2015

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Int. J. Production Economics 161 (2015) 17–30

Contents lists available at ScienceDirect

Int. J. Production Economics

journal homepage: www.elsevier.com/locate/ijpe

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ARTICLE INFO

Article history:
Received 5 June 2014
Accepted 1 November 2014
Available online 13 November 2014

Keywords:
Supply chain
Sustainability
Reputation

ABSTRACT

This paper explores the question of whether ethical sourcing and disclosure of supply chain sources is linked to competitiveness. We model competition between two firms, both of which produce the same consumer good. One sources ethically and the second does not, and market share is affected by the nature of their sources and whether or not they disclose them. Costs include procurement and disclosure. We investigate the tradeoffs involved and the incentives for a firm to disclose the nature of its sourcing in response to its cost and market structure, as well as the characteristics of its competitors. We find that a firm's decision to disclose its sources should depend not only on its cost of disclosure, but also on the actions of its competitor and the effect that its actions will have on its own market share.

1. Introduction

The "triple bottom line" adds social and environmental concerns to the traditional profit objective of a firm. One issue is what effect actions taken in response to social and environmental issues have on profit. Will customers value the firm's humanitarian responsiveness, and might a resulting increase in market share offset costs, and provide an incentive for a firm to act ethically? This paper explores that question, in the context of ethical sourcing and disclosure.

Section 1502 of the Dodd-Frank Wall Street Reform and Consumer Protection Act (2010) requires publicly traded U.S. companies to disclose the source of the so-called conflict minerals. These include tantalum, tin, tungsten and gold that come from the Democratic Republic of Congo, the profits of which are used to fund violent military groups (Chasan, 2012; Harbert, 2010; Schuh and Strohmer, 2012). Proponents claim that this law has already had a positive effect, since trading of three of these minerals from unethical sources was curtailed even before the measure was implemented (Bradshaw, 2011; Davidoff, 2014). Some business organizations, on the other hand, have sued the S.E.C. in federal court, claiming that this regulation places a burden (in terms of costs of disclosure) on companies in the United States (Mont, 2012; DiPietro, 2014a), but a federal appeals court upheld the requirement for companies to file such reports (Ackerman, 2014). The European Union has also adopted a directive that mandates disclosure of "policies, risks and outcomes, as regards environmental matters …[and] respect for human rights" (European Commission, 2014), and emphasizes the role of public authorities in such disclosure activities (European Parliament, 2013).

Studies of companies like Nike and Levi-Strauss, who at first resisted and then complied with demands to make public the details of their supply chains, indicate that there are costs and benefits to such disclosure (Doorey, 2011). In response to a potential shareholder resolution, Exxon recently agreed to disclose how regulation might affect its operational costs, and how it uses that information in its strategic planning (Gilbert, 2014). The Fair Labor Association (2014) collects and disseminates information about companies and nonprofit organizations that disclose the production conditions of their suppliers.

Both Apple and Intel have been working with suppliers to verify that their sources of tantalum and other conflict minerals are not funding armed groups; Intel has gone so far as to pledge that all of its products in 2014 will be "conflict-free" (Wakabayashi, 2014), was the first to file the disclosure report (Clark, 2014), and has publicized its efforts to certify suppliers (King, 2014). Apple has begun publishing a list of suppliers, half of which are already in compliance (Chasan and Schectman, 2014). Motorola and HP have also developed audit programs, which have been joined by Philips, Sony and Panasonic, among other major manufacturers of electronics (Lezhnev and Hellmuth, 2012). Several large firms in the apparel sector have worked together to develop sustainability indices, and collect data (O'Rourke, 2014). So there are countervailing forces at work on companies that need to use these materials in production: on the one hand, public opinion provides pressure to source ethically *and* disclose their sources; on the other hand, this comes at a cost.

