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

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Declaration of interest

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

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

28 recycling (Batista et al., 2019; Jia et al., 2020; Nasir et al., 2017). To this end,
29 government is imposing extended producer responsibility (EPR) on manufacturers,
30 which aims to make product manufacturers financially or physically responsible for
31 recycling and remanufacturing of their own EOL products (Jacobs & Subramanian,
32 2012; Khetriwal et al., 2009; Lindhqvist, 2000). Despite governments' attempts, the
33 investment on EPR has placed a great cost burden on the upstream manufacturer in a
34 CSC (Gui et al., 2016; Ramírez & Morales, 2014; Wang et al., 2018). For instance, a
35 survey examining the reverse logistics cost of 500 auto component manufacturers,
36 shows that their investments on product recovery mostly account for more than 30%
37 of the entire operating cost (Ravi & Shankar, 2015). To alleviate the EPR-related cost
38 pressure, manufacturers may transfer their partial responsibilities to retailers through
39 the wholesale price markup. This behavior of responsibility transmission
40 consequently undermines the original profit distribution mechanism, resulting in
41 inequality from the perspective of the downstream retailer who concerns about the
42 profit distribution fairness (Gu & Wang, 2011; Sharma et al., 2019). There are
43 abundant evidence and examples to show that supply chain firms pay much attention
44 to distribution fairness, i.e., fairness concerns (Cui et al., 2007; Liu et al., 2018; Liu et
45 al., 2021b). In this sense, firms not only are concerned about their self-interest, but
46 also care about their supply chain collaborators' benefits. With fairness concerns,
47 firms may punish their collaborators at the cost of decreasing their own interests if
48 they perceive unfairness (Granot & Yin, 2007; Guan et al., 2020; Wu & Niederhoff,
49 2014; Zheng et al., 2019b).

50 It is important to investigate the interaction between manufacturers'
51 responsibility transmission and retailers' fairness concerns in CSC because it implies a
52 complex and intense competition, in which both parties need to treat carefully. On the
53 manufacturers' side, if they set their wholesale prices without considering the
54 retailers' fairness concerns, it may lead to the dissatisfaction of the retailers who
55 would make the corresponding pricing decisions to resist the manufacturers or even
56 terminate the cooperative relationship with their manufacturers (Choi & Messinger,
57 2016; Wang et al., 2021). On the retailers' side, if they are excessively fairness

58 concerned, their pricing decisions will be far from reasonability, which eventually
59 harm their own interests as well as the overall performance of the supply chain. It can
60 be seen that if the two parties' relationship is not structured and coordinated prudently,
61 the well-intentioned EPR regulations would lead to a lose–lose situation and even
62 have adverse effects on environment. Therefore, our study aims to explore the balance
63 between pricing-based responsibility transmission and fairness concerns. This is an
64 important and interesting question in terms of the game theory. By solving this, we
65 can obtain the trade-off strategies which are not only conducive to EPR fulfilling but
66 also profitable for supply chain members.

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

79 This study contributes to the extant literature in the following ways. First and
80 foremost, this study is the first to investigate the relationship between fairness
81 concerns and pricing-based EPR transmission in a two-echelon CSC according to the
82 authors' best knowledge, which contributes to both the extant behavioral and
83 operational management literatures. Second, we consider and compare the
84 manufacturer's two different attitudes toward retailer's fairness concerns (i.e., models
85 NF and NU) while the existing literature only consider one of them. Third, we derive
86 a robust result not only from the model analysis but also from the empirical study:
87 The CSC can achieve a win–win outcome and environmental benefit if the

88 manufacturer incorporates retailer's fairness preference into his wholesale pricing
89 decisions and the retailer shows moderate fairness concerns with the awareness of
90 undertaking partial EPR responsibility.

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

100 **2. Literature review**

101 We review the literature related to our work that stems from two streams: EPR
102 transmission [in supply chain](#), and fairness concerns in the CSC. The details are
103 presented in the following sections.

104 **2.1. EPR transmission [in supply chain](#)**

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

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

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

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

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

137 **2.2. Fairness concerns in the CSC**

138 Since Cui et al. (2007) first introduce the participant's fairness concerns into the
139 supply chain, many researchers extend this study by incorporating fairness concerns
140 into the CSC. Most of them focus on the fairness of income distribution in the CSC
141 and its impact on the decision-making of CSC members, and explore this issue under
142 different supply chain structures using various game theoretic methods (Guan et al.,
143 2020; Jian et al., 2021; Li et al., 2021; Sharma et al., 2019; Zhang & Wang, 2018;

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

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

170 **Table 1.** Literature positioning of this research.

