\Delta-b)}{4}$
π_M^{NF*}	$\frac{(C + t_0(\Delta-b))^2}{8(1+\lambda)} - kt_0^{\,2}$	$\frac{kC^2}{8k(1+\lambda) - (\Delta-b)^2}$	$\frac{(C + t_1(\Delta-b))^2}{8(1+\lambda)} - kt_1^{\,2}$
π_R^{NF*}	$\frac{(1+3\lambda)(C + t_0(\Delta-b))^2}{16(1+\lambda)}$	$\frac{4k^2C^2(1+\lambda)(1+3\lambda)}{(8k(1+\lambda) - (\Delta-b)^2)^2}$	$\frac{(1+3\lambda)(C + t_1(\Delta-b))^2}{16(1+\lambda)}$

Proof. Appendix B presents the derivation process of the equilibrium solutions in Model NF.

4.3. Model NU: The manufacturer does not consider retailer's fairness concerns

In reality, the manufacturer may not be able to perceive retailer's fairness concerns or may choose to ignore them. In these cases, the manufacturer determines the wholesale price w and the collection rate $\sqrt{I}$ based on the assumption that the retailer is fairness neutral. The retailer makes the sales volume decision q according to the manufacturer's pricing strategy and collection rate as well as the fairness utility maximization principle.

Once more, we employ the KKT optimization condition and backward induction method to solve the decision variables w, $\sqrt{I}$, and q. Table 5 presents the equilibrium solutions for the manufacturer and retailer, where $\Delta^{NU+}=b+\frac{\sqrt{C^2+32kt_1{}^2}-C}{2t_1}$ and $\Delta^{NU-}=b+\frac{\sqrt{C^2+32kt_0{}^2}-C}{2t_0}$ are the upper and lower thresholds for marginal cost savings, respectively.

Table 5. Model NU's equilibrium solutions.

	$\Delta<\Delta^{NU-}$	$\Delta^{NU-}\le\Delta\le\Delta^{NU+}$	$\Delta>\Delta^{NU+}$
w_M^{NU*}	$\frac{2-C-t_0(v_1-v_2)}{2}$	$\frac{1}{2}(2-C-\frac{C(\Delta-b)(v_1-v_2)}{8k-(\Delta-b)^2})$	$\frac{2-C-t_1(v_1-v_2)}{2}$
$\sqrt{I}_M^{NU*}$	t_0	$\frac{C(\Delta-b)}{8k-(\Delta-b)^2}$	t_1
q_R^{NU*}	$\frac{(1-\lambda)(C+t_0(\Delta-b))}{4}$	$\frac{2kC(1-\lambda)}{8k-(\Delta-b)^2}$	$\frac{(1-\lambda)(C+t_1(\Delta-b))}{4}$
π_M^{NU*}	$\frac{(1-\lambda)(C+t_0(\Delta-b))^2}{8}-kt_0{}^2$	$\frac{kC^2(8k(1-\lambda)-(\Delta-b)^2)}{(8k-(\Delta-b)^2)^2}$	$\frac{(1-\lambda)(C+t_1(\Delta-b))^2}{8}-kt_1{}^2$
π_R^{NU*}	$\frac{(1-\lambda)(1+\lambda)(C+t_0(\Delta-b))^2}{16}$	$\frac{4k^2C^2(1-\lambda)(1+\lambda)}{(8k-(\Delta-b)^2)^2}$	$\frac{(1-\lambda)(1+\lambda)(C+t_1(\Delta-b))^2}{16}$

Proof. Appendix C provides the derivation process of the equilibrium solutions in Model NU.

5. Model analysis

Based on Section 4, we first conduct comparative analysis for equilibrium decisions and profits in three models, and using Figures. 2, 3, and 4 to visually show these results. Furthermore, we analyze the three models to examine how fairness concerns affect equilibrium decisions and optimal profits, and how the manufacturer and retailer's marginal revenues as well as the investment in EOL products' recycling and remanufacturing affect the price transmission mechanism with fairness concerns.

5.1. Comparative analysis of equilibrium decisions and profits

In this section, given the equilibrium solutions listed in Tables 3, 4, and 5, we draw the following propositions.

Proposition 1. In Model j, where $j \in \{ND, NF, NU\}$, the optimal decisions for the manufacturer and retailer satisfy the following:

(1) If $\Delta < \Delta^{j-}$, $\frac{\partial w_M^{j*}}{\partial \Delta} < 0$, $\frac{\partial \sqrt{I}_M^{j*}}{\partial \Delta} = 0$, and $\frac{\partial q_R^{j*}}{\partial \Delta} > 0$;

(2) If $\Delta^{j-} \le \Delta \le \Delta^{j+}$, $\frac{\partial w_M^{j*}}{\partial \Delta} < 0$, $\frac{\partial \sqrt{I}_M^{j*}}{\partial \Delta} > 0$, and $\frac{\partial q_R^{j*}}{\partial \Delta} > 0$;

(3) If $\Delta > \Delta^{j+}$, $\frac{\partial w_M^{j*}}{\partial \Delta} < 0$, $\frac{\partial \sqrt{I}_M^{j*}}{\partial \Delta} = 0$, and $\frac{\partial q_M^{j*}}{\partial \Delta} > 0$.

Proof. Appendix D provides the proof for Proposition 1.

Proposition 1 reveals that regardless of whether the manufacturer considers or does not consider retailer's fairness concerns when making pricing decisions, the marginal cost savings parameter Δ positively affects the manufacturer's collection rate for EOL products as well as the sales volume for new products. In contrast, the marginal cost savings parameter Δ negatively affects the wholesale price of new products. Considering that the greater the marginal cost savings, the more obvious the cost advantage of remanufactured products over new products, the manufacturer is more willing to invest more capital in recycling and remanufacturing and collect more EOL products. At this time, the manufacturer may reduce wholesale price of new products to encourage the retailer to sell more new products at a lower price. As such, the consumers have strong incentive to purchase new products and then return these EOL products to the retailer, promoting sales of new products and the collection of EOL products.