The tradeoff between cost and reputation is integral to the disclosure decision. For one thing, companies have found that

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http://dx.doi.org/10.1016/j.ijpe.2014.11.001
0925-5273/

costs of disclosure (which include audits) may be substantial (Meleske, 2011; Goodman, 2012), and benefits are largely related to reputation (Zweig, 2011; Ayogu and Lewis, 2011; Holzer, 2012; Hwang, 2013; Hochfelder, 2014). Consumer activism is a growing force, particularly as it translates into demand (Lezhnev and Hellmuth, 2012), and companies that are known for non-sustainable activities (greenhouse gas emissions, deforestation, etc.) suffer in reputation and future business (Bellman, 2012). There is evidence that customers are interested in the ethics of the entire supply chain, and technological innovations (such as RFID tags and codes that are readable by smart phones) are being developed to convey this information (New, 2010). In the auto industry, manufacturers have found that a company's reputation with regard to sustainability has a direct effect on sales (DiPietro, 2014b). A significant proportion of buyers indicated that they would cease business with suppliers who did not meet their criteria for carbon management (Anonymous, 2010). Companies such as Honda and General Electric measured an increase in their brand value as a result of improvements in supply chain sustainability (Pearson, 2013). Several companies, including Puma footwear and the Walt Disney Company, have translated information about environmental and social impacts into cost-benefit analysis (O'Rourke, 2014). So ethical sourcing is one important element that contributes to a firm's reputation for ethical behavior.

Examples from the apparel industry show that firms such as Nike were threatened with the loss of their sales to large customers such as universities over issues of ethical sourcing (Doorey, 2011). Moreover, "Some companies saw a marketing opportunity in this transparency, and began to advertise their new transparency as evidence of their commitment to respectable labor practices. Factory disclosure had begun a slow ascent as a new badge of honor within the apparel industry. Corporations were taking possession of the idea and were using it as evidence that they 'had nothing to hide' from the public" (Doorey, 2011). A recent example of the implementation of this idea is the new clothing retailer Zady, whose strategy is based on the belief that customers will pay more for highquality, ethically produced clothing. Everlane is another new apparel company that believes that its customers value a sustainable supply chain and transparency about sourcing (Tozzi, 2014; Holmes, 2014). The Swedish apparel chain H&M discloses its sources, including sub-suppliers, on its website (H&M, 2014). Zara, the Spanish company that invented "fast fashion", responded to public pressure by committing to eliminate pollution from hazardous wastes in its supply chain around the world, including sources in China (Greenpeace, 2012), and the Japanese clothing company Uniqlo made a similar commitment (Greenpeace, 2013).

An example from the electronics industry is the Dutch company Fairphone, which claims to be "the world's first smartphone" (Winter, 2013). Because of the complexity of cellphone production and sourcing, this company has succeeded in ethically sourcing only tin and tantalum, as well as working with the production facility to make sure that workers receive fair wages and decent working conditions. While Fairphone will only supply a small fraction of the world's smartphones, they hope to "change the industry from within and make supply chains more transparent, so other companies can more easily identify and use minerals" (Winter, 2013). The Chinese electronics manufacturer Lenovo has acknowledged concerns about the sourcing of conflict minerals, and pledged to comply with disclosure requirements wherever they do business (Lenovo Group, 2014). It has been suggested that multi-national corporations should collaborate to induce their common suppliers to achieve sustainability (Plambeck et al., 2012), and some smaller manufacturing firms hope that a resulting verification system will ease their own disclosure costs (Zweig, 2011). In the food industry, a California law about supply chain disclosure with regard to slavery has motivated Safeway to disclose its supplier requirements, as well as the results of inspections, and has taken the lead in its industry (Garry, 2013).

In this paper, we investigate the effect of the tradeoff between disclosure costs and market share on the disclosure decisions of manufacturers. We consider two firms with different sourcing practices, both of which incur costs of procurement and disclosure (such as increased number of audits). Market share is a function of reputation and response to public discovery of unethical sourcing. We find that a firm's decision to disclose its sources should depend not only on its cost of disclosure, but also on the actions of its competitor and the effect that its actions will have on its own market share. We glean further managerial insights by characterizing the environments in which firms will disclose (or not), in response to:

- Costs of disclosure
- Market response to disclosure,
- Initial market share,
- Probability of discovery,
- Contribution margin.