References	Fairness concerns?	EPR?	Price transmission?	Profit distribution?	Empirical research?
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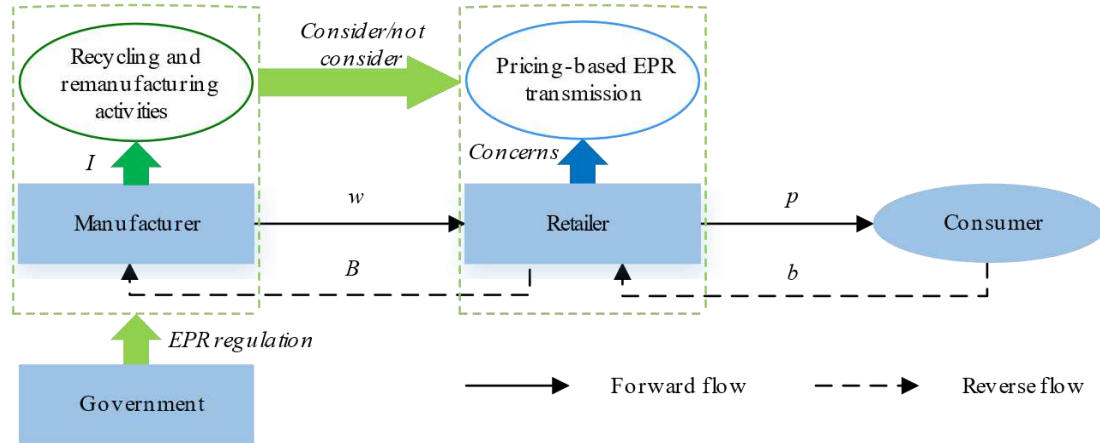
Atasu et al. (2009)		•			
Atasu & Subramanian (2012)		•			
Cui et al. (2007)	•				
Chen et al. (2021b)					•
Cheng et al. (2017)		•			
Guan et al. (2020)	•			•	
Jacobs & Subramanian (2012)		•			
Jian et al. (2021)	•				
Li et al. (2021)	•		•	•	
Sharma et al. (2019)	•				
Wang et al. (2019)			•		
Wu (2013)		•			
Zhang & Wang (2018)	•				•
Zheng et al. (2019a)	•			•	
Zheng et al. (2021)					•
This paper	•	•	•	•	•

171 3. Problem description and model assumptions

172 3.1. Problem description

173 We consider a two-echelon CSC consisting of an upstream manufacturer and a
174 downstream retailer, the former is the leader while the latter is the follower. In such
175 setting, this paper establishes a framework for the CSC system's forward and reverse
176 flows with retailer's fairness concerns, as shown in Figure 1. Specifically, the
177 government imposes EPR regulation (i.e., the minimum collection rate for EOL
178 products) on the manufacturer. The manufacturer needs to undertake the investment
179 responsibility for EOL products' recycling and remanufacturing in addition to produce
180 and wholesale new products to its retailer (Chen et al., 2021a). Then the retailer sells
181 new products to consumers, collects and potentially transfers EOL products to the

182 manufacturer for remanufacturing. Wherein, the investment activity aims to advance
 183 the sustainability in supply chain resource utilization and management (Koh et al.,
 184 2017). Nevertheless, the financially/physically responsibility transmission through
 185 wholesale price markup may damage original profit allocation mechanism. Hence, the
 186 retailer exhibits fairness concerns for such EPR transmission.



187

188

Figure 1. The framework of the CSC system.

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

205 relies on the retailer's profit target, rather than the utility target.

206 **3.2. Model assumptions**

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

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

214 **Assumption 2.** As the undertaker of the investment in EOL products' recycling and
215 remanufacturing the manufacturer's collection rate decision variable is \sqrt{I} , where
216 $I \in [0, 1]$. We assume that the unit marginal cost savings from remanufacturing EOL
217 products is Δ and the unit production cost of new products is c_n , the average unit
218 cost of manufacturing is given by $c_n - \Delta\sqrt{I}$ (Savaskan et al., 2004). The retailer
219 collects EOL products from consumers at the unit price b and then transfers them to
220 the manufacturer at the unit price B , where $0 < b < B < \Delta < 1$ (Cheng et al., 2017;
221 Hong et al., 2021).