In Figure 2, to visually illustrate how the equilibrium decisions vary with marginal cost savings, we select Δ as a representative parameter to plot the graph of the equilibrium decisions w_M^j, $\sqrt{I}_M^j$, and q_M^j, with respect to marginal cost savings Δ, by setting relevant parameters. To strengthen the accuracy and traceability of parameter setting, we first try to obtain the data by the questionnaire survey and in-depth interviews. However, considering the confidentiality of the company's product cost data and the difficulty of quantifying the fairness concern coefficient, we also refer to the parameter settings of the previous research (Liu et al., 2021b; Zhang & Wang, 2018; Zheng et al., 2019b). The example parameters are set as follows: $b=0.01$, $B=0.05$, $t_0=0.4$, $t_1=1$, $k=0.07$, and $\lambda=0.2$. The vertical dashed lines indicate the boundaries between the different cases for Models ND, NF, and NU. Figure 2 not only confirms the conclusions in Proposition 1, but also shows that they hold under the general scenario with fairness-neutral decentralization.

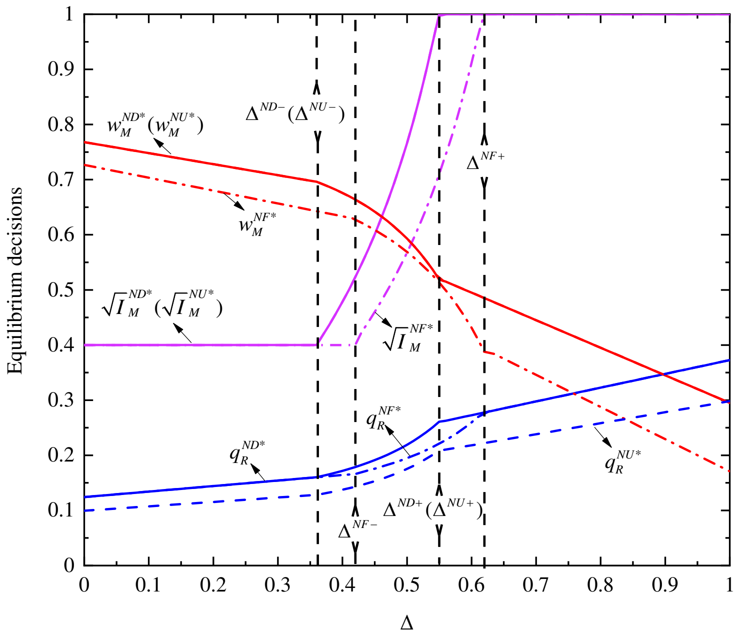

Figure 2. The impact of Δ on the equilibrium decisions in three models.

Proposition 2. In Model j, where $j \in \{ND, NF, NU\}$, the optimal profits for the manufacturer and retailer satisfy the following:

(1) $\frac{\partial \pi_M^{j*}}{\partial \Delta} > 0$ and $\frac{\partial \pi_R^{j*}}{\partial \Delta} > 0$;

(2) $\pi_T^{NF} \geq \pi_T^{ND} > \pi_T^{NU}$.

Proof. Proposition 2's proof is given in Appendix E.

Proposition 2 (1) shows that the marginal cost savings parameter Δ positively affects both the manufacturer and retailer's profits. Proposition 2 (2) confirms that the two-echelon CSC's profit in Model NU is lower than in Models ND and NF. In other words, the manufacturer does not take retailer's fairness concerns into account when making pricing decisions, the profit of the two-echelon CSC is lower than that of the manufacturer considers retailer's fairness concerns. Therefore, the manufacturer should incorporate retailer's interest into his pricing decisions to ensure that there is no decrease in investment and no negative effect on the development of the recycling and remanufacturing business.

Similar to Figure 2, we also select Δ as a representative parameter to plot the graph of π_M^{j*} and π_R^{j*} with respect to the marginal cost savings Δ in Figure 3 and 4, respectively. Considering that we calculate the profits of the three models based on optimal decision variables, thus both the parameter settings and meanings of the vertical dashed lines are consistent with those in Figure 2. Figures 3 and 4 visually display how the marginal cost savings Δ affect the optimal profits of the manufacturer and retailer, confirming the conclusions of Proposition 2 (1). In addition, Figures 3 and 4 also show that no matter what the marginal cost savings, there has $\pi_M^{ND} > \pi_M^{NF} > \pi_M^{NU}$, $\pi_R^{ND} > \pi_R^{NU}$, and $\pi_R^{NF} > \pi_R^{NU}$, confirming the conclusions of Proposition 2 (2).

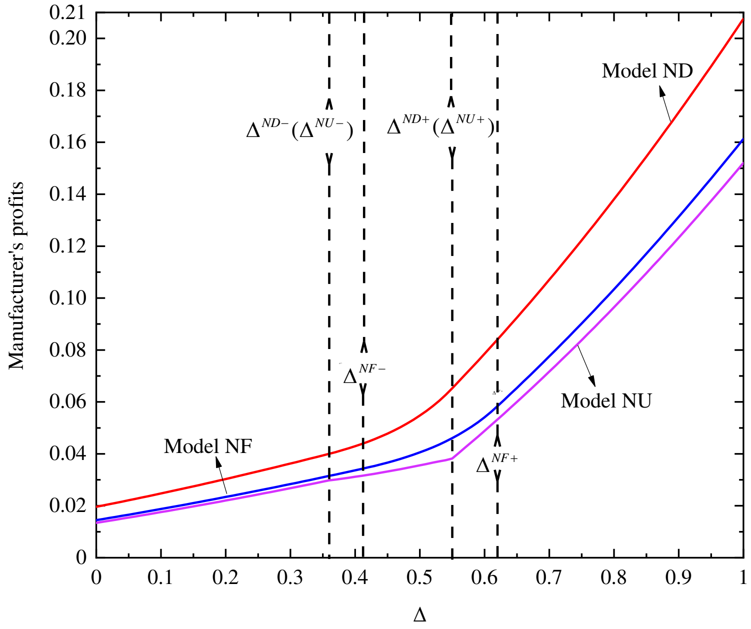

Figure 3. The impact of Δ on the manufacturer's profits in three models.