The remainder of this paper is organized as follows. Section 2 reviews related research. We develop our model in Section 3 and analyze it in Section 4. Section 5 discusses the results and presents our conclusions, and suggestions for future work on this topic.

2. Related work

This paper is related to previous research on sustainability and social responsibility in supply chain management. The literature on corporate social responsibility (CSR) is extensive, and spans several disciplines. For a discussion of research on that topic, and its application to supply chain management, see Andersen and Skjoett-Larsen (2009). See Guo et al. (2013) and Hsueh (2014) for a review of supply chain sourcing and social responsibility. Gimenez and Tachizawa (2012) survey the empirical literature on extending sustainability to suppliers, with a focus on governance structures. Marti and Seifert (2013) review the research on environmental supply chain strategies, including ISO 14001, multiple environmental practices and performance reporting. Belavina and Girotra (2014) provide a literature review of relational sourcing and CSR, and Jira and Toffel (2014) discuss related research on organizational standards, information sharing in the supply chain, and corporate environmental disclosure. O'Rourke (2014) discusses technological advances in tracking supply chain sustainability, and provides numerous examples of how companies and industrial coalitions are developing tools to gather and analyze data on this topic.

Sustainability in the supply chain has recently been studied using empirical as well as modeling approaches. Castka and Balzarova (2008) develop a set of propositions to be used in the investigation of the diffusion of social responsibility standards such as ISO 26000. de Brito et al. (2008) report on a study of sustainability issues in the fashion industry; they find that stakeholders are concerned about the tradeoffs between sustainable practices and economic growth of the firm. Gallear et al. (2012) explore the relationship between CSR and supply chain practices and performance, and suggest that suppliers demonstrate a willingness to be audited and monitored. A revenue-sharing contract that includes CSR is proposed by Hsueh (2014); a mathematical model demonstrates that such a contract can improve corporate responsibility, while it improves profits and benefits across the supply chain. Ni and Li (2012) use game theory to model the interaction between a buyer and supplier with regard to CSR, and describe conditions under which both profitability and CSR may be improved. Below we discuss only those papers that pertain directly to the disclosure of supply chain information in the context of CSR.

Requirements for disclosure are found to drive behavior change in two ways: by measuring environmental impacts, firms become aware of opportunities for change; and by providing data, benchmarking across firms is facilitated (Topping, 2012). In an empirical study of supply chain structure and socially responsible practices, Awaysheh and Klassen (2010) found that transparency about supply chain practices drove adoption of socially responsible behavior among suppliers; the suggestion is that highly visible brands need to sustain their reputation, and can influence the actions of their suppliers. An empirical study by Pedersen and Gwozdz (2013) suggests that firms are sensitive to institutional pressures from their stakeholders.

A study of the impact of announcements of programs to enhance supply chain sustainability found that, though stock prices may be adversely affected by such disclosures, firms may be motivated to make such announcements in order to benefit from positive customer perceptions (Dam and Petkova, 2014). Marti and Seifert (2013) analyze corporate sustainability reports, and find that regulations as well as consumer pressure may motivate firms in industries such as electronics to strive for, and publicize, sustainability in their supply chains. Another investigation of sustainability disclosure initiatives as revealed in company reports suggests that business-to-consumer firms are more likely to make such disclosures than are business-to-business firms (Okongwu et al., 2013). These findings reinforce the importance of the disclosure of sustainability to build and maintain a firm's reputation.

Guo et al. (2013) consider the effect of supply chain structure on a manufacturer's sourcing decisions. They find that responsible sourcing is related to increased downstream competition, sharing of suppliers, and inflexibility of the supply chain. Their results link profit maximization to social responsibility, which they call an "integrative approach." Belavina and Girotra (2014) examine the way in which supply chain structure (in this case, two types of networks) is related to relational sourcing for different product categories; they develop aggregate metrics, and demonstrate the effect on socially responsible behavior.