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

228 **Assumption 4.** Due to fairness concerns, the retailer maximizes fairness utility as the
229 decision-making goal, while the manufacturer takes maximum profit as the
230 decision-making goal. The model of fairness concerns involves both aversion to

231 advantageous inequity and aversion to disadvantageous inequity (Charness & Rabin,
 232 2002; Cui et al., 2007; Katok et al., 2014). As the latter is more common in practice,
 233 many existing studies adopt utility functions similar to those of disadvantageous
 234 inequity (Chen et al., 2017; Liu et al., 2018; Nie & Du, 2017; Pan et al., 2020;
 235 Yoshihara & Matsubayashi, 2021). Therefore, our study follows this line of research
 236 by assuming that retailer's fairness concerns are unidirectional, that is $u_R = \pi_R - \lambda\pi_M$
 237 (Chen et al., 2020; Qian et al., 2020; Zhang et al., 2021a), where $\lambda \geq 0$ is the fairness
 238 concerns coefficient, u_R is the retailer's utility function, and π_M (π_R) is the
 239 manufacturer's (retailer's) profit function. When the retailer is fairness-neutral ($\lambda = 0$),
 240 the retailer's utility equals to its profit. When the retailer has extreme fairness
 241 concerns ($\lambda \rightarrow \infty$), the retailer is willing to pay a great cost to ensure fairness.

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

249 Specifically, we summarize parameters and decision variables in Table 2. For a
 250 more concise description of equilibrium solutions, we denote $C = 1 - c_n > 0$,
 251 $v_1 = \Delta - B > 0$ and $v_2 = B - b > 0$, where C is used as a notation instead of $1 - c_n$
 252 to simplify the calculation results, v_1 is the marginal revenue of EOL products
 253 collected by the manufacturer from the retailer and v_2 is the marginal revenue of
 254 EOL products collected by the retailer from the consumers.

255 **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, $t_0 \leq \sqrt{I} \leq t_1$, 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

256 **4. Model formation**

257 **4.1. Model ND: Fairness-neutral decentralized**

258 In the model without fairness concerns, k is the scale parameter of investment

259 in recycling and remanufacturing, I is the investment in EOL products' recycling
 260 and remanufacturing, and the goal of decision-makers is to maximize their own profit.
 261 The manufacturer is the leader, who first determines the wholesale price w and the
 262 collection rate \sqrt{I} . The retailer is the follower, who then determines the sales volume
 263 q .

264 The manufacturer profit function is:

$$265 \quad \max_{\{w, \sqrt{I}\}} \pi_M^{ND} = q(w - (c_n - \Delta\sqrt{I})) - B\sqrt{I}q - kI \quad (1)$$

$$266 \quad s.t. \quad t_0 \leq \sqrt{I} \leq t_1$$

267 The retailer profit function is:

$$268 \quad \max_{\{q\}} \pi_R^{ND} = q(1 - q - w + (B - b)\sqrt{I}) \quad (2)$$

269 We apply the KKT optimization condition method and backward induction
 270 method to solve the decision variables w , \sqrt{I} , and q . Table 3 lists the equilibrium

271 solutions for the manufacturer and retailer, where $\Delta^{ND+} = b + \frac{\sqrt{C^2 + 32kt_1^2} - C}{2t_1}$ and

272 $\Delta^{ND-} = b + \frac{\sqrt{C^2 + 32kt_0^2} - C}{2t_0}$ are the upper and lower thresholds for marginal cost

273 savings, respectively.

274 **Table 3.** Model ND's equilibrium solutions.

	$\Delta < \Delta^{ND-}$	$\Delta^{ND-} \leq \Delta \leq \Delta^{ND+}$	$\Delta > \Delta^{ND+}$
w_M^{ND*}	$\frac{2 - C - t_0(v_1 - v_2)}{2}$	$\frac{4k(2 - C) + (v_2 C - (\Delta - b)(\Delta - b))}{8k - (\Delta - b)^2}$	$\frac{2 - C - t_1(v_1 - v_2)}{2}$
\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*}	$\frac{(C + t_0(\Delta - b))^2}{16}$	$\frac{4k^2C^2}{(8k - (\Delta - b)^2)^2}$	$\frac{(C + t_1(\Delta - b))^2}{16}$

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

277 **4.2. Model NF: The manufacturer considers retailer's fairness concerns**

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

283
$$u_R = q(1 - q - w + (B - b)\sqrt{I}) - \lambda(q(w - (c_n - \Delta\sqrt{I}))) - B\sqrt{I}q - kI \quad (3)$$

284 We again use the KKT optimization condition and backward induction method to
 285 solve the decision variables w , \sqrt{I} , and q . Table 4 lists the equilibrium solutions

286 for the manufacturer and retailer, where $\Delta^{NF+} = b + \frac{\sqrt{C^2 + 32kt_1^2(1 + \lambda)} - C}{2t_1}$ and

287 $\Delta^{NF-} = b + \frac{\sqrt{C^2 + 32kt_0^2(1 + \lambda)} - C}{2t_0}$ are the upper and lower thresholds for marginal

288 cost savings, respectively.

289 **Table 4.** Model NF's equilibrium solutions.