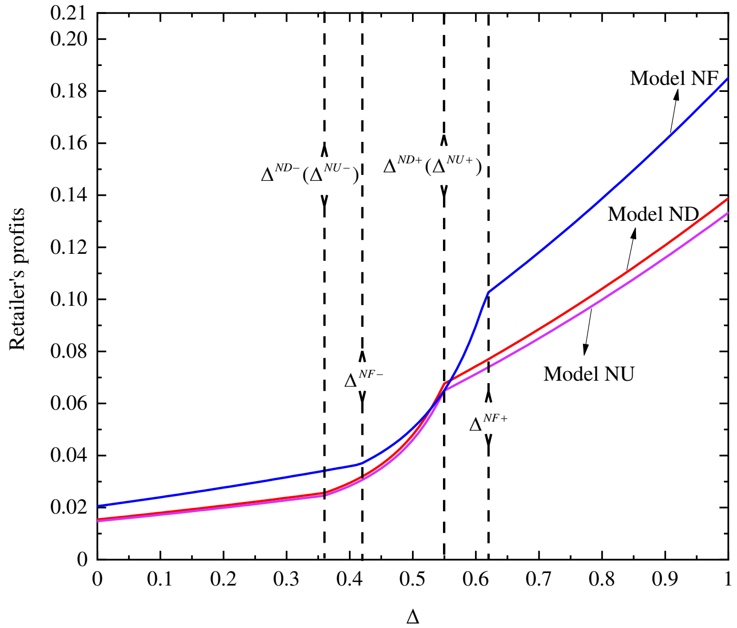

Figure 4. The impact of Δ on the retailer's profits in three models.

5.2. Impact of fairness concerns on equilibrium decisions

Proposition 3 explains the impact of fairness concerns on the equilibrium decisions of the manufacturer and retailer.

Proposition 3. (1) In Model NF, when the manufacturer performs a partial collection rate ($t_0 < \sqrt{I} < t_1$), the wholesale price, sales volume, and collection rate decrease in fairness concerns. When the manufacturer performs a limited collection rate (the minimum/maximum collection rate), the wholesale price decreases with fairness concerns, but the sales volume of new products is independent of fairness concerns. (2) In Model NU, the wholesale price and collection rate are independent of fairness concerns, but the sales volume decreases in fairness concerns.

Proof. Proposition 3's proof is given in Appendix F.

Proposition 3 shows that when the manufacturer considers retailer's fairness concerns during making pricing decisions, as fairness concerns increase, the manufacturer reduces the wholesale price of new products to transfer part of its profit to the retailer. At this time, if the manufacturer chooses to partially collect, the retailer will raise the new products' sales price to obtain more profit, resulting in a reduction in new products' sales quantity and EOL products' collection rate. In addition, the decline in wholesale price and collection rate greatly damages the manufacturer's profit, causing the manufacturer to reduce the investment in EOL products' recycling and remanufacturing. Under the lowest or highest collection behavior, if the intensity of fairness concerns increases, the manufacturer will reduce the product's wholesale price. However, the collection rate is regulated by EPR regulation, which is relatively fixed or unchanged. At this time, the manufacturer's investment in EOL products' recycling and remanufacturing is not correlated with fairness concerns.

When the manufacturer does not take retailer's fairness concerns into account during making pricing decisions, the former's equilibrium decisions, namely wholesale price and collection rate, are independent of fairness concerns. At this time, regardless of the manufacturer's collection strategy, the retailer continues to raise the sales price of the products to obtain higher marginal profits. Thus, the sales quantity decreases, but the manufacturer's investment in EOL products' recycling and remanufacturing has no correlation with fairness concerns.

In summary, when the manufacturer considers retailer's fairness concerns and incorporates retailer's interest into its pricing decisions, part of the manufacturer's profits will be transferred to the retailers through lowering wholesale price. Then the retailer will gradually build trust with the manufacturer and decrease its fairness concerns, such that deepening their cooperation. In turn, the manufacturer also promotes the investment level in EOL products' recycling and remanufacturing. Therefore, such a fairness preference is generally conducive to the manufacturer's recycling and remanufacturing business.

5.3. Impact of fairness concerns on profit

The impact of fairness concerns on profit is shown in Proposition 4.

Proposition 4. (1) In Model NF, when the manufacturer performs a partial collection ($t_0 < \sqrt{I} < t_1$), the two-echelon CSC's profit decreases in fairness concerns. If $k < \frac{3(\Delta - b)^2}{8}$, the retailer's profit initially increases, but then decreases with fairness concerns. Otherwise, the retailer's profit simply increases in fairness concerns. When collection is limited (the minimum/maximum collection rate), the manufacturer's (retailer's) profit decreases (increases) with fairness concerns, while the two-echelon CSC's profit is independent of it. (2) In Model NU, the manufacturer, retailer, and two-echelon CSC's profits decrease in fairness concerns.

Proof. Appendix G provides the proof for Proposition 4.

