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A Game-Theoretic Analysis of Social Responsibility Conduct in Two-Echelon Supply Chains

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31 that the primary firm introduces codes of conduct to ensure its partners' business practices to
32 be socially responsible (Pedersen and Andersen 2006). However, World Bank (2003) reports
33 the difficulty in implementing these codes of conduct due to a wide variety of individual codes
34 on corporate social responsibility (CSR), the effectiveness of the top-down CSR structure, and
35 insufficient understanding of business benefits of CSR commitment.

36 CSR has historically been a significant theme in the business community and attracted
37 considerable research interests from academia. For instance, a survey of the Economist (2005)
38 shows that 85% of 136 executives and 65 investors view CSR as a "central" or "important"
39 consideration in making investment decisions. Different lines of research have been conducted
40 to examine CSR, including qualitative analysis (Bowen 1953, Friedman 1970), empirical
41 investigations on the relationship between CSR and corporate financial performance (Orlitzky
42 et al. 2003, Margolis and Walsh 2001, González-Benito and González-Benito 2005), and
43 formal modeling of CSR (Baron 2001, 2007, Calveras et al. 2007, Giovanni and Giacinta
44 2007).

45 Currently, the majority of research on CSR focuses on individual firms. Recently,
46 researchers have extended the view on CSR and investigated CSR from a supply chain
47 management perspective. Research in this emerging field has taken on different avenues. For
48 qualitative discussions, with the belief that the primary member of a supply chain is morally
49 obligated to manage other members' CSR activities, Boyd et al. (2004) provide a nine-step
50 procedure for supply chain CSR management. Amaeshi et al. (2008) suggest that the more
51 powerful member in a supply chain bears a responsibility to influence the weaker member(s).
52 Empirically, Carter et al. (2000) show that environmental purchasing has significant impact on
53 both income and cost. Carter and Jennings (2002) find a positive relationship between CSR and
54 supplier performance. And more recently, Miao et al. (2011) use a sample of Chinese firms to
55 explore the antecedents of logistics social responsibility. Ageron et al. (2011) take advantage of
56 a French sample to provide a list of enabling conditions and critical success factors for
57 sustainable supply management. In addition, mathematical models have been established to
58 investigate CSR in supply chains. For instance, Savaskan et al. (2004) identify an appropriate
59 supply chain structure for original equipment manufacturers in closed-loop supply chains with
60 product remanufacturing. Cruz (2008) develops a dynamic multi-criteria decision-making

61 framework to derive the equilibriums for supply chain networks with environmental (social)
62 responsibility, and the basic assumption is that environmental responsibility does not directly
63 affect market demand. Cruz and Wakolbinger (2008) extend Cruz (2008) to a multi-period
64 setting to capture the long-term effect of CSR activities. Hsueh and Chang (2008) demonstrate
65 that system-wide optimization can be achieved by appropriately allocating social responsibility
66 via monetary transfers among members in a supply chain network. Ni et al. (2010) examine
67 social responsibility allocation in two-echelon supply chains, where the two supply chain
68 members are bound by a wholesale price contract. A key issue is to determine who should be
69 allocated as the responsibility holder with the right of offering the contract that is designed to
70 characterize the transfer mechanism of social responsibility cost incurred by the supplier.
71 Another concern in Ni et al. (2010) is to examine how this right should be appropriately
72 restricted.

73 Taking a strategic CSR view (Baron 2001), this paper attempts to understand how two
74 supply chain members, a downstream firm (F) and an upstream supplier (S), interact with each
75 other with respect to CSR behaviour in a game-theoretic setting and what impact exogenous
76 factors may have on this interaction and equilibriums. Compared to the otherwise identical
77 product sold by competitors in the final market, the product provided by the supply chain
78 differs with certain CSR commitment that is expected to bring consumers with additional
79 benefits depending on consumers' perceptions. This assumption aims to address empirical
80 findings about the effect of CSR performance on consumer's willingness-to-pay in Mohr and
81 Webb (2005) and De Pelsmacker et al. (2005) and reflects the view that CSR performance can
82 be viewed as a device for both vertical and horizontal product differentiation (McWilliams et al.
83 2006). The final market is assumed to be competitive via price, and this price competition
84 results in a CSR-dependent demand function for the supply chain product due to the
85 differentiation by CSR performance. With this demand function, a dynamic three-stage game
86 model is established to characterize the strategic interaction between S and F in the
87 two-echelon supply chain where the first stage is to capture the behavioural interaction
88 regarding CSR conduct and the last two stages are a standard description of the good/service
89 transaction in a supply chain with a wholesale contract. More specifically, Section 2 considers

90 a simultaneous-move CSR game where S and F simultaneously determine their individual CSR
91 commitment prior to F's purchase decision from S at a wholesale price set by S, F then sells the
92 product or service in a final consumer market. Section 3 examines the situation that S and F
93 declare their individual commitment to CSR activities sequentially (For example, in its 2006
94 annual CSR report, Starbucks announced (committed) the target percentage (66.9%) of 2007
95 paper using that is made of post-consumer fiber), and this modified game is referred to as the
96 *sequential-move* CSR game.

97 With the simultaneous-move CSR game, it is demonstrated that a *mutual incentive* exists
98 between F and S and this mutual incentive leads to a win-win result in the sense that both the
99 CSR and economic performance can be enhanced as long as exogenous parameters exceed
100 certain thresholds (Proposition 2 and 3). Subsequently, it is explored how these thresholds are
101 affected by each exogenous parameter (Proposition 4). An examination of the sequential-move
102 CSR game reveals that the prior commitment to CSR activities by one member strengthens the
103 mutual incentive and makes the win-win performance more likely to be realized by
104 coordinating their social responsibility activities. The enhancement of the mutual incentive is
105 reflected in the relaxation of the critical conditions for achieving the win-win performance
106 (Proposition 5).

107 The research reported in this article falls within the category of mathematical modeling,
108 but the models here significantly differ from the existing approaches. Savaskan et al. (2004)
109 focus on the efficiency differences among four supply chain structures while we demonstrate
110 how a win-win scenario can be achieved via the mutual incentive between S and F, and this
111 incentive may be further strengthened if a member is willing to declare its CSR commitment
112 ahead of another member's CSR decision. In the multi-criteria decision-making framework,
113 Cruz (2008) considers the cost associated with CSR activities and ignores the benefit of CSR
114 commitment on market demand, but the research here accommodates both cost and benefit of
115 CSR. More importantly, this article attempts to understand how to reach a win-win solution
116 through strategic interaction between the two supply chain members while Cruz (2008) and
117 Cruz and Wakolbinger (2008) explore the dynamic evolution of product flows, associated
118 product prices, and different levels of social responsibility activities in supply chain networks.
119 In Hsueh and Chang (2008), the proposed strategy for coordinating CSR in a supply chain

120 network is accomplished by monetary transfers that are assumed to be *exogenously* binding,
121 while the models here investigate how CSR activities *endogenously* interact. As for the
122 difference from the research reported in Ni et al. (2010), this article assumes that each supply
123 chain member incurs its individual CSR cost and the focus is to examine the strategic
124 interaction between the two members. On the other hand, Ni et al. (2010) consider the situation
125 that the cost associated with CSR only incurs by S and is expected to be shared with F through
126 a wholesale price contract.

127 This research differs from the literature on the impact of quality and/or service on market
128 demand in industrial organization (Tirole 1988) where quality/service reflects a vertical
129 differentiation attribute of a product and a higher quality or service level always provides
130 positive extra benefits to all consumers. On the other hand, the CSR performance here is
131 modeled with both vertical and horizontal differentiation aspects where a product with CSR
132 commitment may provide positive or negative extra benefits depending on consumers'
133 perceptions. In addition, the research here focuses on the mutual incentive of CSR conduct
134 between the upstream and downstream players, but the literature on quality improvement
135 incentives under quality-related cost sharing contracts usually does not explicitly consider the
136 impact of quality improvement on final demand or the downstream service competition/
137 coordination in the final market. More detailed comparisons are furnished in Section 2.2 when
138 the basic model setting is explained.

139 The remainder of this article is organized as follows. Section 2 presents a simultaneous-
140 move CSR game model with its equilibriums and comparative results. Section 3 considers the
141 situation that the two members make their CSR decisions sequentially rather than
142 simultaneously. A discussion about adopting quadratic CSR cost functions is furnished in
143 Section 4 and the paper concludes with some remarks in Section 5.

144 **2. A Simultaneous-Move CSR Game**

145 ***2.1. The Final Demand for CSR Products***

146 Consider a two-echelon supply chain with a downstream firm (F) and an upstream supplier (S).
147 F purchases product/service from S at a wholesale price w set by S and sells it in a final
148 market where a large number of firms with a same constant marginal cost ($c_0 = 0$) sell identical

149 products via price competition. The products sold by F and other firms in the final market are
150 only differentiated by CSR activities committed by F and S while other firms provide the same
151 product without CSR commitment. The price competition implies that the equilibrium price of
152 non-CSR goods (p_0) is equal to their marginal cost (i.e. $p_0 = c_0 = 0$).¹

153 Assume that each consumer in the final market purchases at most 1 unit and has
154 homogeneous preference on non-CSR goods provided by other firms, but consumers'
155 preferences are heterogeneous on the CSR product provided by the supply chain. To
156 characterize the difference in CSR preference, it is assumed that a consumer with type θ
157 obtains an extra benefit $ay - b\theta$ (relative to 1 unit of non-CSR good) when he/she buys one
158 unit of good with a given CSR activity (y), where $a > 0$, $b > 0$, $\theta \geq 0$.² Furthermore, if
159 $y = 0$, it is assumed that $ay - b\theta = 0$ for all $\theta \geq 0$. This implies that the extra benefit will be
160 zero if the supply chain system does not provide a differentiated product with CSR
161 commitment.