	$\Delta < \Delta^{NF-}$	$\Delta^{NF-} \leq \Delta \leq \Delta^{NF+}$	$\Delta > \Delta^{NF+}$
w_M^{NF*}	$\frac{1 - C - t_0v_1 + C + t_0(\Delta - b)}{2(1 + \lambda)}$	$\frac{4k(2 - C + 2\lambda(1 - C)) - (\Delta - b)(v_1 + v_2(1 - C))}{8k(1 + \lambda) - (\Delta - b)^2}$	$\frac{1 - C - t_1v_1 + C + t_1(\Delta - b)}{2(1 + \lambda)}$
\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*}	$\frac{(1 + 3\lambda)(C + t_0(\Delta - b))^2}{16(1 + \lambda)}$	$\frac{4k^2C^2(1 + \lambda)(1 + 3\lambda)}{(8k(1 + \lambda) - (\Delta - b)^2)^2}$	$\frac{(1 + 3\lambda)(C + t_1(\Delta - b))^2}{16(1 + \lambda)}$

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

292 4.3. Model NU: The manufacturer does not consider retailer's fairness concerns

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

299 Once more, we employ the KKT optimization condition and backward induction
 300 method to solve the decision variables w , \sqrt{I} , and q . Table 5 presents the
 301 equilibrium solutions for the manufacturer and retailer, where
 302 $\Delta^{NU+} = b + \frac{\sqrt{C^2 + 32kt_1^2} - C}{2t_1}$ and $\Delta^{NU-} = b + \frac{\sqrt{C^2 + 32kt_0^2} - C}{2t_0}$ are the upper and
 303 lower thresholds for marginal cost savings, respectively.

304 **Table 5.** Model NU's equilibrium solutions.

	$\Delta < \Delta^{NU-}$	$\Delta^{NU-} \leq \Delta \leq \Delta^{NU+}$	$\Delta > \Delta^{NU+}$
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*}	$\frac{(1 - \lambda)(1 + \lambda)(C + t_0(\Delta - b))^2}{16}$	$\frac{4k^2C^2(1 - \lambda)(1 + \lambda)}{(8k - (\Delta - b)^2)^2}$	$\frac{(1 - \lambda)(1 + \lambda)(C + t_1(\Delta - b))^2}{16}$

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

307 5. Model analysis

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

314 5.1. Comparative analysis of equilibrium decisions and profits

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

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

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

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

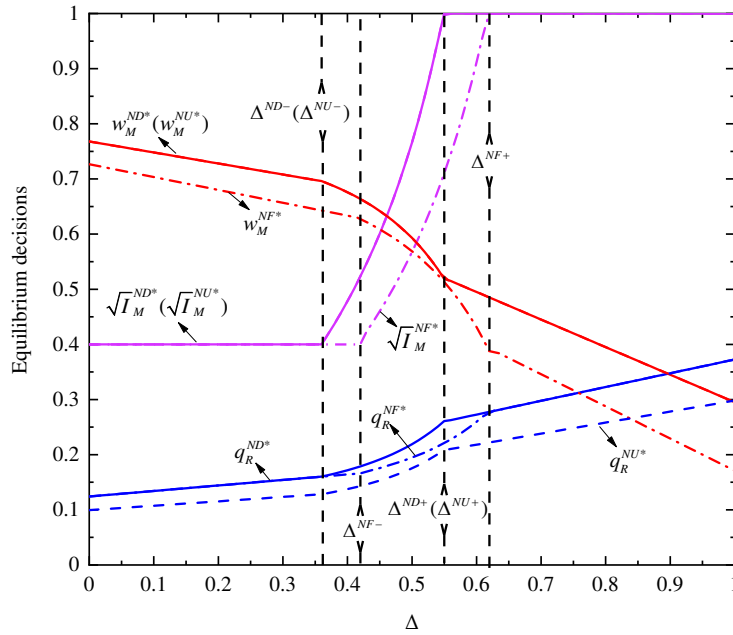
321 (3) If $\Delta > \Delta^{j+}$, $\frac{\partial w_M^{j*}}{\partial \Delta} < 0$, $\frac{\partial \sqrt{I_M^{j*}}}{\partial \Delta} = 0$, and $\frac{\partial q_M^{j*}}{\partial \Delta} > 0$.

322 **Proof.** Appendix D provides the proof for Proposition 1.

323 Proposition 1 reveals that regardless of whether [the manufacturer considers or](#)
324 [does not consider](#) retailer's fairness concerns [when making pricing decisions](#), the
325 marginal cost savings parameter Δ positively affects the manufacturer's collection
326 rate for EOL products as well as the sales volume for new products. In contrast, the
327 marginal cost savings parameter Δ negatively affects the wholesale price of new
328 products. Considering that the greater the marginal cost savings, the more obvious the
329 cost advantage of remanufactured products over new products, the manufacturer is
330 more willing to invest more capital in recycling and remanufacturing and collect more
331 EOL products. At this time, the manufacturer may [reduce wholesale price of new](#)

332 products to encourage the retailer to sell more new products at a lower price. As such,
 333 the consumers have strong incentive to purchase new products and then return these
 334 EOL products to the retailer, promoting sales of new products and the collection of
 335 EOL products.