Proposition 4 shows that the manufacturer takes retailer's fairness concerns into account when making pricing decisions, no matter what the collection efforts (strength of EPR regulation implementation), the excessive degree of fairness concerns always damage the manufacturer's profit. The impact of fairness concerns on the retailer and two-echelon CSC's profits is closely related to the manufacturer's collection strategies. Under the medium collection strategy, if $k < \frac{3(\Delta - b)^2}{8}$, when $0 < \lambda < \frac{8k - 2(\Delta - b)^2}{3(\Delta - b)^2 - 8k}$, the greater retailers' fairness concerns, the stronger their bargaining power, and the higher the profit. Besides, when $\lambda \geq \frac{8k - 2(\Delta - b)^2}{3(\Delta - b)^2 - 8k}$, the excessive degree of fairness concerns greatly damages the two-echelon CSC's profit, and reduces the profit distribution to the retailer. Therefore, the maximum retailer's profit is $\dfrac{4k^2C^2}{(16k-(\Delta-b)^2)(\Delta-b)^2}$.

If $k \geq \dfrac{3(\Delta-b)^2}{8}$, the greater retailer's fairness concerns, the more profit is distributed to the retailer, but the increased retailer's profit is less than the reduced profit of the manufacturer, resulting in a lower two-echelon CSC profit. However, under the lowest or highest collection strategy, the retailer's profit increases in fairness concerns. As the increased retailer's profit is the same as the decreased manufacturer's profit, the two-echelon CSC profit remains unchanged.

Overall, the manufacturer does not take retailer's fairness concerns into account when making pricing decisions, these concerns will damage the economic benefits of the two-echelon CSC, and the greater retailer's fairness concern, the greater the loss of economic benefits for the supply chain members and system. Thus, the manufacturer subject to EPR regulation should incorporate retailer's fairness concerns into his pricing decisions and make an appropriate investment in EOL products' recycling and remanufacturing, while the retailer shouldn't exhibit excessive fairness concerns.

5.4. The adaptable price transmission mechanism with fairness concerns

The adaptable price transmission mechanism with fairness concerns is shown in Proposition 5.

Proposition 5. (1) In Models ND and NU, the optimal wholesale price is $w_M^{j*}=\frac{1}{2}(2-C)-\frac{1}{2}(v_1-v_2)\sqrt{I_M^{j*}}$, $j\in\{ND,NU\}$. (2) In Model NF, the optimal wholesale price is expressed as $w_M^{NF*}=\dfrac{1+(1+2\lambda)(1-C)}{2(1+\lambda)}-\dfrac{((1+2\lambda)v_1-v_2)}{2(1+\lambda)}\sqrt{I_M^{NF*}}$.

Wherein, v_1 is the marginal revenue of EOL products collected by the manufacturer from the retailer and v_2 is the marginal revenue of EOL products collected by the retailer from the consumers.

Proof. Appendix H provides the proof for Proposition 5.

Proposition 5 shows that regardless of whether the retailer exhibits fairness concerns and whether or not the manufacturer considers retailer's fairness concerns when making pricing decisions, the optimal wholesale price w is a linear function of $\sqrt{I}$, denoted by $w^j = w_0^j + \beta^j \sqrt{I}^j$. In Models ND and NU (Model NF), $w_0^j = \frac{1}{2}(2-C)$ ($w_0^{NF} = \frac{1}{2(1+\lambda)}(1+(1+2\lambda)(1-C))$) is the optimal wholesale price when the manufacturer does not bear investment responsibility for recycling and remanufacturing. $\beta^{ND} = \beta^{NU} = -\frac{1}{2}(v_1 - v_2)$ ($\beta^{NF} = -\frac{1}{2(1+\lambda)}((1+2\lambda)v_1 - v_2)$) is the influence coefficient of the manufacturer's investment responsibility on the wholesale price, determined by the distribution strategy of marginal revenue from EOL products collection between the manufacturer and the retailer, as well as retailer's fairness concerns coefficient.

In Models ND and NU, when the manufacturer's marginal revenue ($v_1 = \Delta - B$) from collecting EOL products is higher than that of the retailer ($v_2 = B - b$), that is, $v_1 > v_2$, and the capital investment in EOL products' recycling and remanufacturing increases (decreases), the manufacturer will lower the wholesale price to a greater (less) extent to expand the retailer's sales volume, leading to a higher collection quantity. When the marginal revenue of the manufacturer is lower than that of the retailer ($v_1 < v_2$) and the capital investment in EOL products' recycling and remanufacturing increases (decreases), the manufacturer will transfer part of the investment responsibility to the retailer by raising the wholesale price of new products to a greater (less) extent.

Notably, when the manufacturer considers retailer's fairness concerns during making pricing decisions (Model NF), as the intensity of retailer's fairness concerns increases, the utility of the marginal revenue that the manufacturer obtains from the collection of EOL products (i.e., $\frac{1+2\lambda}{2(1+\lambda)}v_1$) will increase, while this will also reduce the utility of the retailer's marginal revenue from the collection of EOL products (i.e., $\frac{1}{2(1+\lambda)}v_2$). At this time, if $\frac{v_1}{v_2} > \frac{1}{1+2\lambda}$ and the capital investment in EOL products' recycling and remanufacturing increases (decreases), the manufacturer will reduce the wholesale price to a greater (less) extent to expand product sales. If $\frac{v_1}{v_2} < \frac{1}{1+2\lambda}$ and the capital investment in EOL products' recycling and remanufacturing increases (decreases), the manufacturer will transfer part of the investment responsibility to the retailer by increasing the wholesale price to a greater (less) extent.