162 This formulation of extra benefits intends to capture the following impact of CSR
163 activities. Firstly, ay reflects a general intuition that each consumer could potentially benefit
164 from CSR activity y . a is hereafter called the marginal social-benefit potential (MSBP). For
165 a given y , the greater the MSBP, the greater the potential social benefit is generated by this
166 CSR activity. Secondly, $b\theta$ represents consumer θ 's difficulty to perceive the potential
167 benefit of y . b is referred to as the marginal perception difficulty (MPD). A higher MPD
168 indicates that consumer θ feels more difficult to perceive the benefit. Finally, for given a ,
169 y and b , different θ 's embody heterogeneous preferences for a given CSR activity: a
170 consumer with a higher θ receives a lower level of extra benefit by consuming a unit of the
171 CSR goods.

172 Moreover, in the above formulation of consumers' extra benefit, the potential social

¹ The zero marginal cost (and the zero equilibrium price) assumption is for notational simplification, which has no material impact on the following analysis.

² Bagnoli and Watts (2003) also assume an extra benefit of this form for consumers who consume a unit of CSR-linked goods, without any exploration on the implications of vertical and horizontal product differentiation.

173 benefit (ay) reflects the vertical product differentiation property of a CSR activity because all
 174 consumers would potentially benefit from this CSR activity. On the other hand, consumer's
 175 perception difficulty ($b\theta$) captures its horizontal product differentiation property because
 176 different consumers tend to have different preferences on a given CSR activity (y).³ Thus this
 177 formulation intends to capture both vertical and horizontal product differentiation of CSR
 178 activity.⁴ This extra benefit formulation captures consumers' different willingness-to-pay for a
 179 product with a given CSR activity. For instance, De Pelsmacker et al. (2005) empirically show
 180 that the average premium of willingness to pay for fair-trade coffee (relative to no-fair-trade
 181 coffee) varies from 36% for the fair-trade lovers to 3% for the brand lovers.

182 Next we shall consider the demand function for the CSR product supplied by the
 183 two-echelon supply chain consisting of F and S. Assume that the CSR product is priced at p
 184 by F. Consumer θ 's net surpluses are $u_0 + ay - b\theta - p$ and $u_0 - p_0$ if he/she buys (and
 185 consumes) one unit of F's product with the CSR activity y and non-CSR product from
 186 other firms in the final market, respectively, where u_0 is the utility obtained by consuming
 187 one unit of non-CSR product. Then the condition under which consumer θ buys F's CSR
 188 product is $ay - b\theta - p \geq p_0 = c_0 = 0$. Finally, let θ_0 be the critical consumer type satisfying
 189 $ay - b\theta - p = 0$. All consumers with type $\theta \leq \theta_0$ will obtain a positive extra benefit by
 190 consuming F's CSR product, leading to F's demanded quantity at p to be $q = (ay - p)/b$.

191 **2.2 The Supply Chain Model**

192 Let y_F and y_S be the CSR performance achieved via F's and S's CSR activities
 193 respectively, and $y = y_F + y_S$ be the channel CSR performance. The final demand function for
 194 the CSR product provided by the two-echelon supply chain $q = (ay - p)/b$ can be re-written

³ Clearly, for given a , y and b , a consumer with a large enough θ may receive a negative extra benefit by consuming one unit of this CSR good. In this case, consumer θ personally perceives a negative effect of the social clause corresponding to the given CSR. But for the same y , a consumer with a small enough θ would envisage a positive effect of this social clause.

⁴ McWilliams et al. (2006) also believe that CSR can be used as both vertical and horizontal differentiation devices in the field of strategic management.

195 as

$$196 \quad p = a(y_F + y_S) - bq \quad (1)$$

197 where $p \geq 0$ and $q \geq 0$ are the price and demand quantity, respectively.

198 In demand function (1), for given b and $y_F + y_S$, parameter a (the MSBP) determines
199 not only the highest potential willingness-to-pay of consumers in the market segment served by
200 the supply chain (by setting $q = 0$), but also the maximum scale of this market segment (by
201 setting $p = 0$). Thus the MSBP parameter a reflects the potential to attract consumers to the
202 CSR product provided by the supply chain.

203 Parameter b (the MPD) determines the slope of the demand curve for the CSR product
204 market segment and depicts the price sensitivity to demand quantity. Then for given $y_F + y_S$,
205 a and p , parameter b determines how many consumers will purchase the CSR product
206 provided by the supply chain. Note further that b gauges the difficulty for a consumer to
207 personally perceive the benefit of a given CSR activity. A lower b indicates that consumers
208 are easier to perceive the benefit of CSR and tend to get higher extra benefit. Thus the MPD
209 parameter b reveals the attractiveness of the CSR product to consumers.

210 To summarize, a higher MSBP (a) or a lower MPD (b) indicates that the CSR product is
211 more attractive to consumers, reflecting a higher degree of product differentiation for the CSR
212 product by the supply chain from other firms' non-CSR product in the final market. In this case,
213 the competition tends to be less intensive in the final market for the CSR product by the supply
214 chain and the non-CSR product by its competitors. Based on the product differentiation
215 property, the MSBP parameter a and the MPD parameter b can be used to represent the
216 competition intensity that the supply chain has to face in the final market.

217 Let $c_F > 0$ and $c_S > 0$ be the unit CSR cost incurred by S and F, and $\bar{C}_F \geq 0$ and
218 $\bar{C}_S \geq 0$ be the investment budget set aside for CSR activities by F and S, respectively. Then
219 $y_F \in [0, \bar{C}_F / c_F]$ and $y_S \in [0, \bar{C}_S / c_S]$ specify the CSR performance bounds for F and S. The
220 unit CSR cost c_F and c_S can be respectively viewed as parameters to measure F's and S's

221 CSR conduct efficiency at an operational level: a higher unit cost indicates a lower of
222 operational efficiency. We call c_F and c_S respectively the operational efficiency of F's and
223 S's CSR conduct. The CSR investment budget \bar{C}_F and \bar{C}_S can be seen as parameters to
224 represent the levels of the importance that F and S attach to CSR conduct at a strategic level: a
225 higher budget implies that a supply chain member takes CSR conduct as more important and
226 then allocates more resources to its CSR activity. \bar{C}_F and \bar{C}_S can then measure the strategic
227 importance of CSR to F and S, respectively. To concentrate on CSR interaction in supply chain
228 operations, other costs such as the CSR- independent portion of production, stocking, and
229 delivery costs are normalized to be zero.

230 The sequence of decisions is as follows: F and S choose $y_F \geq 0$ and $y_S \geq 0$
231 simultaneously (This simultaneous-move assumption is relaxed to be sequential-move in
232 Section 3), followed by a wholesale price $w \in [0, a(y_F + y_S)]$ offered by S (as noted by
233 Cachon (2003), wholesale price contracts are commonly observed in practice). Finally, F
234 makes its purchase decision q .

235 The aforesaid CSR conduct model setting, at the first glance, appears similar to existing
236 literature on quality improvement incentive within a supply chain (see Chao et al. (2009) for an
237 extensive review). However, our model is significantly different from this body of literature in
238 two aspects. Firstly, our research assumes a CSR-dependent demand function while the latter
239 assumes a profitability difference resulted from different quality levels without explicitly
240 considering the impact of quality improvements on demand. Secondly, our model focuses on
241 strategic interactions of CSR conduct in a supply chain under wholesale price contracts, while
242 the latter mainly concentrates on designing quality-related cost sharing contracts between
243 supply chain members for quality improvement.

244 Moreover, our assumption of a CSR-dependent demand function can be found in recent
245 parallel research on supply chain service competition/coordination. Along this line, Tsay and
246 Agrawal (2000) assume a service-dependent demand function with a substitutive demand
247 effect between two downstream retailers' service levels and examine the impact of relative
248 intensity of price- and service-competition on supply chain operations dynamics. Bernstein and

249 Federgruen (2007) use a demand function with the same property as that in Tsay and Agrawal
250 (2000) to investigate the coordination problem in a supply chain consisting of one common
251 supplier and N retailers. Rather than focusing on downstream competition in the final market,
252 our model is devoted to exploring behavioural interactions of CSR conduct within a supply
253 chain under the assumption that S's and F's CSR activities enable the product supplied by the
254 supply chain to be differentiated both vertically and horizontally from other firms' non-CSR
255 products in the final market. To investigate supply chain coordination where two supply chains,
256 each consisting of one wholesaler and one retailer, compete by service levels, Boyaci and
257 Gallego (2004) adopt the fill rate to measure service levels of the supply chain members, and
258 assume that final demand of each supply chain is determined only by a relative downstream
259 service level, but is independent of upstream service level and retail price (This
260 price-independence assumption is also adopted by Taylor (2002) to describe the impact of sales
261 effort on final market demand). In our model, we assume that the final market demand quantity
262 and retail price are positively associated with both the upstream and the downstream CSR
263 activities. To summarize, the service competition literature is to understand the role of service
264 in downstream competition in the final market, while our model is to explore the
265 upstream-downstream behavioural interactions of CSR conduct in a supply chain. In addition,
266 to describe the impact of service on final demand function, this body of literature follows the
267 theory of industrial organization and views service as a vertical product differentiation device
268 (Tirole, 1988).⁵ With our analysis of the impact of CSR commitment on consumers' extra
269 benefits, this research intends to characterize both vertical and horizontal differentiation
270 properties of CSR conduct.

271 Finally, a number of authors view CSR conduct as a provision of public goods. Bagnoli
272 and Watts (2003), Kotchen (2006), and Besley and Ghatak (2007) are concerned with
273 inter-firm competition where firms strategically provide certain amount of public goods (CSR
274 performance). And then they analyze the efficiency implication of the public goods provision
275 according to the corresponding market equilibriums. Rather than examining market efficiency
276 under inter-firm competition, we focus on behavioural and operational implications of the
277 strategic cooperation/conflict of CSR conduct within a supply chain under a linear demand

⁵ Quality is also treated as a vertical differentiation device in the theory of industrial organization.

278 function (1), in which the parameters a and b reflect competition intensity in the final
 279 market.