Kim (2013) draws on reliability theory and law enforcement economics to investigate the relationship between inspection and disclosure of environmental performance. Violations are modeled as a Markov chain, and the actions of the firm and regulator as a two-stage Stackelberg game. Costs include the (societal) cost of pollution, a fixed cost of inspection, and a penalty for noncompliance. If the firm discloses noncompliance, it can avoid the penalty. The intensity of inspection and the amount of the penalty are complements, rather than substitutes, when the firm is opportunistic in disclosing violations. Policy implications include the insight that larger firms can be controlled with relatively higher penalties and random inspection, while smaller firms should be inspected periodically.

Plambeck and Taylor (2014) analyze the conditions under which a buyer can motivate a supplier to comply with responsible manufacturing practices, if the supplier has the option to hide violations. They include costs of auditing, costs of hiding, and cost of reputation ("brand damage") if a violation occurs. They find that increasing auditing efforts may backfire, and result in increased efforts on the supplier's part to hide noncompliance through deceit or bribery. Increasing financial incentives to pass the audit may also result in lower compliance, which differs from previous models (without hiding) where financial incentives do lead to compliance (Guo et al., 2013; Kim, 2013).

Jira and Toffel (2014) focus on the propensity of suppliers to disclose climate change information to their buyers, in the context of the Carbon Disclosure Project. The tradeoff here is between the investment in information collection and analysis, and the potential improvement of competitive advantage. They find that suppliers are more willing to share such information when they receive more requests from buyers, when buyers are committed to utilizing it for procurement in the future, and also when suppliers are relatively more profitable, and are subject to greenhouse-gas emissions regulations. They note that these results also apply to public disclosures.

Our model contributes to this research stream by analyzing the incentives for a firm to disclose the nature of its sourcing (sustainable or not), when there are tradeoffs between the costs of disclosure and the benefits of a reputation for sustainable sourcing, namely, a positive market response, or conversely, damage control by a firm that discloses its sourcing practices in an attempt to retain market share. Our model includes a market response to ethical behavior, as well as disclosure. To the best of our knowledge, this is the first study of supply chain ethics and public disclosure of sourcing in a competitive setting.

3. The model

Consider a differentiated duopoly, namely, two competing firms, both of which produce the same consumer good. When incorporating competition, many studies assume a duopolistic environment to investigate the effects of interaction between heterogeneous firms; for example, see Tang (2010), Zhen (2012), Ye and Mukhopadhyay (2013), Jena and Sarmah (2014). Firm E (the *E*thical firm which does not buy from unethical suppliers) has market share $m \in [0,1]$ and Firm U (the *U*nethical firm which may use unethical suppliers), has market share $(1-m)$. The total market is normalized to one as in Guo et al. (2013). Each firm incurs a per-unit cost of procurement (c_i, $i=\{E,U\}$) and (optional) cost of disclosure (d_i), and sells the product at price p_i (where $p_i - c_i > 0$). The market share of each is affected by whether the firms source ethically, by whether or not they disclose their sources, and by the public discovery (with probability θ) of undisclosed unethical sourcing. We use δ to represent the proportion of market share that switches from the unethical to the ethical firm, based on customer response to unethical sourcing and/or disclosure. We recognize that ethical sourcing is only one component of a firm's reputation. However, as the examples cited in Section 1 demonstrate, companies recognize that this component alone may have a significant effect on market share. For purposes of exposition, we use "ethical" and "unethical" to refer to the sourcing decision.

We use the following notation (Eqs. (1)–(8)) to denote the profit functions of the two firms. For example, π_E^{DN} in (1) denotes the profit realized by the *E*thical firm, when it *D*iscloses but its *U*nethical rival does *N*ot. In this case, firm E's contribution margin is $(p_E - c_E - d_E)$; thus its expected profit is that margin times firm E's expected share of the market. If firm E discloses, but firm U does not, then firm E's market share will be m if U's unethical sourcing is *not* discovered, and the probability of that event is $1-\theta$. If firm U's unethical sourcing *is* discovered, and θ is the probability of that happening, then firm E's market share will be $m+(1-m)\delta_{DN}$. Thus, the expected value of firm E's market share is $m(1-\theta)+[m+(1-m)\delta_{DN}]\theta = m+(1-m)\delta_{DN}\theta$. Eqs. (2)–(8) are derived in an analogous manner:

$$\pi_E^{DN} = [m+(1-m)\delta_{DN}\theta](p_E - c_E - d_E) \tag{1}$$

$$\pi_U^{DN} = [(1-m)(1-\delta_{DN})\theta + (1-m)(1-\theta)](p_U - c_U) \tag{2}$$