336 In Figure 2, to visually illustrate how the equilibrium decisions vary with
 337 marginal cost savings, we select Δ as a representative parameter to plot the graph of
 338 the equilibrium decisions w_M^j , $\sqrt{I_M^j}$, and q_R^j , with respect to marginal cost savings
 339 Δ , by setting relevant parameters. To strengthen the accuracy and traceability of
 340 parameter setting, we first try to obtain the data by the questionnaire survey and
 341 in-depth interviews. However, considering the confidentiality of the company's
 342 product cost data and the difficulty of quantifying the fairness concern coefficient, we
 343 also refer to the parameter settings of the previous research (Liu et al., 2021b; Zhang
 344 & Wang, 2018; Zheng et al., 2019b). The example parameters are set as follows:
 345 $b = 0.01$, $B = 0.05$, $t_0 = 0.4$, $t_1 = 1$, $k = 0.07$, and $\lambda = 0.2$. The vertical dashed
 346 lines indicate the boundaries between the different cases for Models ND, NF, and NU.
 347 Figure 2 not only confirms the conclusions in Proposition 1, but also shows that they
 348 hold under the general scenario with fairness-neutral decentralization.



349

350

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

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

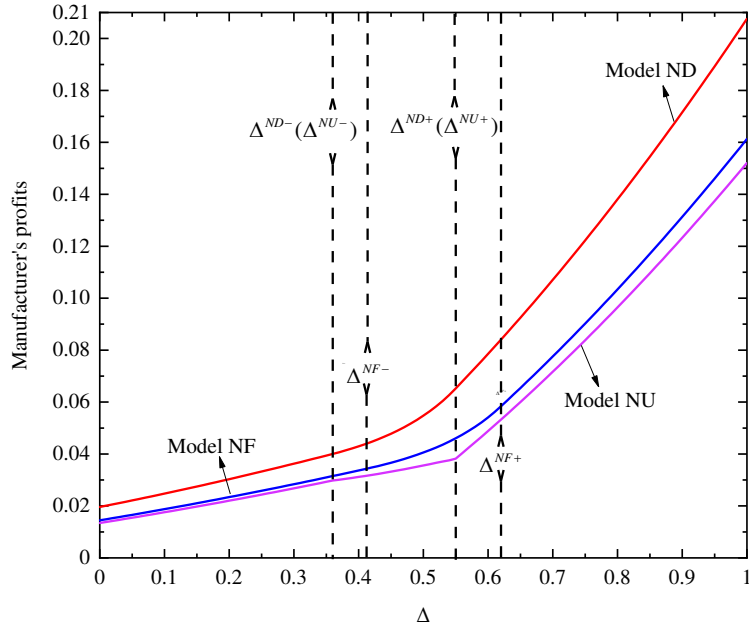
353 (1) $\frac{\partial \pi_M^{j*}}{\partial \Delta} > 0$ and $\frac{\partial \pi_R^{j*}}{\partial \Delta} > 0$;

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

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

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

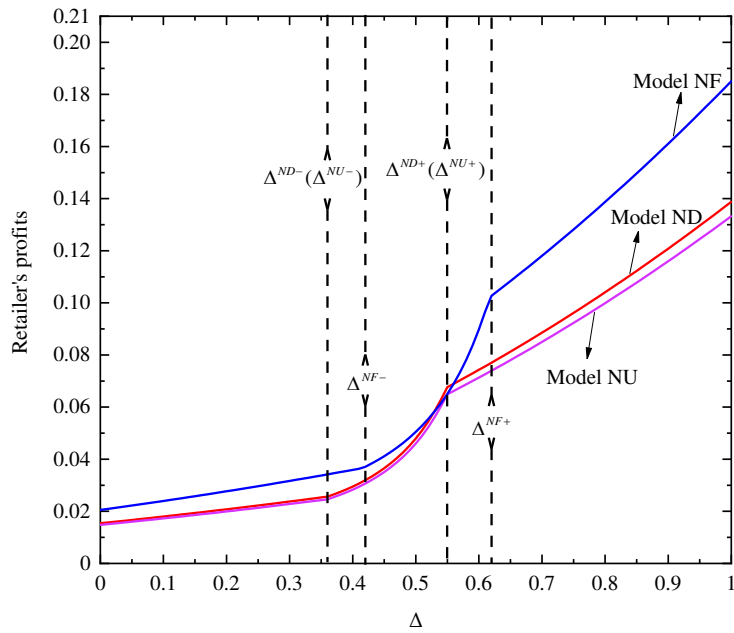
365 Similar to Figure 2, we also select Δ as a representative parameter to plot the
 366 graph of π_M^{j*} and π_R^{j*} with respect to the marginal cost savings Δ in Figure 3 and
 367 4, respectively. Considering that we calculate the profits of the three models based on
 368 optimal decision variables, thus both the parameter settings and meanings of the
 369 vertical dashed lines are consistent with those in Figure 2. Figures 3 and 4 visually
 370 display how the marginal cost savings Δ affect the optimal profits of the
 371 manufacturer and retailer, confirming the conclusions of Proposition 2 (1). In addition,
 372 Figures 3 and 4 also show that no matter what the marginal cost savings, [there has](#)
 373 $\pi_M^{ND} > \pi_M^{NF} > \pi_M^{NU}$, $\pi_R^{ND} > \pi_R^{NU}$, and $\pi_R^{NF} > \pi_R^{NU}$, confirming the conclusions of
 374 Proposition 2 (2).