280 **2.3. The Equilibriums**

281 The subgame perfect Nash equilibrium of this three-stage dynamic game can be solved by
 282 backward induction.

283 In stage 3, F selects q to maximize

$$284 \quad \Pi_F(y_F, y_S, w, q) = (a(y_F + y_S) - bq)q - wq - c_F y_F$$

285 Clearly, Π_F is concave in q . Then the first-order condition implies

$$286 \quad q(y_F, y_S, w) = \frac{a(y_F + y_S) - w}{2b} \quad (2)$$

287 In stage 2, in anticipation of F's reaction captured by (2), S chooses w to maximize⁶

$$288 \quad \Pi_S(y_F, y_S, w, q(y_F, y_S, w)) = wq(y_F, y_S, w) - c_S y_S = \frac{a(y_F + y_S)w - w^2}{2b} - c_S y_S$$

289 It is easy to check that Π_S is concave in w . From the first-order condition, we have

$$290 \quad w^*(y_F, y_S) = \frac{a(y_F + y_S)}{2} \quad (3)$$

291 Substituting (3) into (2), one can get

$$292 \quad q^*(y_F, y_S) = \frac{a(y_F + y_S)}{4b} \quad (4)$$

293 With the demand function (1), the final market price is

$$294 \quad p^*(y_F, y_S) = \frac{3a(y_F + y_S)}{4} \quad (5)$$

295 Further, substituting (3) and (4) into the profit function for S and F, their stage-1 profits
 296 are⁷

⁶ Here, an alternative assumption is that F and S simultaneously choose q and w in the same stage. In this case, S's profit function is written as $\Pi_S(y_F, y_S, w, q) = wq - c_S y_S$ and F's profit function and reaction function are the same as those in the sequential-move case. Next, we will show that the unique Nash equilibrium is $q=0$ and $w = a(y_F + y_S)$. Firstly, for any given $q > 0$, as S's profit linearly increases in w , S's optimal reaction is the upper bound $w = a(y_F + y_S)$, which in turn makes F choose $q=0$ by (2). This implies that any $q > 0$ cannot be in a Nash equilibrium. In addition, for $q=0$, if S chooses $w < a(y_F + y_S)$, then F will choose $q > 0$ as per (2). This confirms that $q=0$ and $w < a(y_F + y_S)$ cannot be in an equilibrium, either. Finally, for $w = a(y_F + y_S)$, F's optimal reaction is $q=0$, which makes S indifferent for all w in $[0, a(y_F + y_S)]$. Therefore, $(q=0, w = a(y_F + y_S))$ arises as the unique Nash equilibrium.

⁷ In reality, the benefit and the cost of CSR activities do not occur simultaneously. In this case, a discount factor can be added to discount the stage-3 profit. However, it can be easily checked that this modification does not change the main results.

297
$$\Pi_S^*(y_F, y_S) = \frac{a^2(y_F + y_S)^2}{8b} - c_S y_S$$

298
$$\Pi_F^*(y_F, y_S) = \frac{a^2(y_F + y_S)^2}{16b} - c_F y_F$$

299 Note that these two profit functions are convex and quadratic, so the profit achieves its
 300 maximum at either the upper or lower bound. As such, the optimal reaction of F (S) to its
 301 opponent is to choose 0 or \bar{C}_F / c_F (0 or \bar{C}_S / c_S), depending on the corresponding axis of
 302 symmetry that is contingent upon its opponent's choice y_S (y_F).

303 For $\Pi_S^*(y_F, y_S)$, its axis of symmetry is $y_S = 4bc_S / a^2 - y_F$. Then the supplier chooses
 304 $y_S = \bar{C}_S / c_S$ if $4bc_S / a^2 - y_F \leq \bar{C}_S / (2c_S)$, implying that $\Pi_S^*(y_F, \bar{C}_S / c_S) \geq \Pi_S^*(y_F, 0)$.
 305 Otherwise $y_S = 0$. To summarize, S's reaction function is

306
$$y_S = f(y_F) \equiv \begin{cases} \frac{\bar{C}_S}{c_S}, & \text{if } y_F \geq \frac{4bc_S}{a^2} - \frac{\bar{C}_S}{2c_S} \\ 0, & \text{otherwise} \end{cases} \quad (6)$$

307 In (6), we assume for tie-breaking that S chooses the greater $y_S > 0$ when $\Pi_S^*(y_F, y_S) = \Pi_S^*(y_F, 0)$.

308 The same assumption is applied to F's reaction function (7).

309 Analogically, F's reaction function is

310
$$y_F = g(y_S) \equiv \begin{cases} \frac{\bar{C}_F}{c_F}, & \text{if } y_S \geq \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F} \\ 0, & \text{otherwise} \end{cases} \quad (7)$$

311 Reaction functions (6) and (7) imply that the greater y_S (y_F) chosen by S (F), the more
 312 likely its opponent will be induced to select its upper bound $y_F = \bar{C}_F / c_F$ ($y_S = \bar{C}_S / c_S$). This
 313 reveals the existence of a mutual incentive between S and F.

314 The reasons for the existence of this mutual incentive are as follows. Note that (3) and (5)
 315 imply that F's profit margin, $a(y_F + y_S) / 4$, increases in y_S . Furthermore, the quantity sold in
 316 the final market also increases in y_S . Thus for a given unit CSR cost c_F , a higher y_S means
 317 a higher profit margin for each unit of y_F . This is likely to stimulate F to choose a higher y_F .

318 On the other hand, since both the wholesale price and order quantity increase in y_F , S will
 319 reap a higher profit for each unit of y_S when F chooses a higher y_F . Thus a higher y_F
 320 tends to induce S to select a higher y_S as well.

321 Denote

$$322 \quad y_F^\#(a, b, \bar{C}_S, c_S) \equiv \frac{4bc_S}{a^2} - \frac{\bar{C}_S}{2c_S} \quad \text{and} \quad y_S^\#(a, b, \bar{C}_F, c_F) \equiv \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F}$$

323 It is clear that $y_F^\#$ decreases in a and \bar{C}_S but increases in b and c_S , and that $y_S^\#$
 324 decreases in a and \bar{C}_F but increases in b and c_F .

325 With the reaction functions (6) and (7), the Nash equilibriums of the stage-1 subgame are
 326 derived as shown in Lemma 1.

327 **Lemma 1:** (i) if $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, or $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$
 328 and $y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$, then $(y_F^*, y_S^*) = (\bar{C}_F / c_F, \bar{C}_S / c_S)$ is the unique Nash equilibrium.

329 (ii) if $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$, then $(y_F^*, y_S^*) = (0, \bar{C}_S / c_S)$ is
 330 the unique Nash equilibrium.

331 (iii) if $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$ and $y_F^\#(a, b, \bar{C}_S, c_S) > \bar{C}_F / c_F$, then $(y_F^*, y_S^*) = (\bar{C}_F / c_F, 0)$ is
 332 the unique Nash equilibrium.

333 (iv) if $0 < y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$ and $0 < y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, then $(y_F^*, y_S^*) =$
 334 $(0, 0)$ and $(y_F^*, y_S^*) = (\bar{C}_F / c_F, \bar{C}_S / c_S)$ are the two Nash equilibriums.

335 (v) if $y_F^\#(a, b, \bar{C}_S, c_S) > 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$, or $y_S^\#(a, b, \bar{C}_F, c_F) > 0$ and
 336 $y_F^\#(a, b, \bar{C}_S, c_S) > \bar{C}_F / c_F$, then $(y_F^*, y_S^*) = (0, 0)$ is the unique Nash equilibrium.

337 The proof of this lemma is given in the Appendix A.1.

338 With the aforesaid equilibrium result for the stage-1 subgame, the subgame perfect Nash
 339 equilibriums of the three-stage game are derived as follows. The proof can be completed by
 340 plugging (y_F^*, y_S^*) in Lemma 1 into (3) and (4) as well as the profit functions for S and F.

341 **Proposition 1:** (i) if $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, or $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$

342 and $y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$, the equilibrium path of the three-stage game model is

343 (E)
$$\left\{ (y_F^*, y_S^*) = \left(\frac{\bar{C}_S}{c_S}, \frac{\bar{C}_F}{c_F} \right) \rightarrow w^* = \frac{a}{2} \left(\frac{\bar{C}_F}{c_F} + \frac{\bar{C}_S}{c_S} \right) \rightarrow q^* = \frac{a}{4b} \left(\frac{\bar{C}_F}{c_F} + \frac{\bar{C}_S}{c_S} \right) \right\}$$

344 and the corresponding equilibrium profits are $\Pi_F^*(y_F^*, y_S^*) = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (16b) - \bar{C}_F$ and

345
$$\Pi_S^*(y_F^*, y_S^*) = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (8b) - \bar{C}_S.$$

346 (ii) if $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$, the equilibrium path is

347
$$\left\{ (y_F^*, y_S^*) = (0, \bar{C}_S / c_S) \rightarrow w^* = a\bar{C}_S / (2c_S) \rightarrow q^* = a\bar{C}_S / (4bc_S) \right\}$$
, and the corresponding

348 equilibrium profits are $\Pi_F^*(y_F^*, y_S^*) = a^2(\bar{C}_S / c_S)^2 / (16b)$ and $\Pi_S^*(y_F^*, y_S^*) = a^2(\bar{C}_S / c_S)^2 / (8b) - \bar{C}_S$.

349 (iii) if $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$ and $y_F^\#(a, b, \bar{C}_S, c_S) > \bar{C}_F / c_F$, the equilibrium path is

350
$$\left\{ (y_F^*, y_S^*) = (\bar{C}_F / c_F, 0) \rightarrow w^* = a\bar{C}_F / (2c_F) \rightarrow q^* = a\bar{C}_F / (4bc_F) \right\}$$
, and the corresponding

351 equilibrium profits are $\Pi_F^*(y_F^*, y_S^*) = a^2(\bar{C}_F / c_F)^2 / (16b) - \bar{C}_F$ and $\Pi_S^*(y_F^*, y_S^*) = a^2(\bar{C}_F / c_F)^2 / (8b)$.