Table 1
The disclosing game.

		Firm U	
		Disclose	Not disclose
Firm E	Disclose	π_E^{DD}, π_U^{DD}	π_E^{DN}, π_U^{DN}
	Not disclose	π_E^{ND}, π_U^{ND}	π_E^{NN}, π_U^{NN}

$$\pi_E^{DD} = [m+(1-m)\delta_{DD}](p_E - c_E - d_E) \tag{3}$$

$$\pi_U^{DD} = (1-m)(1-\delta_{DD})(p_U - c_U - d_U) \tag{4}$$

$$\pi_E^{NN} = [m+(1-m)\delta_{NN}\theta](p_E - c_E) \tag{5}$$

$$\pi_U^{NN} = [(1-m)(1-\delta_{NN})\theta + (1-m)(1-\theta)](p_U - c_U) \tag{6}$$

$$\pi_E^{ND} = [m+(1-m)\delta_{ND}](p_E - c_E) \tag{7}$$

$$\pi_U^{ND} = (1-m)(1-\delta_{ND})(p_U - c_U - d_U) \tag{8}$$

The strategy space and consequent expected profits of the game between the two firms are summarized in Table 1.

4. Analysis

The Nash equilibria of the disclosing game under normal-form representation can be characterized by evaluating each firm's best response to the other firm's strategy. For ease of presentation, we define the following threshold values for disclosure costs:

$$d_E^I = \frac{\delta_{DD} - \delta_{ND}}{\delta_{DD} + \dfrac{m}{1-m}}(p_E - c_E) \tag{9}$$

$$d_E^{II} = \frac{\theta\delta_{DN} - \theta\delta_{NN}}{\theta\delta_{DN} + \dfrac{m}{1-m}}(p_E - c_E) \tag{10}$$

$$d_U^I = \frac{\theta\delta_{DN} - \delta_{DD}}{1-\delta_{DD}}(p_U - c_U) \tag{11}$$

$$d_U^{II} = \frac{\theta\delta_{NN} - \delta_{ND}}{1-\delta_{ND}}(p_U - c_U) \tag{12}$$

Each of the above expressions specifies a threshold value of d_i, below which firm E (firm U) chooses to disclose given firm U's (firm E's) strategy. Using the profit functions (1)–(8), it is straightforward to show that $\pi_E^{DD} > \pi_E^{ND}$ if and only if (iff) $d_E < d_E^I$, and so if firm U discloses, firm E will disclose when its disclosure cost is sufficiently low. On the other hand, if firm U does not disclose its sourcing, firm E will disclose iff $d_E < d_E^{II}$ (derived from $\pi_E^{DN} > \pi_E^{NN}$). Similarly, if firm E discloses, then firm U will disclose iff $d_U < d_U^I$ (derived from $\pi_U^{DD} > \pi_U^{DN}$), and if firm E does not disclose, firm U will disclose iff $d_U < d_U^{II}$ (derived from $\pi_U^{ND} > \pi_U^{NN}$).

We assume some structural properties of the changes in market share (δ_{jk}) to glean further insights. The following lemma makes explicit the relationships among these changes, and relates them to the thresholds for disclosure cost.

Lemma 1. *When the following two conditions hold:*

(i) $\delta_{DD} - \delta_{ND} = \delta_{DN} - \delta_{NN} \equiv \Delta_E > 0$, *and*
(ii) $\delta_{DN} - \delta_{DD} = \delta_{NN} - \delta_{ND} \equiv \Delta_U > 0$

then $d_E^{II} < d_E^I$, *and* $d_U^I < d_U^{II}$ *iff* (iii) $\theta < 1/(1+\Delta_U) \equiv \overline{\theta}$.

