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Debing Ni

Kevin W. Li Dr.
University of Windsor

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Debing Ni[1, 2] and Kevin W. Li [2, 3*]

1 School of Management and Economics, University of Electronic Science and Technology of China, Chengdu, Sichuan, P. R. China, 610054

2 Odette School of Business, University of Windsor, Windsor, Ontario, Canada, N9B 3P4

3 Department of Value and Decision Science, Tokyo Institute of Technology, W9-38, 2-12-1 Ookayama, Meguro, Tokyo 152-8552, Japan

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[*] Correspondence author, phone: 1-519-253-3000 ext 3456, fax: 1-519-973-7073, e-mail: kwli@uwindsor.ca

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

2   **Chains**

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5   **Abstract**: This research investigates how two supply chain members, a downstream firm

6   (F) and an upstream supplier (S), interact with each other with respect to corporate social

7   responsibility (CSR) behaviour and what impact exogenous parameters may have on this

8   interaction. A game-theoretic analysis is conducted to obtain equilibriums for both

9   simultaneous-move and sequential-move CSR games. Under certain assumptions, it is

10   concluded that (1) there exists a mutual incentive between their CSR behaviour, whereby a

11   win-win performance in terms of both CSR and profitability is achieved as long as exogenous

12   parameters exceed certain critical thresholds; (2) A higher consumer marginal social-benefit

13   potential (MSBP) or a lower consumer marginal perception difficulty (MPD) helps to lower the

14   critical thresholds of CSR budgets and CSR operational efficiency by S and F, making it easier

15   to achieve the win-win performance; (3) An increase in one supply chain member's CSR

16   budget or CSR operational efficiency tends to make the supply chain easier to attain a win-win

17   performance scenario; (4) if CSR decisions are made sequentially, a prior commitment to CSR

18   activities from one supply chain member strengthens the mutual incentive and facilitates the

19   realization of the win-win performance. Business implications of these research findings are

20   also discussed.

21   **Keywords**: Supply chain management; corporate social responsibility; game theory; mutual

22   incentive; commitment

23

24   **1. Introduction**

25   With the continued trend of globalization, more and more firms have been taking advantage of

26   global supply chains to improve their competitive edge by lowering cost, accelerating product

27   development, and getting access to natural and human resources in the international arena

28   (Boyd et al. 2004). As firms enjoy the benefits, many leading global brands such as Nike, GAP,

29   Adidas, and McDonalds have been faced with intense pressure for socially responsible supply

30   chain management (Amaeshi et al. 2008). A commonly observed response to this pressure is

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

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

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

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

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

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

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

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[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.

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

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

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

287　In stage 2, in anticipation of F's reaction captured by (2), S chooses w to maximize[6]

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

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

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

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

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

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

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

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

296　are[7]

---

[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, $\left(q = 0, w = a(y_F + y_S)\right)$ 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.

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

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

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 $\overline{C}_F / c_F$ (0 or $\overline{C}_S / c_S$), 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    $y_S = \overline{C}_S / c_S$ if $4bc_S / a^2 - y_F \leq \overline{C}_S / (2c_S)$,   implying   that $\Pi_S^*(y_F, \overline{C}_S / c_S) \geq \Pi_S^*(y_F, 0)$.

305   Otherwise $y_S = 0$. To summarize, S's reaction function is

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

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

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

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

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

328   and $y_F^\#(a,b,\bar{C}_S,c_S) \le \bar{C}_F / c_F$, then $(y_F^*, y_S^*) = (\bar{C}_F / c_F, \bar{C}_S / c_S)$ is the unique Nash equilibrium.