When the marginal cost savings of recycling and remanufacturing EOL products are low (high), that is, $\Delta < \Delta^{j-}$ ($\Delta > \Delta^{j+}$), the manufacturer's marginal revenue v_1 from collecting EOL products decreases (increases) while the retailer's marginal revenue v_2 remains unchanged. Under the effect of the adaptable price transmission mechanism with fairness concerns, the manufacturer should take retailer's fairness concerns into consideration when setting its wholesale price, while the retailer shouldn't exhibit excessive fairness concerns. Specifically, the manufacturer reduces the wholesale price of new products to transfer part of the investment responsibility (expand product sales). In addition, lower (higher) marginal cost savings also make the manufacturer to reduce (enhance) investment in EOL products' recycling and remanufacturing, that is, to invest these businesses in accordance with the minimum (maximum) collection requirements for EOL products regulated by the government. Accordingly, the retailer lowers its fairness concerns to reduce the loss of marginal revenue, and undertakes partially investment responsibility through a lower sales price while contributes to EPR fulfilling.

6. Survey and in-depth interviews

To empirically validate the results derived from the models, we conducted a survey and in-depth interviews with managers representing the manufacturers or retailers. The survey aimed to clarify the respondents' interests and opinions regarding EPR-related activities and the existence of retailers' fairness concerns in the case of EPR transmission. Furthermore, we supplemented the survey results with findings from the field interviews with managers.

6.1. Methodology and research process

We used a contact list provided by alumni of four universities (e.g., Anhui Polytechnic University, Hefei University of Technology, Fujian Agriculture and Forestry University, and Minjiang University) in Anhui and Fujian provinces, China. We conducted the electronic questionnaire survey and in-depth interviews, which were divided into four stages, as shown in Figure 5.

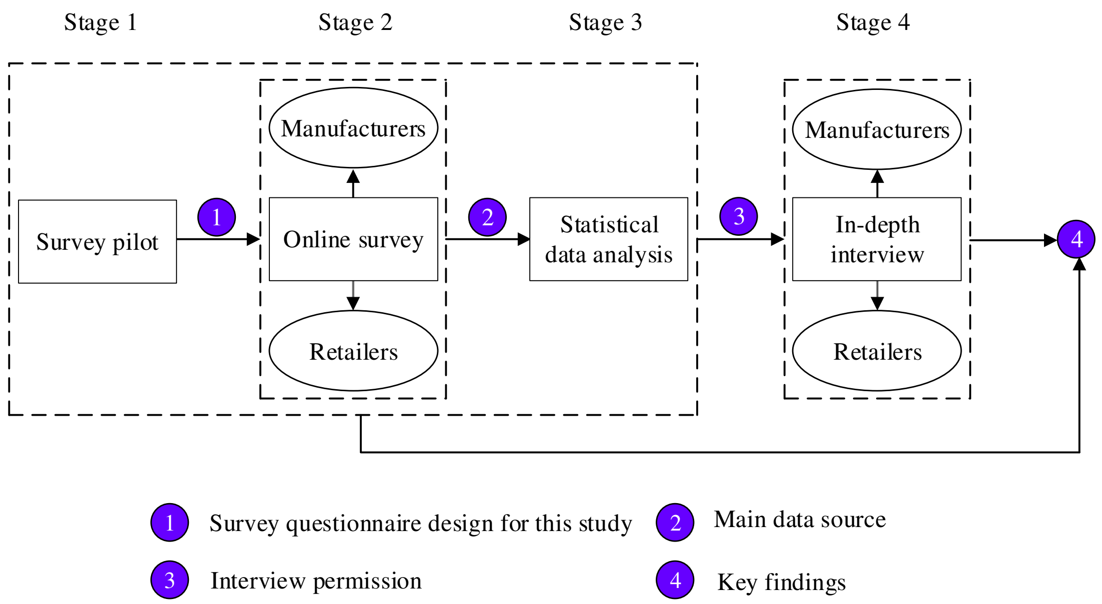

Figure 5. Framework for the survey and in-depth interviews.

In Stage 1 (Survey pilot), a pilot survey was conducted to select firms that represent manufacturers and retailers who produce and sell new/remanufactured products, respectively. Specifically, we first invited 134 alumni on the contact list via phone or e-mail, and 112 alumni from 10 firms agreed to be the initial survey subjects (see Appendix I). We created a WeChat group composed of 112 alumni. Subsequently, a questionnaire tailored to upstream manufacturers and downstream retailers was developed on the basis of three research questions in Section 1 (see Appendix J).

In Stage 2 (Online survey), we sent the questionnaire to the created alumni WeChat group. Some alumni cooperated with the first or corresponding authors of this paper on some off-campus subjects, while others were managers of school-enterprise cooperation units. The authors have built sufficient trust with these individuals, resulting in a high completion rate. We received 89 questionnaires. Among these, 12 were rejected due to incompleteness, while the remaining 77 valid questionnaires were from 43 manufactures and 34 retailers.

In Stage 3 (Statistical data analysis), we tested any significant difference between the manufacturers and retailers using Pearson's chi-squared test. The formula for Pearson's chi-squared test is expressed as follows:

$$\chi^2 = \sum_{\mu=1}^{r}\sum_{\nu=1}^{c}\frac{(O_{\mu\nu}-E_{\mu\nu})^2}{E_{\mu\nu}}, \tag{4}$$

where r and c indicate the rows and columns of the contingency table, respectively, and $O_{\mu\nu}$ and $E_{\mu\nu}$ refer to observed and expected frequencies, respectively. Here, $E_{\mu\nu} = \frac{R_\mu C_\nu}{T_o}$, where R_μ and C_ν are the row and column observed frequency totals, respectively, and $T_o = R_\mu + C_\nu$. When T_o is relatively large, χ^2 is Pearson's chi-squared statistic with an appropriate distribution on $(r-1)(c-1)$ degrees of freedom (Pandey & Bright, 2008).