All proofs can be found in the Appendix.

Intuitively, Lemma 1 provides a ranking of the threshold values for the cost of disclosure. The threshold cost for firm E to disclose is higher when firm U discloses, than when it does not (i.e., $d_E^{II} < d_E^I$). So firm E is willing to pay more to disclose, if its rival does so. This reflects the reality that an ethical firm (which has nothing to hide) will incur higher costs of disclosure, in order to maintain, and even gain, market share from its competitor. Historical examples include the trend among leaders in the electronics industry to prove that their sourcing is ethical (Lezhnev and Hellmuth, 2012), and similar events in the apparel industry (Doorey, 2011; Tozzi, 2014).

When the probability of discovery is below a certain value ($\theta < \overline{\theta}$), the threshold cost for firm U to disclose is lower when firm E discloses, than when it does not (i.e., $d_U^I < d_U^{II}$). So when the probability of discovery is relatively low, the unethical firm may be willing to risk not disclosing, valuing its cost of disclosure more than the market share that it may lose to its competitor.

However, this is reversed when the probability of discovery is relatively high ($\theta > \overline{\theta}$). When its unethical sourcing is more likely to be be found out (i.e., θ is larger), the threshold cost for firm U to disclose is higher, when firm E *does* disclose, than when it does not (i.e., $d_U^I > d_U^{II}$). This is because if firm U chooses not to disclose, its expected loss of market share is much greater when firm E does disclose, than when it does not ($\theta\delta_{DN} \geqslant \theta\delta_{NN}$).

The assumptions in Lemma 1 are based on the following rationale:

(i) Firm E gains more market share by disclosing than by not disclosing, whether or not firm U discloses ($\delta_{Dk} \geq \delta_{Nk}$, $k = \{D, N\}$), and in both cases, the gain is the same. This reflects the goodwill from consumers, directed toward a company that "comes clean."
(ii) Firm U loses more market share by not disclosing, whether or not firm E discloses ($\delta_{jN} \geq \delta_{jD}$, $j = \{D, N\}$), and in both cases, the loss is the same. This reflects the suspicion of customers, directed toward a company that seems to be hiding something.
(iii) The probability threshold ($\overline{\theta} = 1/(1+\Delta_U)$) is inversely related to firm U's loss by not disclosing (Δ_U). As the potential loss increases, the probability threshold decreases. So a lower risk of discovery is offset by a larger loss (and conversely, a smaller loss comes with a higher probability of discovery). The two possible ranges of θ reflect two different scenarios with regard to the risk of discovery. When that risk is relatively low, the incentive for the unethical firm to disclose its sources is based on disclosure cost. In the second scenario, when discovery is more likely, the incentive for firm U to disclose arises from a higher expected loss of market share when it does not disclose.

The following propositions characterize the dependence of the Nash equilibria on the parameters of the model. Proposition 1 focuses on the disclosure costs.

Proposition 1. *For* $\Delta_E > 0$ *and* $\Delta_U > 0$,

a. *When* $d_E^I < d_E$ *and* $d_U < d_U^{II}$, *ND is the unique equilibrium.*
b. *When* $d_E < d_E^{II}$ *and* $d_U^I < d_U$, *DN is the unique equilibrium.*
c. *If* $d_U^I < d_U^{II}$ (i.e., $\theta < \overline{\theta}$), *then*
   (i) *When* $d_E < d_E^I$ *and* $d_U < d_U^I$, *DD is the unique equilibrium.*
   (ii) *When* $d_E > d_E^{II}$ *and* $d_U > d_U^{II}$, *NN is the unique equilibrium.*
   (iii) *When* $d_E^{II} < d_E < d_E^I$ *and* $d_U^I < d_U < d_U^{II}$, *a pure-strategy equilibrium does not exist. The unique mixed-strategy equilibrium is*

$$\text{firm E discloses with probability } \left[1 + \left(\frac{1-\delta_{DD}}{1-\delta_{ND}}\right)\left(\frac{d_U - d_U^I}{d_U^{II} - d_U}\right)\right]^{-1} \text{ and}$$

firm U discloses with probability $\left[1+\left(\frac{m+(1-m)\delta_{DD}}{m+(1-m)\theta\delta_{DN}}\right)\left(\frac{d_E^I-d_E}{d_E-d_E^{II}}\right)\right]^{-1}$.