329   (ii) if $y_F^\#(a,b,\bar{C}_S,c_S) \le 0$ 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 $y_S^\#(a,b,\bar{C}_F,c_F) \le 0$ 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 $0 < y_F^\#(a,b,\bar{C}_S,c_S) \le \bar{C}_F / c_F$ and $0 < y_S^\#(a,b,\bar{C}_F,c_F) \le \bar{C}_S / c_S$, 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 $y_F^\#(a,b,\bar{C}_S,c_S) \le 0$ and $y_S^\#(a,b,\bar{C}_F,c_F) \le \bar{C}_S / c_S$, or $y_S^\#(a,b,\bar{C}_F,c_F) \le 0$

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

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

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

347     $\left\{ (y_F^*, y_S^*) = (0, \bar{C}_S / c_S) \rightarrow w^* = a\bar{C}_S / (2c_S) \rightarrow q^* = a\bar{C}_S / (4bc_S) \right\} \quad$, 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 $\quad y_S^\#(a,b,\bar{C}_F,c_F) \leq 0 \quad$ and $\quad y_F^\#(a,b,\bar{C}_S,c_S) > \bar{C}_F / c_F \quad$, the equilibrium path is

350     $\left\{ (y_F^*, y_S^*) = (\bar{C}_F / c_F, 0) \rightarrow w^* = a\bar{C}_F / (2c_F) \rightarrow q^* = a\bar{C}_F / (4bc_F) \right\} \quad$, 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 $\quad 0 < y_F^\#(a,b,\bar{C}_S,c_S) \leq \bar{C}_F / c_F \quad$ and $\quad 0 < y_S^\#(a,b,\bar{C}_F,c_F) \leq \bar{C}_S / c_S$, 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 $\quad \Pi_F^*(y_F^*, y_S^*) = a^2(\bar{C}_F / c_F + \bar{C}_S / c_S)^2 / (16b) - \bar{C}_F \quad$ and $\quad \Pi_S^*(y_F^*, y_S^*) =$

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

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

434
$$= \begin{cases} 0, & \text{if } \dfrac{8bc_F}{a^2} - \dfrac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \dfrac{4bc_S}{a^2} - \dfrac{\bar{C}_F}{c_F} \leq 0 \\[2ex] \min\left\{\bar{C}_{S_1}^{\#}, \bar{C}_{S_2}^{\#}\right\}, & \text{if } \dfrac{8bc_F}{a^2} - \dfrac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \dfrac{4bc_S}{a^2} - \dfrac{\bar{C}_F}{c_F} > 0 \\[2ex] \bar{C}_{S_1}^{\#}, & \text{otherwise} \end{cases} \qquad (8)$$

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

436
$$\bar{C}_F^{\#}(\bar{C}_S, c_S, c_F, a, b) = \min\left\{\bar{C}_F \geq 0 : F_1(\bar{C}_F) \leq 0 \text{ or } F_2(\bar{C}_F) \leq 0\right\} \qquad (9)$$

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

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

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 $\overline{C}_S^{\#}(a_1) \leq \overline{C}_S^{\#}(a_2)$, $\overline{C}_F^{\#}(a_1) \leq \overline{C}_F^{\#}(a_2)$,

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 $\overline{C}_S^{\#}(b_1) \geq \overline{C}_S^{\#}(b_2)$, $\overline{C}_F^{\#}(b_1) \geq \overline{C}_F^{\#}(b_2)$,

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

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

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

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

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

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

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

450   (vi) let c_S be the only variable, if $c_S^1 \geq c_S^2$, then $\overline{C}_S^{\#}(c_S^1) \geq \overline{C}_S^{\#}(c_S^2)$, $\overline{C}_F^{\#}(c_S^1) \geq \overline{C}_F^{\#}(c_S^2)$ 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 $\overline{C}_S^{\#}$ and $\overline{C}_F^{\#}$) 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
$$\Pi_{SD}^*(y_S) = \begin{cases} \dfrac{a^2(\bar{C}_F / c_F + y_S)^2}{8b} - c_S y_S, & \text{if } y_S \geq y_S^\# \\ \dfrac{a^2 y_S^2}{8b} - c_S y_S, & \text{otherwise} \end{cases}$$

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,

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

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

514   satisfied:

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

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

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

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, $y_S^* = \overline{C}_S / c_S$ or $y_F^* = \overline{C}_F / c_F$, 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.