375

376

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



377

378

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

379

5.2. Impact of fairness concerns on equilibrium decisions

380

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

382

Proposition 3. (1) In Model NF, when the manufacturer performs a partial collection

383

rate ($t_0 < \sqrt{I} < t_1$), the wholesale price, sales volume, and collection rate decrease in

384

fairness concerns. When the manufacturer performs a limited collection rate (the

385 minimum/maximum collection rate), the wholesale price decreases with fairness
386 concerns, but the sales volume of new products is independent of fairness concerns. (2)
387 In Model NU, the wholesale price and collection rate are independent of fairness
388 concerns, but the sales volume decreases in fairness concerns.

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

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

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

410 In summary, when the manufacturer **considers** retailer's fairness concerns and
411 **incorporates retailer's interest into its pricing decisions**, part of the manufacturer's
412 profits will be transferred to the retailers through **lowering** wholesale price. Then the
413 retailer will gradually build trust with the manufacturer and decrease its fairness
414 concerns, such that deepening their cooperation. In turn, the manufacturer also

415 promotes the investment level in EOL products' recycling and remanufacturing.
 416 Therefore, such a fairness preference is generally conducive to the manufacturer's
 417 recycling and remanufacturing business.

418 **5.3. Impact of fairness concerns on profit**

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

420 **Proposition 4.** (1) In Model NF, when the manufacturer performs a partial collection

421 ($t_0 < \sqrt{I} < t_1$), the two-echelon CSC's profit decreases in fairness concerns. If

422 $k < \frac{3(\Delta-b)^2}{8}$, the retailer's profit initially increases, but then decreases with fairness

423 concerns. Otherwise, the retailer's profit simply increases in fairness concerns. When

424 collection is limited (the minimum/maximum collection rate), the manufacturer's

425 (retailer's) profit decreases (increases) with fairness concerns, while the two-echelon

426 CSC's profit is independent of it. (2) In Model NU, the manufacturer, retailer, and

427 two-echelon CSC's profits decrease in fairness concerns.

428 **Proof.** Appendix G provides the proof for Proposition 4.

429 Proposition 4 shows that the manufacturer takes retailer's fairness concerns into

430 account when making pricing decisions, no matter what the collection efforts

431 (strength of EPR regulation implementation), the excessive degree of fairness

432 concerns always damage the manufacturer's profit. The impact of fairness concerns

433 on the retailer and two-echelon CSC's profits is closely related to the manufacturer's

434 collection strategies. Under the medium collection strategy, if $k < \frac{3(\Delta-b)^2}{8}$, when

435 $0 < \lambda < \frac{8k-2(\Delta-b)^2}{3(\Delta-b)^2-8k}$, the greater retailers' fairness concerns, the stronger their

436 bargaining power, and the higher the profit. Besides, when $\lambda \geq \frac{8k-2(\Delta-b)^2}{3(\Delta-b)^2-8k}$, the

437 excessive degree of fairness concerns greatly damages the two-echelon CSC's profit,

438 and **reduces the profit distribution** to the retailer. Therefore, the maximum retailer's

439 profit is $\frac{4k^2C^2}{(16k - (\Delta - b)^2)(\Delta - b)^2}$.

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

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

454 **5.4. The adaptable price transmission mechanism with fairness concerns**

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

457 **Proposition 5.** (1) In Models ND and NU, the optimal wholesale price is

458 $w_M^{j*} = \frac{1}{2}(2 - C) - \frac{1}{2}(v_1 - v_2)\sqrt{I_M^j}$, $j \in \{ND, NU\}$. (2) In Model NF, the optimal

459 wholesale price is expressed as $w_M^{NF*} = \frac{1 + (1 + 2\lambda)(1 - C)}{2(1 + \lambda)} - \frac{((1 + 2\lambda)v_1 - v_2)}{2(1 + \lambda)}\sqrt{I_M^{NF*}}$.