352 (iv) if $0 < y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$ and $0 < y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, there exist two

353 equilibrium paths (E) and $\left\{ (y_F^*, y_S^*) = (0, 0) \rightarrow w^* = 0 \rightarrow q^* = 0 \right\}$, and the corresponding

354 equilibrium profits are $\Pi_F^*(y_F^*, y_S^*) = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (16b) - \bar{C}_F$ and $\Pi_S^*(y_F^*, y_S^*) =$

355 $a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (8b) - \bar{C}_S$, and $\Pi_F^*(y_F^*, y_S^*) = 0$ and $\Pi_S^*(y_F^*, y_S^*) = 0$, respectively.

356 (v) if $y_F^\#(a, b, \bar{C}_S, c_S) > 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$, or $y_S^\#(a, b, \bar{C}_F, c_F) > 0$ and

357 $y_F^\#(a, b, \bar{C}_S, c_S) > \bar{C}_F / c_F$, the equilibrium path is $\left\{ (y_F^*, y_S^*) = (0, 0) \rightarrow w^* = 0 \rightarrow q^* = 0 \right\}$, and

358 the corresponding equilibrium profits are $\Pi_F^*(y_F^*, y_S^*) = 0$ and $\Pi_S^*(y_F^*, y_S^*) = 0$.

359 **2.4. Main Results**

360 Next, comparative statics are presented about the equilibriums derived in Section 2.2. In the

361 following study, it is assumed that changes are examined one at a time. When one parameter is

362 considered for possible changes, all other parameters are assumed to remain constant.

363 **Proposition 2:** Denote the system-wide profit by $\Pi^* = \Pi_F^* + \Pi_S^*$, then

364 (i) The equilibrium profits Π_F^* , Π_S^* and Π^* are nondecreasing in \bar{C}_S , \bar{C}_F , and a ,

365 respectively;

366 (ii) The equilibrium profits Π_F^* , Π_S^* and Π^* are nonincreasing in c_S , c_F , and b ,
367 respectively.

368 The proof of Proposition 2 is provided in Appendix A.2.

369 **Remark 1:** The exogenous parameters in this model can be categorized into three groups:
370 market competition intensity parameters a and b , CSR strategic importance parameters \bar{C}_S
371 and \bar{C}_F , and CSR operational efficiency parameters c_S and c_F . Proposition 2 examines the
372 relationship between equilibrium profit functions (both individual and channel) and these
373 exogenous parameters. For market parameters a (the MSBP) and b (the MPD), a
374 characterizes the level of the vertical product differentiation of CSR performance. Proposition
375 2 indicates that a higher MSBP (i.e. a higher level of vertical differentiation) leads to higher
376 profitability (both individually and globally). As for b , the MPD reflects the horizontal
377 product differentiation role of CSR performance and is interpreted as the difficulty for
378 consumers to perceive the benefit of CSR activities. Proposition 2 demonstrates that a higher
379 MPD (i.e. a higher level of perception difficulty or a lower level of horizontal differentiation)
380 tends to result in lower equilibrium profitability for both individuals and the whole channel.
381 The intuition is clear: for a higher a (a lower b), CSR commitment makes the supply
382 chain's product easier to be differentiated from non-CSR goods from competitors and more
383 attractive to consumers, thereby lowering competition intensity in the final market and
384 resulting in higher profitability. For strategic importance parameters \bar{C}_S and \bar{C}_F and the
385 operational efficiency parameters c_S and c_F , due to the symmetry of the game model, it is
386 only necessary to consider \bar{C}_S and c_S as \bar{C}_F and c_F can be discussed similarly.
387 Proposition 2 shows that both individual and channel profitability increases with a higher
388 social responsibility budget \bar{C}_S and decreases in the unit CSR cost c_S . Thus proposition 2
389 furnishes a theoretical basis for supply chain members to highlight the importance with a
390 higher commitment to CSR activities at strategic level (higher \bar{C}_S and \bar{C}_F) and improve their
391 efficiency in social responsibility conduct at an operational level (lower c_S and c_F). This

392 result is consistent with the observation that more and more supply chain members (especially
 393 the primary members) have invested more and more resources in addressing social and/or
 394 environmental problems and enhanced their efficiency via technological and/or organizational
 395 improvements. For example, Cone/Roper Cause Related Trends Report (1999) points out that
 396 nearly 50% of larger corporations have programs associated with social issues.

397 **Proposition 3:** For the six market, strategic importance and operational efficiency parameters,
 398 $\bar{C}_S, \bar{C}_F, a, c_S, c_F$ and b ,

399 (i) given \bar{C}_F, a, c_S, c_F and b , there exists $\bar{C}_S^\# \equiv \bar{C}_S^\#(\bar{C}_F, a, c_S, c_F, b)$ such that (E) is the
 400 unique subgame perfect Nash equilibrium for all $\bar{C}_S \geq \bar{C}_S^\#$;

401 (ii) given \bar{C}_S, a, c_S, c_F and b , there exists $\bar{C}_F^\# \equiv \bar{C}_F^\#(\bar{C}_S, a, c_S, c_F, b)$ such that (E) is the
 402 unique subgame perfect Nash equilibrium for all $\bar{C}_F \geq \bar{C}_F^\#$;

403 (iii) given $\bar{C}_S, \bar{C}_F, c_S, c_F$ and b , there exists $a^\# \equiv a^\#(\bar{C}_S, \bar{C}_F, c_S, c_F, b)$ such that (E) is
 404 the unique subgame perfect Nash equilibrium for all $a \geq a^\#$;

405 (iv) given $\bar{C}_S, \bar{C}_F, a, c_F$ and b , there exists $c_S^\# \equiv c_S^\#(\bar{C}_S, \bar{C}_F, a, c_F, b)$ such that (E) is the
 406 unique subgame perfect Nash equilibrium for all $c_S \leq c_S^\#$;

407 (v) given $\bar{C}_S, \bar{C}_F, a, c_S$ and b , there exists $c_F^\# \equiv c_F^\#(\bar{C}_S, \bar{C}_F, a, c_S, b)$ such that (E) is the
 408 unique subgame perfect Nash equilibrium for all $c_F \leq c_F^\#$;

409 (vi) given $\bar{C}_S, \bar{C}_F, a, c_S$ and c_F , there exists $b^\# \equiv b^\#(\bar{C}_S, \bar{C}_F, a, c_S, c_F)$ such that (E) is the
 410 unique subgame perfect Nash equilibrium for all $b \leq b^\#$.

411 The proof of Proposition 3 appears in Appendix A.3.

412 **Remark 2:** Proposition 3 demonstrates that both S and F, constrained by $y_S \in [0, \bar{C}_S / c_S]$ and
 413 $y_F \in [0, \bar{C}_F / c_F]$, will choose their maximum CSR performance $y_S^* = \bar{C}_S / c_S$ and $y_F^* =$
 414 \bar{C}_F / c_F as their unique equilibrium as long as any of the six exogenous parameters $\bar{C}_S, \bar{C}_F,$
 415 $a, c_S, c_F,$ and b is extended beyond certain critical threshold ($\bar{C}_S \geq \bar{C}_S^\#, \bar{C}_F \geq \bar{C}_F^\#$,

416 $a \geq a^\#, c_S \leq c_S^\#, c_F \leq c_F^\#,$ or $b \leq b^\#$). Each threshold therein is determined one at a time by
417 keeping the other five parameters constant. Note that Proposition 2 reveals that the profit
418 functions for S, F, and the whole channel increase in \bar{C}_S, \bar{C}_F and a , and decrease in c_S, c_F
419 and b . Therefore, as long as $\bar{C}_S, \bar{C}_F,$ or a is increased above its lower bound, $\bar{C}_S^\#, \bar{C}_F^\#,$ or
420 $a^\#,$ or $c_S, c_F,$ or b is decreased below its upper bound $c_S^\#, c_F^\#,$ or $b^\#,$ a win-win scenario
421 arises in the sense that the supply chain system not only achieves its maximum CSR
422 performance $y_S^* = \bar{C}_S / c_S$ and $y_F^* = \bar{C}_F / c_F,$ but also enhances its profitability for both
423 individual members and the whole channel. This research finding supports existing empirical
424 studies reported in Margolis and Walsh (2001) and Orlitzky et al. (2003): CSR performance is
425 positively related to corporate financial performance. Finally, Proposition 3 explores potential
426 venues for supply chain practitioners to reconcile CSR performance with the profitability of
427 supply chain operations: choosing CSR initiatives with a higher MSBP and/or a lower MPD,
428 raising resource commitment to CSR activities, and improving CSR operational efficiency.

429 Note that the two-echelon supply chain considered here is characterized by strategic
430 importance parameters (\bar{C}_S and \bar{C}_F) and operational efficiency parameters ($c_S,$ and c_F).
431 We shall examine more carefully how the corresponding system parameter thresholds obtained
432 in Proposition 3, $\bar{C}_S^\#, \bar{C}_F^\#, c_S^\#,$ and $c_F^\#,$ are affected by the changes in other exogenous
433 parameters. Define $\bar{C}_S^\#(\bar{C}_F, c_S, c_F, a, b)$ as

$$\begin{aligned}
& \bar{C}_S^\#(\bar{C}_F, c_S, c_F, a, b) \equiv \min \{ \bar{C}_S \geq 0 : F_1(\bar{C}_S) \leq 0 \text{ or } F_2(\bar{C}_S) \leq 0 \} \\
& = \begin{cases} 0, & \text{if } \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \frac{4bc_S}{a^2} - \frac{\bar{C}_F}{c_F} \leq 0 \\ \min \{ \bar{C}_{S_1}^\#, \bar{C}_{S_2}^\# \}, & \text{if } \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \frac{4bc_S}{a^2} - \frac{\bar{C}_F}{c_F} > 0 \\ \bar{C}_{S_1}^\#, & \text{otherwise} \end{cases} \quad (8)
\end{aligned}$$

435 and similarly define as $\bar{C}_F^\#(\bar{C}_S, c_S, c_F, a, b), c_S^\#(\bar{C}_S, \bar{C}_F, c_F, a, b)$ and $c_F^\#(\bar{C}_S, \bar{C}_F, c_S, a, b)$ as

$$\bar{C}_F^\#(\bar{C}_S, c_S, c_F, a, b) = \min \{ \bar{C}_F \geq 0 : F_1(\bar{C}_F) \leq 0 \text{ or } F_2(\bar{C}_F) \leq 0 \} \quad (9)$$