4. Discussions

In this section, the constant marginal CSR cost assumption in Section 2 is relaxed to allow for a quadratic term in the CSR cost function. Assume that the CSR cost function for F and S are $c_F y_F + d_F y_F^2 / 2$ 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, the profit functions of S and F in the first stage are

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

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

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

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

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

5. Concluding Remarks

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

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[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**

Appendix A.1. Proof of Lemma 1

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

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

(iv) $0 < y_F^{\#}(a,b,\overline{C}_S,c_S) \le \overline{C}_F/c_F$ and $0 < y_S^{\#}(a,b,\overline{C}_F,c_F) \le \overline{C}_S/c_S$ imply that $[0, y_F^{\#}) \ne \Phi$, $[y_F^{\#}, \overline{C}_F/c_F] \ne \Phi$, $[0, y_S^{\#}) \ne \Phi$ and $[y_S^{\#}, \overline{C}_S/c_S] \ne \Phi$. Then the reaction curves intersect twice at $(0,0)$ and $(\overline{C}_F/c_F, \overline{C}_S/c_S)$, resulting in the two Nash equilibriums. (iv) is thus 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.

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: $y_F^\#(a,b,\bar{C}_S,c_S)\le 0$ and $y_S^\#(a,b,\bar{C}_F,c_F)\le\bar{C}_S/c_S$, or $y_S^\#(a,b,\bar{C}_F,c_F)\le 0$ and

627    $y_F^\#(a,b,\bar{C}_S,c_S)\le\bar{C}_F/c_F$. Due to symmetry of the game, only the first subcase,

628    $y_F^\#(a,b,\bar{C}_S,c_S)\le 0$ and $y_S^\#(a,b,\bar{C}_F,c_F)\le\bar{C}_S/c_S$, is examined. Given that $\bar{C}_S$ satisfies

629    $y_F^\#(a,b,\bar{C}_S,c_S)\le 0$ and $y_S^\#(a,b,\bar{C}_F,c_F)\le\bar{C}_S/c_S$, 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, $y_F^\#(a,b,\bar{C}_S,c_S)\le 0$ implies that $\bar{C}_S\ge 8bc_S^2/a^2$

633    $>4bc_S^2/a^2-c_S\bar{C}_F/c_F$. Then any $\bar{C}_S$ satisfying $y_F^\#(a,b,\bar{C}_S,c_S)\le 0$ 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: $y_F^\#(a,b,\bar{C}_S,c_S)\le 0$ 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 $\{(y_F^*,y_S^*)=(0,0)\to w^*=0\to q^*=0\}$, $\Pi_S^*=0$ and

647 $\Pi_F^*=0$ are constant, and hence, nondecresing 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 nondecresing 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 → Case 4 → 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 → 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 → Case 2 → 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 → 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 $$\bar{C}_S^*(\bar{C}_F, c_S, c_F, a, b) = \min\left\{\bar{C}_S \geq 0 : y_F^{\#}(a,b,\bar{C}_S,c_S) \leq \bar{C}_F / c_F\right\}$$

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

684 and

685

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

686   This indicates that the equilibrium profit functions for S and F are nondecreasing after the

687   jump at the threshold $\overline{C}_S^*$. In a similar fashion, one can verify that this nondecreasing property

688   holds true for all of other possible equilibrium jumps. The proof of Proposition 2 is thus

689   completed.

690   **Appendix A.3. Proof of Proposition 3**

691   Let

692
$$F_1(\overline{C}_S,\overline{C}_F,c_S,c_F,a,b)\equiv\max\left\{y_F^{\#}(a,b,\overline{C}_S,c_S),y_S^{\#}(a,b,\overline{C}_S,c_S)-\frac{\overline{C}_S}{c_S}\right\}$$

$$=\max\left\{\frac{4bc_S}{a^2}-\frac{\overline{C}_S}{2c_S},\frac{8bc_F}{a^2}-\frac{\overline{C}_F}{2c_F}-\frac{\overline{C}_S}{c_S}\right\}$$

693
$$F_2(\overline{C}_S,\overline{C}_F,c_S,c_F,a,b)\equiv\max\left\{y_F^{\#}(a,b,\overline{C}_S,c_S)-\frac{\overline{C}_F}{c_F},y_S^{\#}(a,b,\overline{C}_F,c_F)\right\}$$

$$=\max\left\{\frac{4bc_S}{a^2}-\frac{\overline{C}_S}{2c_S}-\frac{\overline{C}_F}{c_F},\frac{8bc_F}{a^2}-\frac{\overline{C}_F}{2c_F}\right\}$$