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

463 **Proof.** Appendix H provides the proof for Proposition 5.

464 Proposition 5 shows that regardless of whether the retailer exhibits fairness
465 concerns and whether or not the manufacturer **considers retailer's fairness concerns**
466 **when making pricing decisions**, the optimal wholesale price w is a linear function of

467 \sqrt{I} , denoted by $w^j = w_0^j + \beta^j \sqrt{I}^j$. In Models ND and NU (Model NF),

468 $w_0^j = \frac{1}{2}(2 - C)$ ($w_0^{NF} = \frac{1}{2(1 + \lambda)}(1 + (1 + 2\lambda)(1 - C))$) is the optimal wholesale price

469 when the manufacturer does not bear investment responsibility for recycling and

470 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

471 influence coefficient of the manufacturer's investment responsibility on the wholesale
472 price, determined by the distribution strategy of marginal revenue from EOL products
473 collection between the manufacturer and the retailer, as well as retailer's fairness
474 concerns coefficient.

475 In Models ND and NU, when the manufacturer's marginal revenue ($v_1 = \Delta - B$)

476 from collecting EOL products is higher than that of the retailer ($v_2 = B - b$), that is,

477 $v_1 > v_2$, and the capital investment in EOL products' recycling and remanufacturing

478 increases (decreases), the manufacturer will lower the wholesale price to a greater

479 **(less)** extent to expand the retailer's sales volume, leading to a higher collection

480 quantity. When the marginal revenue of the manufacturer is lower than that of the

481 retailer ($v_1 < v_2$) and the capital investment in EOL products' recycling and

482 remanufacturing increases (decreases), the manufacturer will transfer part of the

483 investment responsibility to the retailer by raising the wholesale price of new products

484 to a greater **(less)** extent.

485 Notably, when **the manufacturer considers retailer's fairness concerns during**

486 **making pricing decisions** (Model NF), as the intensity of retailer's fairness concerns

487 increases, the utility of the marginal revenue that the manufacturer obtains from the

488 collection of EOL products (i.e., $\frac{1+2\lambda}{2(1+\lambda)}v_1$) will **increase, while** this will also reduce
 489 the utility of the retailer's marginal revenue from the collection of EOL products (i.e.,
 490 $\frac{1}{2(1+\lambda)}v_2$). At this time, if $\frac{v_1}{v_2} > \frac{1}{1+2\lambda}$ and the capital investment in EOL products'
 491 recycling and remanufacturing increases (decreases), the manufacturer will reduce the
 492 wholesale price to a greater (**less**) extent to expand product sales. If $\frac{v_1}{v_2} < \frac{1}{1+2\lambda}$ and
 493 the capital investment in EOL products' recycling and remanufacturing increases
 494 (decreases), the manufacturer will transfer part of the investment responsibility to the
 495 retailer by increasing the wholesale price to a greater (**less**) extent.

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

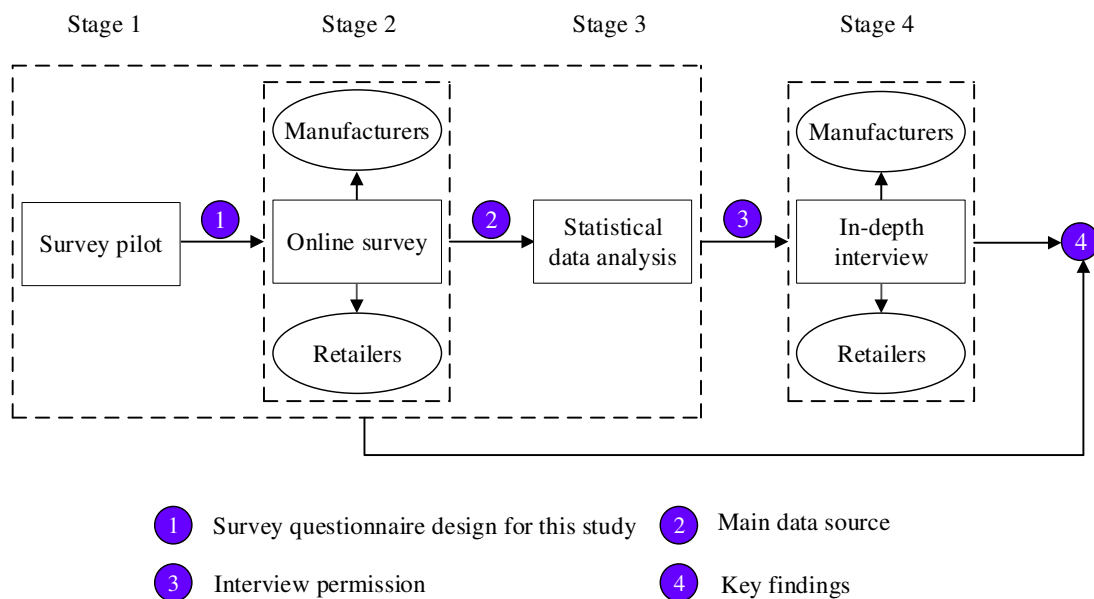
511 **6. Survey and in-depth interviews**