Pearson's chi-squared test provides us a method to measure whether the observed frequencies (e.g., different groups' responses to a question) differ from certain specific expected frequencies that define the null hypothesis. The larger the chi-squared value, the greater the deviation between the two frequencies, the smaller the correlation between their corresponding variables, and the stronger the independence (Garson & Moser, 1995). Furthermore, we assume a significance level $\alpha = 0.05$ and consider a p-value less than or equal to α as a statistically significant difference between the variables (Shan et al., 2014).

In Stage 4 (In-depth interview), owing to a favorable horizontal cooperation relationship, eight managers agreed to be interviewed. Interviews are a favorable technique to collect empirical information which is stored in the interviewee's memory (Eisenhardt & Graebner, 2007; Gong et al., 2018; Jia et al., 2019). To avoid single-source bias, the interviewees were deliberately selected from different firms (e.g., manufacturing sectors or channel sales managers of home appliances, electric equipment recycling/remanufacturing, and electric equipment/automotive parts; see Appendix K). In particular, open and semi-structured interview questions were designed based on the three research questions in Section 1 (see Table 6). We interviewed three managers via phone, and interviewed the rest face-to-face between March 30–April 3, 2021. Each interview lasted approximately 30–50 minutes and was conducted at free periods before, during, or after work. Necessary notes were taken during the interviews.

Table 6. Interview questions.

Question number	Interview items
Q1	Does EPR regulation affect your company's operating costs?
Q2	Does EPR transmission exist in the supply chain?
Q3	Do retailers show fairness concerns in the case of EPR fulfilling?
Q4	If the answer to Q3 is "yes", how do fairness concerns influence the benefits of your company?

6.2. Key findings

In this section, we summarize the results of the survey and in-depth interviews based on four interview questions. The survey results obtained by Pearson's chi-squared test are presented in Table 7, and specific raw data are listed in Appendix L.

Table 7. Summary of the survey results.

Interview items	χ^2	*df*	*p* -value	Is there a significant difference between manufacturers and retailers?
Does EPR regulation affect your	3.689	1	0.055	No

company's operating costs?				
Does EPR transmission exist in supply chain?	8.318	2	0.016	Yes
Do retailers show fairness concerns in the case of EPR fulfilling?	0.934	1	0.334	No

6.2.1. Does EPR regulation affect your company's operating costs?

The first question we aim to answer is whether EPR regulation affects business operating costs. The survey results are illustrated in Table 8.

Table 8. Respondents' attitudes toward EPR regulation.

Interview item	Respondent type	Yes	No	Total	$(\frac{\text{Yes}}{\text{Total}})\%$
Does EPR regulation affect your company's operating costs?	Manufacturer	35	8	43	81%
	Retailer	21	13	34	62%
	Total	56	21	77	73%

From our survey results, most of the respondents (73%, as shown in Table 8) hold that EPR regulation definitely influences companies' operating cost. Along this line, the implementation of EPR-related businesses (e.g., recycling and remanufacturing) can be speculated to result in a direct or an indirect effect on these firms' operation. This finding is also explained by our interviews. For example, the manufacturing sector manager M1 stated the following:

"*The EPR regulation requires us to take responsibility for the green design of new products and remanufacturing of EOL products. Of course, these businesses can indeed improve resource utilization and open up new markets. However, our operating costs have also increased. And we have also invested a lot, which forced us to cut off some of the business.*"

The channel sales manager R1 similarly noted the following:

"*The upstream manufacturers entrust us to recycle EOL products, and we will transport these products returned from consumers to them. It is not our main business,* *and its benefits are also limited. This actually increases our operating costs.*"

Table 8 shows that no significant differences exist ($\chi^2 = 3.689$, $df = 1$, and p-value $= 0.055$) between the manufacturers and retailers. However, the degree of influence of EPR regulations on both parties may vary (one is 81% and the other is 62%). These two results demonstrate that the potential EPR-related businesses' capital input or consumers' lower awareness of recycling may lead to high cost burden. Our interviews confirm this possibility. For example, the manufacturing sectors' manager M2 stated the following:

"*Certainly, the government's environmental policy and sustainable initiatives push us to undertake the responsibilities of recycling and reprocessing of EOL products. However, we have been facing a huge cost burden, especially during the COVID-19 period.*"

Similarly, the channel sales manager R2 explained the following:

"*The strength of our recycling business is that we are the closest to consumers. Nevertheless, the current consumer awareness of recycling is not strong, which brings about a large number of discarded products not entering the recycling channel. Although it is necessary to enhance corporate reputation and fulfill corporate social responsibility, this business is not profitable, and we must reserve a certain amount of funds to order new products.*"

Based on these statements, we believe that the underlying reason for manufacturers' EPR transmission is that substantial costs are incurred for investment in fulfilling EPR.

6.2.2. Does EPR transmission exist in the supply chain?

The second question we attempt to answer is regarding the existence of EPR transmission in the supply chain. Specifically, our survey aims to examine whether manufacturers share their upfront cost via EPR transmission such that retailers undertake parts of the producer's recycling and remanufacturing responsibilities. Table 9 illustrates that 53% of the respondents agreed to its existence.

Table 9. Respondents' experience with EPR-related responsibility involving transmission.