437
$$c_S^\#(\bar{C}_S, \bar{C}_F, c_F, a, b) = \max \{c_S > 0: F_1(c_S) \leq 0 \text{ or } F_2(c_S) \leq 0\} \quad (10)$$

438
$$c_F^\#(\bar{C}_S, \bar{C}_F, c_S, a, b) = \max \{c_F > 0: F_1(c_F) \leq 0 \text{ or } F_2(c_F) \leq 0\} \quad (11)$$

439 **Proposition 4:** For the four system parameter thresholds given in (8)–(11),

440 (i) let a be the only variable, if $a_1 \geq a_2$, then $\bar{C}_S^\#(a_1) \leq \bar{C}_S^\#(a_2)$, $\bar{C}_F^\#(a_1) \leq \bar{C}_F^\#(a_2)$,

441 $c_S^\#(a_1) \geq c_S^\#(a_2)$ and $c_F^\#(a_1) \geq c_F^\#(a_2)$;

442 (ii) let b be the only variable, if $b_1 \geq b_2$, then $\bar{C}_S^\#(b_1) \geq \bar{C}_S^\#(b_2)$, $\bar{C}_F^\#(b_1) \geq \bar{C}_F^\#(b_2)$,

443 $c_S^\#(b_1) \leq c_S^\#(b_2)$ and $c_F^\#(b_1) \leq c_F^\#(b_2)$;

444 (iii) let \bar{C}_F be the only variable, if $\bar{C}_F^1 \geq \bar{C}_F^2$, then $\bar{C}_S^\#(\bar{C}_F^1) \leq \bar{C}_S^\#(\bar{C}_F^2)$, $c_S^\#(\bar{C}_F^1) \geq c_S^\#(\bar{C}_F^2)$ and

445 $c_F^\#(\bar{C}_F^1) \geq c_F^\#(\bar{C}_F^2)$;

446 (iv) let c_F be the only variable, if $c_F^1 > c_F^2$, then $\bar{C}_S^\#(c_F^1) \geq \bar{C}_S^\#(c_F^2)$, $\bar{C}_F^\#(c_F^1) \geq \bar{C}_F^\#(c_F^2)$ and

447 $c_S^\#(c_F^1) \leq c_S^\#(c_F^2)$;

448 (v) let \bar{C}_S be the only variable, if $\bar{C}_S^1 \geq \bar{C}_S^2$, then $\bar{C}_F^\#(\bar{C}_S^1) \leq \bar{C}_F^\#(\bar{C}_S^2)$, $c_F^\#(\bar{C}_S^1) \geq c_F^\#(\bar{C}_S^2)$ and

449 $c_S^\#(\bar{C}_S^1) \geq c_S^\#(\bar{C}_S^2)$;

450 (vi) let c_S be the only variable, if $c_S^1 \geq c_S^2$, then $\bar{C}_S^\#(c_S^1) \geq \bar{C}_S^\#(c_S^2)$, $\bar{C}_F^\#(c_S^1) \geq \bar{C}_F^\#(c_S^2)$ and

451 $c_F^\#(c_S^1) \leq c_F^\#(c_S^2)$.

452 The proof of Proposition 4 is given in Appendix A.4.

453 **Remark 3:** Proposition 4 explores how the critical thresholds of the four system parameters are

454 affected by other parameters, thereby revealing the external market characteristics and the

455 internal coordination opportunities for a supply chain to achieve win-win performance. Part (i)

456 indicates that the higher the MSBP (a larger a , indicating a higher degree of vertical

457 differentiation and pointing to a higher potential willingness-to-pay), the lower the requirement

458 on the critical thresholds for CSR resource budgets (smaller $\bar{C}_S^\#$ and $\bar{C}_F^\#$) and operational

459 efficiency (larger $c_S^\#$ and $c_F^\#$) by S and F, thereby making the supply chain easier to attain the

460 win-win performance scenario (equilibrium E) given in Proposition 3. Conversely, part (ii)

461 shows that supply chain members are easier to achieve the win-win performance with lower
 462 critical thresholds for CSR resource budgets (smaller $\bar{C}_S^\#$ and $\bar{C}_F^\#$) and operational efficiency
 463 (larger $c_S^\#$ and $c_F^\#$) when the MPD is lower (a smaller b , indicating a higher degree of CSR
 464 horizontal differentiation and easier for consumers to perceive the potential social benefit). On
 465 the other hand, if the vertical and horizontal differentiation feature of the supply chain CSR
 466 product cannot effectively reduce the competition intensity with non-CSR product in the final
 467 market (i.e., resulting in a smaller a and/or larger b), Proposition 4 (i) and (ii) demonstrate that
 468 higher thresholds of the system parameters (larger $\bar{C}_S^\#$ and $\bar{C}_F^\#$, attaching a higher strategic
 469 importance level to CSR conduct, or smaller $c_S^\#$ and $c_F^\#$, corresponding to higher operational
 470 efficiency requirement) are needed to achieve the win-win scenario in Proposition 3, making it
 471 less attainable. This finding is compatible with Bagnoli and Watts' (2003) conclusion that
 472 social responsibility performance (the provision of public goods) varies inversely with the
 473 competitiveness of private-good market. On the other hand, parts (iii)–(vi) examine how
 474 changes in one of the four internal systematic parameter affect the thresholds of the other three
 475 systematic parameters. For example, (iii) and (v) demonstrate that if S or F commits more
 476 resources to socially responsible activities (a higher budget \bar{C}_S or \bar{C}_F), the other member's
 477 critical resource budget decreases (a lower $\bar{C}_F^\#$ or $\bar{C}_S^\#$) and the thresholds of operational
 478 efficiencies become lower for both S and F (larger $c_S^\#$ and $c_F^\#$). (iv) and (vi) reveal that the
 479 critical operational efficiency of a member has to be higher (a smaller $c_S^\#$ or $c_F^\#$) if the other
 480 member's operational efficiency is low (a larger c_F or c_S), but a higher operational
 481 efficiency (a smaller c_F or c_S) helps to reduce the thresholds of resource budgets (lower $\bar{C}_F^\#$
 482 and $\bar{C}_S^\#$). (iii)–(vi) shed significant insights into the opportunities of coordinating supply chain
 483 CSR resource commitment (the strategic importance) and operational efficiency based on the
 484 mutual incentive mechanism for the two supply chain members: if a member wishes to induce
 485 the other member to attain the win-win performance, it should increase its CSR resource
 486 budget or CSR operational efficiency so that the corresponding thresholds for its partner can be

487 reduced, thereby making it easier for its partner to enter into the commitment. Furthermore,
 488 Proposition 2 points out that both individual and channel profitability will be improved if CSR
 489 resource budgets and operational efficiency are increased. Therefore, this mutual incentive
 490 makes the recommendation implementable for both members to raise their standards in CSR
 491 resource budgets and operational efficiency whereby enhancing their profitability and attaining
 492 the win-win performance scenario.

493 **3 The Role of Prior Commitment**

494 In Sections 2, it is assumed that S and F choose their CSR activity levels simultaneously. This
 495 simultaneous-move assumption cannot accommodate the situation that one supply chain
 496 member announces its commitment to CSR investment prior to the other member's decision
 497 and how the other member responds to this prior commitment. This section relaxes the
 498 simultaneous-move assumption and considers the case that S and F make their choices
 499 sequentially. Without loss generality, the following study entertains the case that S first chooses
 500 y_S and, then, F selects y_F , while the other assumptions remain as is in Section 2. This
 501 consideration results in a four-stage sequential-move game: S first chooses y_S , the firm then
 502 selects y_F in stage 2, followed by S's choice of w in stage 3, and finally F's decision q .
 503 This model can be imagined as an abstraction of a manufacture-distributor supply chain where
 504 the manufacturer (S here) is the primary member and makes the first move.

505 In this model, for any given y_S selected by S, F's reaction is captured by (6) in Section 2
 506 where $y_F^* = \bar{C}_F / c_F$ if $y_S \geq y_S^\# = 8bc_F / a^2 - \bar{C}_F / (2c_F)$ or 0 if $y_S \leq y_S^\#$. Substituting (6) into
 507 S's profit function $\Pi_S^*(y_F, y_S)$ yields

$$508 \quad \Pi_{SD}^*(y_S) = \begin{cases} \frac{a^2(\bar{C}_F / c_F + y_S)^2}{8b} - c_S y_S, & \text{if } y_S \geq y_S^\# \\ \frac{a^2 y_S^2}{8b} - c_S y_S, & \text{otherwise} \end{cases}$$

509 where the subscript "D" is introduced to differentiate the dynamics of this sequential-move
 510 game from the simultaneous-move case in Section 2.