512 To empirically validate the results derived from the models, we conducted a

513 survey and in-depth interviews with managers representing the manufacturers or
 514 retailers. The survey aimed to clarify the respondents' interests and opinions regarding
 515 EPR-related activities and the existence of retailers' fairness concerns in the case of
 516 EPR transmission. Furthermore, we supplemented the survey results with findings
 517 from the field interviews with managers.

518 **6.1. Methodology and research process**

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



524

525

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

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

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

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

$$543 \quad \chi^2 = \sum_{\mu=1}^r \sum_{v=1}^c \frac{(O_{\mu v} - E_{\mu v})^2}{E_{\mu v}}, \quad (4)$$

544 where r and c indicate the rows and columns of the contingency table, respectively,
 545 and $O_{\mu v}$ and $E_{\mu v}$ refer to observed and expected frequencies, respectively. Here,

$$546 \quad E_{\mu v} = \frac{R_{\mu} C_v}{T_o},$$

where R_{μ} and C_v are the row and column observed frequency totals,

547 respectively, and $T_o = R_{\mu} + C_v$. When T_o is relatively large, χ^2 is Pearson's
 548 chi-squared statistic with an appropriate distribution on $(r-1)(c-1)$ degrees of
 549 freedom (Pandey & Bright, 2008).

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

558 In Stage 4 (In-depth interview), owing to a favorable horizontal cooperation

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

571 **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?

572 6.2. Key findings

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

577 **Table 7.** Summary of the survey results.

Interview items	χ^2	<i>df</i>	<i>p</i> -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

578 6.2.1. Does EPR regulation affect your company's operating costs?

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

581 **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%

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

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

593 The channel sales manager R1 similarly noted the following:

594 *"The upstream manufacturers entrust us to recycle EOL products, and we will*
595 *transport these products returned from consumers to them. It is not our main business,*

596 *and its benefits are also limited. This actually increases our operating costs.”*

597 Table 8 shows that no significant differences exist ($\chi^2 = 3.689$, $df = 1$, and p
598 $-value = 0.055$) between the manufacturers and retailers. However, the degree of
599 influence of EPR regulations on both parties may vary (one is 81% and the other is
600 62%). These two results demonstrate that the potential EPR-related businesses’ capital
601 input or consumers’ lower awareness of recycling may lead to high cost burden. Our
602 interviews confirm this possibility. For example, the manufacturing sectors’ manager
603 M2 stated the following:

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

608 Similarly, the channel sales manager R2 explained the following:

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

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

618 6.2.2. Does EPR transmission exist in the supply chain?

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

624 **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%

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

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

634 Similarly, the manufacturing sector manager M4 explained the following:

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

639 Nevertheless, significant differences exist ($\chi^2 = 8.318$, $df = 2$, and p -value
640 =0.016) between experiences with EPR-related responsibility that involve
641 transmission of manufacturers and that of retailers. This result may demonstrate that
642 most manufacturers **have** shifted portions of EPR-related responsibility to retailers.
643 This may be due to manufacturers’ strong market position, and retailers passively
644 **accept** this. This result suggests that, with respect to manufacturers’ responsibility
645 transmission behavior trends, these retailers reluctantly yielded to undertake recycling
646 responsibility of EOL products. For example, as the channel sales manager R3
647 explained the following:

648 *“Our manufacturers do not give us the discounts when ordering new products,*

649 *which is also a considerable expense for us. Certainly, we can increase sales price to*
 650 *reduce our losses, but this also makes our cooperation with manufacturers unpleasant.*
 651 *We hope to achieve long-term cooperation, but our unilateral efforts are not enough.”*

652 6.2.3. Do retailers show fairness concerns in the case of EPR fulfilling?

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

656 **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%

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

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

667 Similarly, R2 noted that:

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

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

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

686 Similarly, M2 noted that:

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

691 6.2.4. If the answer to Q3 is “yes”, how do fairness concerns influence the benefits of
692 your company?

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

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

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

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

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

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

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

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

731 Similarly, M4 suggested that:

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

736 **7. Discussion and conclusion**

737 **7.1. Main findings**

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

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

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

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

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

778 **7.2. Theoretical contributions**

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

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

789 management literature.

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

798 **7.3. Practical implications**

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

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

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

814 **7.4. Limitations and future research directions**

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

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

827 **Appendices**

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

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