694   Given $\overline{C}_F$, c_S, c_F, a and b, it is trivial to verify that F_1 decreases in $\overline{C}_S$ and F_2

695   decreases in $\overline{C}_S$ for $4bc_S/a^2-\overline{C}_S/(2c_S)-\overline{C}_F/c_F\geq8bc_F/a^2-\overline{C}_F/(2c_F)$ and achieves its

696   maximum $4bc_S/a^2-\overline{C}_F/c_F$ at $\overline{C}_S=0$, otherwise, F_2 remains constant at

697    $8bc_F/a^2-\overline{C}_F/(2c_F)$. Moreover, both F_1 and F_2 are continuous in $\overline{C}_S$.

698   For F_1, since $F_1(0)=\max\{4bc_S^2/a^2,8bc_F/a^2-\overline{C}_F/c_F\}>0$ and $F_1(+\infty)=-\infty$, the continuity

699   and monotonicity of F_1 implies that there exists a unique $\overline{C}_{S_1}^{\#}$ such that $F_1\leq0$ for any

700    $\overline{C}_S\geq\overline{C}_{S_1}^{\#}$

701   For F_2, If $8bc_F/a^2-\overline{C}_F/(2c_F)>0$, then $F_2>0$ for any $\overline{C}_S\geq0$; if

702    $8bc_F/a^2-\overline{C}_F/(2c_F)\leq0$ and $4bc_S/a^2-\overline{C}_F/c_F\leq0$, then $F_2\leq0$ for any $\overline{C}_S\geq0$; if

703    $8bc_F/a^2-\overline{C}_F/(2c_F)\leq0$ and $4bc_S/a^2-\overline{C}_F/c_F>0$, then there exists a unique $\overline{C}_{S_2}^{\#}\in[0,+\infty)$

704   such that $F_2\leq0$ for any $\overline{C}_S\geq\overline{C}_{S_2}^{\#}$ due to the monotonic decreasing property of F_2.

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

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

706
$$= \begin{cases} 0, \text{ if } \dfrac{8bc_F}{a^2} - \dfrac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \dfrac{4bc_S}{a^2} - \dfrac{\bar{C}_F}{c_F} \leq 0 \\[2ex] \min\left\{\bar{C}_{S_1}^{\#}, \bar{C}_{S_2}^{\#}\right\}, \text{ if } \dfrac{8bc_F}{a^2} - \dfrac{\bar{C}_F}{2c_F} \leq 0 \text{ and } \dfrac{4bc_S}{a^2} - \dfrac{\bar{C}_F}{c_F} > 0 \\[2ex] \bar{C}_{S_1}^{\#}, \text{ otherwise} \end{cases} \tag{8}$$

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

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

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 $y_S^* = \overline{C}_S / c_S$, F's optimal

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

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

731 of Proposition 2). Therefore, S's optimal decision is $y_S^* = \overline{C}_S / c_S$ 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
$$y_S = \frac{4bc_S - a^2 y_F}{a^2 - 4bd_S} \quad \text{and} \quad y_S = \frac{8bc_F - a^2 y_S}{a^2 - 8bd_F}$$

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

738 functions are

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

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

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

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

743 Denote

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

745
$$y_S^\#(a, b, \overline{C}_F, c_F) \equiv \frac{8bc_F - (a^2 - 8bd_F)}{a^2} \times \frac{-c_F + \sqrt{c_F^2 + 2d_F\overline{C}_F}}{d_F} \tag{13}$$

746   Finally, following the step-by-step proofs of Lemma 1 and Propositions 1-5, we can verify

747   that Proposition 6 is true if (1) $y_F^\#(a, b, \overline{C}_S, c_S)$ and $y_S^\#(a, b, \overline{C}_F, c_F)$ therein are respectively

748   replaced with (12) and (13), and (2) $\overline{C}_k / c_k$ is replaced with $\left(-c_k + \sqrt{c_k^2 + 2d_k\overline{C}_k}\right)/d_k$ ($k = S, F$).

749

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