511 **Proposition 5:** For the four-stage sequential-move game,

$$(E1) \quad \left\{ y_S^* = \frac{\bar{C}_S}{c_S} \rightarrow y_F^* = \frac{\bar{C}_F}{c_F} \rightarrow w^* = \frac{a}{2} \left(\frac{\bar{C}_F}{c_F} + \frac{\bar{C}_S}{c_S} \right) \rightarrow q^* = \frac{a}{4b} \left(\frac{\bar{C}_F}{c_F} + \frac{\bar{C}_S}{c_S} \right) \right\}$$

513 is the unique subgame perfect Nash equilibrium if any of the following three conditions is
514 satisfied:

$$515 \quad (i) \quad y_F^\#(a, b, \bar{C}_S, c_S) \leq 0 \quad \text{and} \quad y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S,$$

$$516 \quad (ii) \quad y_S^\#(a, b, \bar{C}_F, c_F) \leq 0 \quad \text{and} \quad y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F,$$

$$517 \quad (iii) \quad 0 < y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F \quad \text{and} \quad 0 < y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S.$$

518 The proof of Proposition 5 is provided in Appendix A.5.

519 **Remark 4:** Conditions (i) and (ii) here correspond to Case (i), and condition (iii) is the same as
520 Case (iv) in Lemma 1 and Proposition 1 in Section 2, respectively. In the simultaneous-move
521 game, (E) arises as the unique desired equilibrium only if (i) or (ii) is satisfied. Proposition 5
522 demonstrates that another avenue (iii), in addition to (i) and (ii), becomes available for S and F
523 to reach the unique desired equilibrium (E1) in the sequential-move case. (E) and (E1) are
524 claimed as the desired equilibrium in the sense that both the CSR performance and profitability
525 (individual and system-wide) are maximized in these cases compared to other possible
526 equilibriums. This additional avenue (iii) becomes possible because the first-mover's prior
527 commitment to CSR, $y_S^* = \bar{C}_S / c_S$ or $y_F^* = \bar{C}_F / c_F$, deters its partner from choosing $y_F = 0$
528 or $y_S = 0$ due to the profit maximization consideration. Therefore, Proposition 5 can be
529 interpreted as that a prior commitment to CSR performance from one supply chain member
530 furnishes another vehicle to achieve the win-win performance scenario, enhances the mutual
531 incentive between the two supply chain members, and makes the win-win performance more
532 likely to be attained. This finding helps us to understand the case of Starbucks: while enjoying
533 a rising tendency of profitability as measured by net earnings and EPS, Starbucks takes its
534 initiative and introduces a C.A.F.E. certification program to encourage socially and
535 environmentally responsible practices by its suppliers (Starbucks 2004-2006; Lee et al. 2007).
536 In short, prior commitment can be viewed as another way (relative to the simultaneous-move
537 case) to enhance the mutual incentive and foster the realization of the win-win performance
538 scenario.

539 **4. Discussions**

540 In this section, the constant marginal CSR cost assumption in Section 2 is relaxed to allow for a
541 quadratic term in the CSR cost function. Assume that the CSR cost function for F and S are
542 $c_F y_F + d_F y_F^2 / 2$ and $c_S y_S + d_S y_S^2 / 2$, respectively, where $d_F \geq 0$ and $d_S \geq 0$.⁸ In this case,
543 the profit functions of S and F in the first stage are

544
$$\Pi_S^*(y_F, y_S) = \frac{a^2(y_F + y_S)^2}{8b} - c_S y_S - \frac{1}{2} d_S y_S^2$$

545
$$\Pi_F^*(y_F, y_S) = \frac{a^2(y_F + y_S)^2}{16b} - c_F y_F - \frac{1}{2} d_F y_F^2$$

546 **Proposition 6:** Under the quadratic cost function assumption, if $d_S < a^2 / (4b)$ and
547 $d_F < a^2 / (8b)$, then all properties in Lemma 1 and Propositions 1-5 remain valid.

548 The proof of Proposition 6 is provided in Appendix A.6.

549 Proposition 6 shows that the results in Section 2 and 3 remain true under a quadratic cost
550 function as long as the coefficients of the quadratic terms are not too big. Note that d_k reflects
551 the speed at which k 's marginal cost increases in its CSR performance y_k ($k = S, F$). Thus
552 the main results are not only true in a constant-marginal-cost setting (Section 2 and 3), but also
553 remain valid in certain increasing-marginal-cost settings (as long as marginal costs with regard
554 to CSR activity do not increase too rapidly).

555 **5. Concluding Remarks**

556 In this paper we take a strategic CSR view and assume that relative to a non-CSR product, a
557 CSR product provides consumers with some extra benefit which varies across those consumers.
558 This assumption implies that CSR can be used as both a vertical and horizontal product
559 differentiation device. The demand function is deduced for the CSR product provided by a two-
560 echelon supply chain based on the price competition equilibrium in the final market. With this
561 demand function, we investigate how supply chain members interact with respect to their CSR
562 behaviour from a game-theoretic perspective. Subgame perfect Nash equilibriums are derived

⁸ Röller (1990) theoretically shows that a quadratic cost function can behave well for analyzing global cost concepts (e.g. diminishing marginal returns (or increasing marginal cost)) by properly choosing the parameters. In the OM/OR area, Tsay and Agrawal (2000), Gurnani et al. (2007), Xiao and Yang (2008) employed quadratic functions of some special form in their research.

563 for both simultaneous-move and sequential-move game settings and the impact of exogenous
564 parameters on this interaction is also examined. Under a set of simple and intuitive assumptions,
565 the following analytical results are obtained.

566 (1) There exists a mutual incentive between S and F with respect to their CSR behaviour.
567 This mutual incentive leads to a win-win performance scenario (E) in terms of both CSR and
568 profitability performance as long as exogenous parameters are extended beyond certain critical
569 thresholds (Propositions 2 and 3).

570 (2) A higher consumer's marginal social benefit potential (MSBP) and a lower consumer's
571 marginal perception difficulty (MPD), pointing to a less intense final market competition
572 environment due to vertical and horizontal product differentiation roles of CSR performance,
573 help to lower the critical thresholds of CSR budgets (reflecting its strategic importance) and
574 operational efficiency by S and F to achieving the win-win performance (parts (i) and (ii) of
575 Proposition 4).

576 (3) An increase in one supply chain member's CSR budget (operational efficiency) tends
577 to lower its own CSR operational efficiency (budget) threshold and the other member's CSR
578 budget and operational efficiency thresholds, thereby making it more easier to attain the
579 win-win performance scenario (parts (iii)-(vi) of Proposition 4).

580 (4) A prior commitment to CSR activities by any supply chain member strengthens the
581 mutual incentive and makes the win-win performance scenario (E1) more likely to be realized
582 in the sense that this commitment provides additional vehicles for (E1) to arise as the desired
583 equilibrium (Proposition 5).

584 Business implications of these research findings are discussed in the remarks. This
585 research, to a certain extent, helps us to understand how businesses interact with each other
586 with respect to their CSR conduct. As stated in the basic model settings, information
587 asymmetry is not considered for the CSR budget or operational efficiency. Further research is
588 needed to accommodate this information asymmetry and other extensions (for example, adding
589 supply chain members to introduce competition within a supply chain system) so that a more
590 complete picture can be portrayed about how supply chain members interact and respond to the
591 call for socially responsible practices.

592 **Appendices. Proofs of Lemma 1 and Propositions**

593 **Appendix A.1. Proof of Lemma 1**

594 (i) As the game is symmetric, it is only necessary to show that $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and
 595 $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$ imply that $(y_F^*, y_S^*) = (\bar{C}_F / c_F, \bar{C}_S / c_S)$ is the unique Nash equilibrium.
 596 As $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0 \leq y_F$, it follows that $y_S = f(y_F) = \bar{C}_S / c_S$ for all $y_F \in [0, \bar{C}_F / c_F]$ as
 597 per (5). $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$ implies that $[y_S^\#, \bar{C}_S / c_S] \neq \Phi$. Since $y_S = \bar{C}_S / c_S$, from (6),
 598 one can get $y_F = g(y_S) = g(\bar{C}_S / c_S) = \bar{C}_F / c_F$. Thus $(y_F^*, y_S^*) = (\bar{C}_F / c_F, \bar{C}_S / c_S)$ is a Nash
 599 equilibrium. Suppose that there exists another Nash equilibrium. It has to be one of $(0, 0)$,
 600 $(0, \bar{C}_S / c_S)$, and $(\bar{C}_F / c_F, 0)$ based on the reaction functions (5) and (6). Consider $(0, 0)$ first.
 601 F's optimal reaction to S's choice $y_S = 0$ is either $y_F = 0$ if $y_S^\#(a, b, \bar{C}_F, c_F) > 0$, or
 602 $y_F = \bar{C}_F / c_F$ if $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$. The latter case implies that $(0, 0)$ is not a Nash
 603 equilibrium. For the former case, S's optimal reaction to $y_F = 0$ should be $y_S = \bar{C}_S / c_S \neq 0$
 604 based on (5), leading to a contradiction. Similarly, it can be verified that neither $(0, \bar{C}_S / c_S)$
 605 nor $(\bar{C}_F / c_F, 0)$ is a Nash equilibrium. Hence, $(y_F^*, y_S^*) = (\bar{C}_F / c_F, \bar{C}_S / c_S)$ is the unique
 606 Nash equilibrium.

607 (ii) $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$ implies that $[y_S^\#, \bar{C}_S / c_S] = \Phi$. That is, for all $y_S \in$
 608 $[0, \bar{C}_S / c_S]$, F's optimal reaction is $y_F = g(y_S) = 0$. $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ implies that
 609 $y_S = f(y_F) = \bar{C}_S / c_S$ for all $y_F \in [0, \bar{C}_F / c_F]$. Then the two reaction curves uniquely intersect
 610 at $(0, \bar{C}_S / c_S)$. Thus $(y_F^*, y_S^*) = (0, \bar{C}_S / c_S)$ is the unique Nash equilibrium. Due to symmetry
 611 of the game model, (iii) can be proved in the same way.

612 (iv) $0 < y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$ and $0 < y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$ imply that $[0, y_F^\#] \neq$
 613 Φ , $[y_F^\#, \bar{C}_F / c_F] \neq \Phi$, $[0, y_S^\#] \neq \Phi$ and $[y_S^\#, \bar{C}_S / c_S] \neq \Phi$. Then the reaction curves intersect
 614 twice at $(0, 0)$ and $(\bar{C}_F / c_F, \bar{C}_S / c_S)$, resulting in the two Nash equilibriums. (iv) is thus
 615 proved.

616 (v) The symmetry of the game model allows us to consider only the case of
617 $y_F^\#(a, b, \bar{C}_S, c_S) > 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$, and the other condition can be confirmed in
618 the same manner. $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$ implies that $[y_S^\#, \bar{C}_S / c_S] = \Phi$. Then F's optimal
619 reaction is $y_F = g(y_S) = 0$ for all $y_S \in [0, \bar{C}_S / c_S]$. So, $y_F^\#(a, b, \bar{C}_S, c_S) > 0 = y_F$ implies that
620 $y_S = f(y_F) = 0$. (v) is proved.