Interview item	Respondent type	Yes	No	Unsure	Total	$(\frac{\text{Yes}}{\text{Total}})\%$
Does EPR responsibility transmission exist in the supply chain?	Manufacturer	29	8	6	43	67%
	Retailer	12	15	7	34	35%
	Total	41	23	13	77	53%

Furthermore, majority of manufacturers are more likely to implement their responsibility transmission to reduce EPR cost (67%, as shown in Table 9). This finding is also demonstrated by our interviews. For example, the manufacturing sector manager M3 stated the following:

"*We need to make a large number of upfront investments, such as EOL products' collection, disassembly, and assembly. However, these investments also significantly increased our operating costs for a while. We can raise our new products' price and even reduce the scale of production according to the specific situation to ease our financial pressure.*"

Similarly, the manufacturing sector manager M4 explained the following:

"*Sometimes, we set a higher wholesale price because of EPR investment. In the short term, we will also receive dividends from sales of finished goods in the market. However, it is unfavorable in the long run. To this end, we will also make some adjustments to our contract in order to maintain partnerships with retailers.*"

Nevertheless, significant differences exist ($\chi^2 = 8.318$, $df = 2$, and p -value $= 0.016$) between experiences with EPR-related responsibility that involve transmission of manufacturers and that of retailers. This result may demonstrate that most manufacturers have shifted portions of EPR-related responsibility to retailers. This may be due to manufacturers' strong market position, and retailers passively accept this. This result suggests that, with respect to manufacturers' responsibility transmission behavior trends, these retailers reluctantly yielded to undertake recycling responsibility of EOL products. For example, as the channel sales manager R3 explained the following:

"*Our manufacturers do not give us the discounts when ordering new products,* *which is also a considerable expense for us. Certainly, we can increase sales price to reduce our losses, but this also makes our cooperation with manufacturers unpleasant. We hope to achieve long-term cooperation, but our unilateral efforts are not enough.*"

6.2.3. Do retailers show fairness concerns in the case of EPR fulfilling?

The third question we aim to answer is whether retailers exhibit fairness concerns in the case of EPR fulfilling, and whether such fairness preference is considered by manufacturers. Our survey results are summarized in Table 10.

Table 10. Respondents' attitudes toward fairness concerns

Interview item	Respondent type	Yes	No	Total	$(\frac{\text{Yes}}{\text{Total}})\%$
Do the retailers show fairness concerns in the case of EPR fulfilling?	Manufacturer	36	7	43	84%
	Retailer	31	3	34	91%
	Total	67	10	77	87%

Table 10 illustrates that 87% of respondents prove the existence of fairness concerns. Moreover, no significant differences are observed between these groups of respondents ($\chi^2 = 0.934$, $df = 1$, and p-value$= 0.334$). Therefore, majority of the respondent retailers (91%) are also likely to exhibit fairness concerns due to pricing-based investment burden transmission. Our interviews further verify this result. For example, R1 stated that:

"*With the introduction of carbon peak and neutrality targets, manufacturers have put increasing pressures on us. Sometimes they set the wholesale price too high. In fact, the profit margin of this business itself is not large. We do not satisfy with such a result.*"

Similarly, R2 noted that:

"*Our manufacturers in the name of recycling and remanufacturing investment adjust their original pricing strategy, which makes us not treated fairly. If there is beyond the limits we can undertake, we would be likely to terminate our cooperation with them.*"

Furthermore, our survey demonstrates that 85% of manufacturers consider such fairness preference when setting their wholesale price (see part II of Appendix J). This result implies that majority of manufacturers are more likely to make pricing concessions. This is possibly because these firms are willing to negotiate with retailers, and indeed such attitude toward fairness concerns contributed to long-term cooperation. Consistent with Proposition 3, Table 10 also shows that majority of respondent manufacturers (84%) are likely to concern about such fairness of other supply chain member. This trend is further verified by our interviews. For example, M1 explained that:

"*Given recycling and remanufacturing activities require a large initial capital, we shoulder a lot of financial pressure. To this end, we sometimes change pricing and production plan. We can also feel that retailers are dissatisfied with such results, thus a simple contract between us is reached, and the agreement is renegotiated every year.*"

Similarly, M2 noted that:

"*In addition to the investment in building infrastructure, our recycling and remanufacturing business also needs to hire professional and technical personnel, which is not a small expense. Sometimes we will raise the wholesale price, but it is determined after negotiating with the retailer and signing the contract.*"

6.2.4. If the answer to Q3 is "yes", how do fairness concerns influence the benefits of your company?

Consistent with Proposition 3, our interviews demonstrate that retailers tend to increase new products' retail price to resist inequality, which is actually a behavioral manifestation of fairness concerns. However, such behavior is not always beneficial to them. For example, R2 stated that:

"*We increase the sales price of our products, and we can indeed deal with some difficulties in the short term. In the long run, it won't help if they don't consider our situation. Of course, it also makes us recognize that the proper pursuit of fairly benefits plays a vital role in safeguarding common interests.*"

Our interview result also reveals either too high or too low fairness concerns altogether bring negative effects on retailers. For example, R3 explained that:

"*We recycle EOL products in response to low-carbon initiatives and manufacturers' promise, but such high wholesale price is unacceptable to us. As the main bearers of producer responsibilities, they should not take all the responsibilities on us. Judging from past experience, our new product sales cannot offset our purchase cost. At this time, if we do not take measures, the increased operating costs will also bring us great losses.*"

Furthermore, our interviews show that the impact of retailers' fairness concerns on manufacturers' profits in the case of EPR fulfilling is widespread. For example, M1 argued that:

"*When we make a large number of investments in early stage, we will raise wholesale price appropriately. According to our experience, it will have an impact on retailers' business, which in turn will affect our revenue. Certainly, we are willing to negotiate with them to ensure that both parties' benefits are not seriously affected. We believe that it is conducive to the development of recycling and remanufacturing businesses.*"

As stated in Propositions 4 and 5, regardless of the manufacturer's collection efforts for EOL products, when the manufacturer does not consider the retailer's fairness concerns, these concerns will always damage the manufacturer's profit. Conversely, when the manufacturer considers the retailer's fairness concerns, its wholesale price setting is closely related to these concerns. Furthermore, our survey demonstrates that 72% of respondent manufacturers are aware of/concerned about the downstream retailers' demand for fairness in profit distribution (see part II of Appendix J). Our interviews further provide evidence to support these propositions. For example, as mentioned by M3:

"*We sometimes overlook this long-term benefit and fail to consider retailers' benefits. However, we did not get a high profit or even lost part of it. Past experience also tells us that only consider our own economic benefits cannot achieve the sustainable development of the company.*"

Similarly, M4 suggested that:

"*Our company is aware of the fairness problem of downstream retailers and we consider these concerns before making pricing decisions. Doing this can help us maintain a stable and lasting relationship with retailers. According to our experience, it is possible to realize the win-win situation for both parties.*"

7. Discussion and conclusion

7.1. Main findings

The increasing conflicts between the manufacturer and the retailer originate from the former's pricing-based EPR transmission and the latter's attendant fairness concerns. This motivates us to investigate the relationship between fairness concerns and EPR transmission to obtain a trade-off strategy achieving a win–win situation for these two members. Therefore, we formulate a two-echelon CSC comprising a manufacturer subject to EPR regulation (i.e., minimum collection rate) and a retailer who exhibits fairness concerns as a leader–follower Stackelberg game. Therein, the manufacturer transfers its recycling and remanufacturing responsibility to its retailer through wholesale price markup, and the retailer perceives unfairness and makes the corresponding pricing decisions to resist its manufacturer. Based on this setting, we apply equilibrium analysis to explore a balance between fairness concerns and EPR transmission. Further, we conduct a survey and in-depth interviews to empirically verify the results derived from the models. Specifically, this study analyzes the impact of fairness concerns on equilibrium decisions and profits, and obtains the adaptable price transmission mechanism. The following is the summary of our main findings.

(1) Equilibrium decisions and payoffs are closely related to the manufacturer's attitudes toward retailer's fairness concerns. In particular, we found that when the fairness-concerned retailer resists the manufacturer's pricing-based EPR transmission by increasing its sales price of new products, the manufacturer can always attain higher benefits when he incorporates the fairness concerns into their pricing decisions than the case when he does not do so.

(2) The stronger the fairness concerns, the fiercer the channel competition

between the manufacturer and the retailer. Excessive fairness concerns will harm the overall profit of the supply chain channel as well as the retailer's own profit. Nevertheless, with no or a few fairness concerns, the retailer would incur substantial cost due to the high wholesale price associated with EPR transmission, which could not be accepted by the retailer in reality. Therefore, a moderate level of fairness concerns can benefit both members in the CSC because of the less channel competition and less marginal revenue loss than in the case of excessive or a few even no fairness concerns.

(3) The adaptable price transmission mechanism is derived from a balance between pricing-based EPR transmission and retailer's fairness concerns: Regarding the manufacturer's perspective, he considers retailer's fairness concerns when determining wholesale price, which can enhance the cooperation between the manufacturer and the retailer. Regarding the retailer's perspective, they lower sales price with a moderate level of fairness concerns to undertake partially investment responsibility, which not only improves their marginal revenue but also contributes to EPR fulfilling. Hence, a win–win situation is obtained in the sense of higher profits attained by the manufacturer and the retailer comparing to the case when the fairness concerns do not be incorporated into the manufacturer's decisions.

7.2. Theoretical contributions

This paper is the first to examine the interaction between the EPR transmission and fairness concerns. This study contributes to the existing literature in the following two aspects.

First, in previous supply chain research on EPR transmission, players are assumed to be profit maximizers whose only concerns are profits. In this study, the retailer facing the EPR transmission pressures from the manufacturer is assumed to be fairness concerned. In this regard, we provide enough evidence to prove its occurrence associated with EPR transmission through our empirical study. Moreover, using game theory, we study and better understand the complex interaction between them. In this sense, this study contributes to both the behavioral and operational management literature.

Second, we conceptualize and model the interaction between the EPR transmission and fairness concerns in the framework of game theory. Along this line, through the equilibrium analysis based on the robust convexity condition in the non-cooperative game theory, another contribution of the paper lies in finding a valuable result: All the supply chain members can benefit from the simultaneous achievement of the manufacturer incorporating the retailer's fairness concerns into his decisions and the retailer's moderate fairness concerns. Also, we provide credible and verifiable evidence to support this result.

7.3. Practical implications

Combining the results of our model analysis with a survey and in-depth interviews, we provide suggestions and compelling opinions on how firms formulate their strategies in accordance with the operational characteristics of the CSC as follows.

From the manufacturer perspective, manufacturers should realize that it is inevitable for retailers to exhibit fairness concerns and resist them if manufacturers transfer EPR to them. Therefore, the manufacturers had better take such fairness preferences into their pricing decisions and appropriately reduce wholesale price.

From the retailers' perspective, retailers should realize that it is inevitable for manufacturers to reduce their risk through responsibility transmission when a large investment for implementing EPR regulation is imposed by the government. Given these, retailers should be aware that excessive fairness concerns will harm others and ultimately damage their own interest. Certainly, retailers should also establish corporate social responsibility and transform their internal ideology that serves to pacify themselves, thereby making a more rational and beneficial decisions.

7.4. Limitations and future research directions

This paper has several limitations that provide opportunities for future research. First, we carry on this study in the scenario where the market demand is certain.

Future studies can address the uncertainties of demand response in the context of a two-echelon CSC. Second, our model only involves a two-echelon CSC comprising an upstream manufacturer and a downstream retailer. Future research can investigate more complex supply networks, such as multiple manufacturers, remanufacturers, and third-party recyclers. Third, this study considers retailer's fairness concerns with the manufacturer's EPR transmission. Considering other behaviors of supply chain members (e.g., loss aversion and reciprocity) would be an interesting extension in future studies. Finally, we assume that the direct collecting price of EOL products paid to the consumer is exogenous, which will be considered as an endogenous variable in future research.

Appendices

Appendices to this article can be found at online Supplementary material.

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