621 **Appendix A.2. Proof of Proposition 2**

622 It is shown below that the equilibrium profits Π_F^* and Π_S^* are nondecreasing in \bar{C}_S ,
623 implying that Π^* is nondecreasing in \bar{C}_S as well. Remaining claims can be proved in a
624 similar fashion. Corresponding to the five equilibrium paths in Proposition 1, the equilibrium
625 profit functions are examined exhaustively as follows:

626 Case 1: $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, or $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$ and
627 $y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$. Due to symmetry of the game, only the first subcase,
628 $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, is examined. Given that \bar{C}_S satisfies
629 $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, and the other parameters \bar{C}_F , a , c_S , c_F
630 and b remain constant, S's profit function $\Pi_S^* = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (8b) - \bar{C}_S$ (See
631 Proposition 1) is quadratic and convex with respect to \bar{C}_S , and its axis of symmetry is
632 $\bar{C}_S = 4bc_S^2 / a^2 - c_S \bar{C}_F / c_F$. Furthermore, $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ implies that $\bar{C}_S \geq 8bc_S^2 / a^2$
633 $> 4bc_S^2 / a^2 - c_S \bar{C}_F / c_F$. Then any \bar{C}_S satisfying $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ is to the right of the
634 symmetry axis of Π_S^* . Thus Π_S^* increases in \bar{C}_S . From F's profit function given in
635 Proposition 1, $\Pi_F^* = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (16b) - \bar{C}_F$, it immediately follows that Π_F^* increases
636 in \bar{C}_S .

637 Case 2: $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$. From Proposition 1, S's
638 equilibrium profit function is $\Pi_S^* = a^2(\bar{C}_S / c_S)^2 / (8b) - \bar{C}_S$, and its axis of symmetry is $\bar{C}_S =$

639 $4bc_s^2/a^2$. Again, $y_F^\#(a,b,\bar{C}_S,c_S) \leq 0$ implies that $\bar{C}_S \geq 8bc_s^2/a > 4bc_s^2/a^2$, indicating that \bar{C}_S
640 satisfying $y_F^\#(a,b,\bar{C}_S,c_S) \leq 0$ is to the right of the symmetry axis $\bar{C}_S = 4bc_s^2/a^2$. Thus Π_S^*
641 increases in \bar{C}_S . In addition, $\Pi_F^* = a^2(\bar{C}_S/c_S)^2/(16b)$ is clearly increasing in \bar{C}_S .

642 Case 3: $y_S^\#(a,b,\bar{C}_F,c_F) \leq 0$ and $y_F^\#(a,b,\bar{C}_S,c_S) > \bar{C}_F/c_F$. Proposition 1 gives $\Pi_S^* =$
643 $a^2(\bar{C}_F/c_F)^2/(8b)$ and $\Pi_F^* = a^2(\bar{C}_F/c_F)^2/(16b) - \bar{C}_F$, which are independent of \bar{C}_S . Then they
644 are nondecreasing in \bar{C}_S .

645 Case 4: $0 < y_F^\#(a,b,\bar{C}_S,c_S) \leq \bar{C}_F/c_F$ and $0 < y_S^\#(a,b,\bar{C}_F,c_F) \leq \bar{C}_S/c_S$. There exist two
646 subgame perfect Nash equilibriums. For $\{(y_F^*, y_S^*) = (0,0) \rightarrow w^* = 0 \rightarrow q^* = 0\}$, $\Pi_S^* = 0$ and
647 $\Pi_F^* = 0$ are constant, and hence, nondecreasing in \bar{C}_S . For the other equilibrium (E), the profit
648 functions are the same as those given in Case 1. We show that Π_S^* increases in \bar{C}_S by
649 checking that \bar{C}_S satisfying $y_F^\#(a,b,\bar{C}_S,c_S) \leq \bar{C}_F/c_F$ is to the right of the symmetry axis of
650 Π_S^* . Indeed, $y_F^\#(a,b,\bar{C}_S,c_S) \leq \bar{C}_F/c_F$ implies that
651 $\bar{C}_S \geq 2(4bc_s^2/a^2 - c_S\bar{C}_F/c_F) > 4bc_s^2/a^2 - c_S\bar{C}_F/c_F$ if $4bc_s/a^2 - \bar{C}_F/c_F > 0$, and it naturally holds
652 that $\bar{C}_S > 0 \geq 4bc_s^2/a^2 - c_S\bar{C}_F/c_F$ whenever $4bc_s/a^2 - \bar{C}_F/c_F \leq 0$. The proof of Π_F^* 's increase in
653 \bar{C}_S is similar to that in Case 1.

654 Case 5: If $y_F^\#(a,b,\bar{C}_S,c_S) > 0$ and $y_S^\#(a,b,\bar{C}_F,c_F) > \bar{C}_S/c_S$, or $y_S^\#(a,b,\bar{C}_F,c_F) > 0$ and
655 $y_F^\#(a,b,\bar{C}_S,c_S) > \bar{C}_F/c_F$, $\Pi_S^* = 0$ and $\Pi_F^* = 0$, implying their nondecreasing in \bar{C}_S .

656 The aforesaid five cases indicate the nondecreasing property of the equilibrium profit
657 functions in \bar{C}_S when \bar{C}_S changes within the ranges specified by the corresponding
658 conditions. As $y_F^\#(a,b,\bar{C}_S,c_S) = 4bc_s/a^2 - \bar{C}_S/(2c_S)$ decreases in \bar{C}_S , when \bar{C}_S increases
659 from 0 to $+\infty$ with other parameters being fixed, a sufficiently small \bar{C}_S exists such as
660 $y_F^\#(a,b,\bar{C}_S,c_S) > 0$. For such a given \bar{C}_S , the conditions in Case 2 and the first scenario of
661 Case 1 do not hold. If the conditions in the second scenario of Case 1 are satisfied, the

662 equilibrium profit functions are always characterized by $\Pi_S^* = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (8b)$
663 $-\bar{C}_S$ and $\Pi_F^* = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (16b) - \bar{C}_F$, thereby the nondecreasing property of Π_S^*
664 and Π_F^* in \bar{C}_S is ascertained. For remaining cases, when \bar{C}_S increases from 0 to $+\infty$, the
665 equilibrium may “jump” following one of the four possible paths: Case 5 \rightarrow Case 4 \rightarrow Case 1
666 (if the initial \bar{C}_S is selected such that $y_S^\#(a, b, \bar{C}_F, c_F) > 0$ and $y_F^\#(a, b, \bar{C}_S, c_S) > \bar{C}_F / c_F$),
667 Case 4 \rightarrow Case 1 (if the initial \bar{C}_S is chosen such that $y_S^\#(a, b, \bar{C}_F, c_F) > 0$ and
668 $0 < y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$), Case 5 \rightarrow Case 2 \rightarrow Case 1 (if the initial \bar{C}_S satisfies
669 $y_F^\#(a, b, \bar{C}_S, c_S) > 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) > \bar{C}_S / c_S$), and Case 3 \rightarrow Case 1 (if the initial \bar{C}_S is
670 chosen such that $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$). Next, we shall prove that the nondecreasing property
671 remains valid at the threshold where the equilibrium jumps from one case to another along any
672 path.

673 Consider, for example, one equilibrium jump from Case 5 to Case 4. In this case, the
674 initial \bar{C}_S and other parameters \bar{C}_F , c_F , a , b , and c_S satisfy $y_S^\#(a, b, \bar{C}_F, c_F) > 0$ and
675 $y_F^\#(a, b, \bar{C}_S, c_S) > \bar{C}_F / c_F$.

676 As $y_F^\#$ decreases in \bar{C}_S , a sufficiently large \bar{C}_S will guarantee that $y_F^\# \leq \bar{C}_F / c_F$. Let

$$677 \quad \bar{C}_S^*(\bar{C}_F, c_S, c_F, a, b) = \min \{ \bar{C}_S \geq 0 : y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F \}$$

678 Then for any $\bar{C}_S < \bar{C}_S^*$, we have $y_F^\#(a, b, \bar{C}_S, c_S) > \bar{C}_F / c_F$. Lemma 1 implies that the
679 equilibrium is $(0, 0)$ for all $\bar{C}_S < \bar{C}_S^*$, and the corresponding profits are $\Pi_S^* = 0$ and $\Pi_F^* = 0$.

680 When $\bar{C}_S = \bar{C}_S^*$, Lemma 1 indicates that both $(0, 0)$ and $(\bar{C}_F / c_F, \bar{C}_S^* / c_S)$ are equilibriums.

681 For the first scenario, equilibrium profits are both zero for S and F. For the second scenario,

682 plugging \bar{C}_S^* into the profit functions in Proposition 1 yields

$$683 \quad \Pi_S^* \left(\frac{\bar{C}_F}{c_F}, \frac{\bar{C}_S^*}{c_S} \right) = \frac{a^2}{8b} \left(\frac{\bar{C}_F}{c_F} + \frac{\bar{C}_S^*}{c_S} \right)^2 - \bar{C}_S^* \geq \Pi_S^* \left(\frac{\bar{C}_F}{c_F}, 0 \right) = \frac{a^2}{8b} \left(\frac{\bar{C}_F}{c_F} \right)^2 > 0$$

684 and

$$\Pi_F^* \left(\frac{\bar{C}_F}{c_F}, \frac{\bar{C}_S^*}{c_S} \right) = \frac{a^2}{16b} \left(\frac{\bar{C}_F}{c_F} + \frac{\bar{C}_S^*}{c_S} \right)^2 - \bar{C}_F \geq \Pi_F^* \left(0, \frac{\bar{C}_S^*}{c_S} \right) = \frac{a^2}{16b} \left(\frac{\bar{C}_S^*}{c_S} \right)^2 > 0$$

This indicates that the equilibrium profit functions for S and F are nondecreasing after the jump at the threshold \bar{C}_S^* . In a similar fashion, one can verify that this nondecreasing property holds true for all of other possible equilibrium jumps. The proof of Proposition 2 is thus completed.

Appendix A.3. Proof of Proposition 3

Let

$$\begin{aligned} F_1(\bar{C}_S, \bar{C}_F, c_S, c_F, a, b) &\equiv \max \left\{ y_F^\#(a, b, \bar{C}_S, c_S), y_S^\#(a, b, \bar{C}_S, c_S) - \frac{\bar{C}_S}{c_S} \right\} \\ &= \max \left\{ \frac{4bc_S}{a^2} - \frac{\bar{C}_S}{2c_S}, \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F} - \frac{\bar{C}_S}{c_S} \right\} \\ F_2(\bar{C}_S, \bar{C}_F, c_S, c_F, a, b) &\equiv \max \left\{ y_F^\#(a, b, \bar{C}_S, c_S) - \frac{\bar{C}_F}{c_F}, y_S^\#(a, b, \bar{C}_F, c_F) \right\} \\ &= \max \left\{ \frac{4bc_S}{a^2} - \frac{\bar{C}_S}{2c_S} - \frac{\bar{C}_F}{c_F}, \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F} \right\} \end{aligned}$$

Given \bar{C}_F , c_S , c_F , a and b , it is trivial to verify that F_1 decreases in \bar{C}_S and F_2 decreases in \bar{C}_S for $4bc_S/a^2 - \bar{C}_S/(2c_S) - \bar{C}_F/c_F \geq 8bc_F/a^2 - \bar{C}_F/(2c_F)$ and achieves its maximum $4bc_S/a^2 - \bar{C}_F/c_F$ at $\bar{C}_S = 0$, otherwise, F_2 remains constant at $8bc_F/a^2 - \bar{C}_F/(2c_F)$. Moreover, both F_1 and F_2 are continuous in \bar{C}_S .

For F_1 , since $F_1(0) = \max\{4bc_S^2/a^2, 8bc_F/a^2 - \bar{C}_F/c_F\} > 0$ and $F_1(+\infty) = -\infty$, the continuity and monotonicity of F_1 implies that there exists a unique $\bar{C}_{S_1}^\#$ such that $F_1 \leq 0$ for any $\bar{C}_S \geq \bar{C}_{S_1}^\#$

For F_2 , If $8bc_F/a^2 - \bar{C}_F/(2c_F) > 0$, then $F_2 > 0$ for any $\bar{C}_S \geq 0$; if $8bc_F/a^2 - \bar{C}_F/(2c_F) \leq 0$ and $4bc_S/a^2 - \bar{C}_F/c_F \leq 0$, then $F_2 \leq 0$ for any $\bar{C}_S \geq 0$; if $8bc_F/a^2 - \bar{C}_F/(2c_F) \leq 0$ and $4bc_S/a^2 - \bar{C}_F/c_F > 0$, then there exists a unique $\bar{C}_{S_2}^\# \in [0, +\infty)$ such that $F_2 \leq 0$ for any $\bar{C}_S \geq \bar{C}_{S_2}^\#$ due to the monotonic decreasing property of F_2 .

705 Furthermore, given \bar{C}_F , c_S , c_F , a and b , let

$$\begin{aligned}
\bar{C}_S^\#(\bar{C}_F, c_S, c_F, a, b) &\equiv \min \left\{ \bar{C}_S \geq 0 : F_1(\bar{C}_S) \leq 0 \text{ or } F_2(\bar{C}_S) \leq 0 \right\} \\
&= \begin{cases} 0, & \text{if } \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \frac{4bc_S}{a^2} - \frac{\bar{C}_F}{c_F} \leq 0 \\ \min \{ \bar{C}_{S_1}^\#, \bar{C}_{S_2}^\# \}, & \text{if } \frac{8bc_F}{a^2} - \frac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \frac{4bc_S}{a^2} - \frac{\bar{C}_F}{c_F} > 0 \\ \bar{C}_{S_1}^\#, & \text{otherwise} \end{cases} \quad (8)
\end{aligned}$$

707 Finally, since $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$ are equivalent to $F_1 \leq 0$
708 and $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$ and $y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$ are equivalent to $F_2 \leq 0$, then $\bar{C}_S \geq \bar{C}_S^\#$
709 implies (E) is the unique equilibrium by Lemma 1. Part (i) of this proposition is thus proved.

710 Parts (ii) – (vi) can be verified in the similar fashion. Proposition 3 is then proved.

711 **Appendix A.4. Proof of Proposition 4**

712 The following proof confirms that $a_1 > a_2 \Rightarrow \bar{C}_S^\#(a_1) \leq \bar{C}_S^\#(a_2)$ and remaining parts can be
713 proved similarly. Given \bar{C}_F , c_S , c_F and b , assume that $a_1 > a_2$. As F_1 and F_2 decreases in
714 a , $F_i(\bar{C}_S, a_2) \leq 0$ implies $F_i(\bar{C}_S, a_1) \leq 0$ for any \bar{C}_S , $i = 1, 2$. Thus

$$715 \left\{ \bar{C}_S \geq 0 : F_1(\bar{C}_S, a_2) \leq 0 \text{ or } F_2(\bar{C}_S, a_2) \leq 0 \right\} \subseteq \left\{ \bar{C}_S \geq 0 : F_1(\bar{C}_S, a_1) \leq 0 \text{ or } F_2(\bar{C}_S, a_1) \leq 0 \right\}$$

716 By the definition of $\bar{C}_S^\#$ in (7) and the nonincreasing property of F_i in \bar{C}_S , we have
717 $\bar{C}_S^\#(a_1) \leq \bar{C}_S^\#(a_2)$. The proof of this proposition is thus completed.

718 **Appendix A.5. Proof of Proposition 5**

719 First, we prove that if $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ and $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$, (E1) arises as the
720 unique subgame perfect Nash equilibrium for the four-stage sequential-move game.
721 $y_F^\#(a, b, \bar{C}_S, c_S) \leq 0$ implies that S chooses $y_S^* = \bar{C}_S / c_S$ in stage 1 regardless of F's choice in
722 stage 2. Given S's decision $y_S^* = \bar{C}_S / c_S$ in stage 1, F will choose $y_F^* = \bar{C}_F / c_F$ in stage 2 due
723 to $y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$. Thus (E1) is the unique subgame perfect Nash equilibrium. Due to
724 the symmetry of the game, one can show that (E1) is the unique equilibrium if

725 $y_S^\#(a, b, \bar{C}_F, c_F) \leq 0$ and $y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$ in a similar way.

726 Next, we shall show that if $0 < y_F^\#(a, b, \bar{C}_S, c_S) \leq \bar{C}_F / c_F$ and $0 < y_S^\#(a, b, \bar{C}_F, c_F) \leq \bar{C}_S / c_S$,

727 (E1) is also the unique subgame perfect Nash equilibrium. These conditions imply that if S

728 chooses $y_S^* = 0$, F will respond with $y_F^* = 0$, and if S selects $y_S^* = \bar{C}_S / c_S$, F's optimal

729 response is $y_F^* = \bar{C}_F / c_F$. S's profit can be correspondingly given as $\Pi_{SD}^*(0) = \Pi_S^*(0, 0) = 0$ and

730 $\Pi_{SD}^*(\bar{C}_S / c_S) = \Pi_S^*(\bar{C}_F / c_F, \bar{C}_S / c_S) = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (8b) - \bar{C}_S > 0 = \Pi_{SD}^*(0)$ (see the proof

731 of Proposition 2). Therefore, S's optimal decision is $y_S^* = \bar{C}_S / c_S$ in stage 1, leading to the

732 unique equilibrium (E1). This completes the proof of Proposition 5.

733 **Appendix A.6. Proof of Proposition 6**

734 **Proof:** $d_S < a^2 / (4b)$ and $d_F < a^2 / (8b)$ imply that Π_S^* and Π_F^* are strictly convex in y_S

735 and y_F , respectively. Their symmetric axes are

$$736 \quad y_S = \frac{4bc_S - a^2 y_F}{a^2 - 4bd_S} \quad \text{and} \quad y_S = \frac{8bc_F - a^2 y_S}{a^2 - 8bd_F}$$

737 Following the same approaches in Section 2, it can be shown that S's and F's reaction

738 functions are

$$739 \quad y_S = f(y_F) \equiv \begin{cases} \frac{-c_S + \sqrt{c_S^2 + 2d_S \bar{C}_S}}{d_S}, & \text{if } y_F \geq \frac{4bc_S - (a^2 - 4bd_S)}{a^2} \times \frac{-c_S + \sqrt{c_S^2 + 2d_S \bar{C}_S}}{d_S} \\ 0, & \text{otherwise} \end{cases}$$

$$740 \quad y_F = g(y_S) \equiv \begin{cases} \frac{-c_F + \sqrt{c_F^2 + 2d_F \bar{C}_F}}{d_F}, & \text{if } y_S \geq \frac{8bc_F - (a^2 - 8bd_F)}{a^2} \times \frac{-c_F + \sqrt{c_F^2 + 2d_F \bar{C}_F}}{d_F} \\ 0, & \text{otherwise} \end{cases}$$

741 where $(-c_k + \sqrt{c_k^2 + 2d_k \bar{C}_k}) / d_k$ is the positive solution to $c_k y_k + d_k y_k^2 / 2 = \bar{C}_k$ ($k = S, F$), i.e.

742 firm k 's maximum (feasible) CSR performance under its own CSR budget.

743 Denote

$$744 \quad y_F^\#(a, b, \bar{C}_S, c_S) \equiv \frac{4bc_S - (a^2 - 4bd_S)}{a^2} \times \frac{-c_S + \sqrt{c_S^2 + 2d_S \bar{C}_S}}{d_S} \quad (12)$$

$$y_S^\#(a, b, \bar{C}_F, c_F) \equiv \frac{8bc_F - (a^2 - 8bd_F)}{a^2} \times \frac{-c_F + \sqrt{c_F^2 + 2d_F\bar{C}_F}}{d_F} \quad (13)$$

Finally, following the step-by-step proofs of Lemma 1 and Propositions 1-5, we can verify that Proposition 6 is true if (1) $y_F^\#(a, b, \bar{C}_S, c_S)$ and $y_S^\#(a, b, \bar{C}_F, c_F)$ therein are respectively replaced with (12) and (13), and (2) \bar{C}_k / c_k is replaced with $(-c_k + \sqrt{c_k^2 + 2d_k\bar{C}_k}) / d_k$ ($k = S, F$).

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