d. *If* $d_U^{II}<d_U^{I}$ *(i.e.,* $\theta>\overline{\theta}$*), then*
 (i) *When* $d_E<d_E^I$ *and* $d_U<d_U^{II}$ *OR* $d_E<d_E^{II}$ *and* $d_U<d_U^{I}$*, DD is the unique equilibrium.*
 (ii) *When* $d_E>d_E^I$ *and* $d_U>d_U^{II}$ *OR* $d_E>d_E^{II}$ *and* $d_U>d_U^{I}$*, NN is the unique equilibrium.*
 (iii) *When* $d_E^{II}<d_E<d_E^I$ *and* $d_U^{II}<d_U<d_U^{I}$*, DD and NN are pure-strategy equilibria and NN Pareto-dominates DD.*

Proposition 1 characterizes the equilibria of the disclosing game based on the threshold values for the disclosure costs of both firms. Figs. 1 and 2 provide graphical illustrations based on a numerical example ($p_E=1.00$, $c_E=0.25$, $p_U=0.90$, $c_U=0.10$, $m=0.25$, $\delta_{DN}=0.65$, $\delta_{DD}=0.30$, $\delta_{NN}=0.40$, $\delta_{ND}=0.05$, and $\theta=0.65<\overline{\theta}=0.74$ or $\theta=0.90>\overline{\theta}$). In our discussion of these and subsequent figures, a "region" is defined as a polygon in which a particular Nash equilibrium (such as DN, DD, mixed, etc.) occurs. An interpretation of the different regions in these figures is as follows.

In some cases, both scenarios discussed in Lemma 1 produce identical results; that is, the nature of the Nash equilibrium does not depend on θ. For both Fig. 1(a) and (b), when firm E's disclosure cost is greater than its threshold (given that firm U discloses), and firm U's disclosure cost is lower than its threshold, then only firm U discloses (ND). Conversely, when firm U's disclosure cost is greater than its threshold (given that firm E discloses), and firm E's disclosure cost is lower than its threshold, then only firm E discloses (DN). Here we see that the firms' disclosure decisions are motivated by cost.

Next we discuss the first (low-risk) scenario (where $\theta<\overline{\theta}$, and so $d_U^I<d_U^{II}$, see Fig. 1(a)), which consists of three subcases, two of which result in unique pure-strategy equilibria. Both firms disclose when their disclosure costs are below the relevant thresholds (DD), and don't disclose when they are higher (NN).

The third subcase of this scenario results in a mixed-strategy equilibrium. We can interpret the probabilities (see c.(iii) of Proposition 1) as follows. Surprisingly, within the feasible region of mixed-strategy equilibrium, each firm's probability of disclosing depends on the other firm's disclosure cost rather than its own disclosure cost. As firm U's cost of disclosure decreases, firm E's probability of disclosing increases. So firm E is *more* likely to disclose its sources, if its competitor has *lower* disclosure costs; thus firm E wants to keep its market advantage in case firm U discloses because of its lower cost. On the other hand, firm U is *more* likely to disclose its sources, and defend its market share, if it costs *more* for its rival to disclose.

We next consider the second (high-risk) scenario (where $\theta>\overline{\theta}$, and so $d_U^I>d_U^{II}$). Comparing Fig. 1(a) and (b), we see that the various regions (DD, DN, NN, ND) are in the same orientation, but in Fig. 1(b), intermediate values result in multiple equilibria (DD and NN). However, NN is the unique Pareto-dominant equilibrium

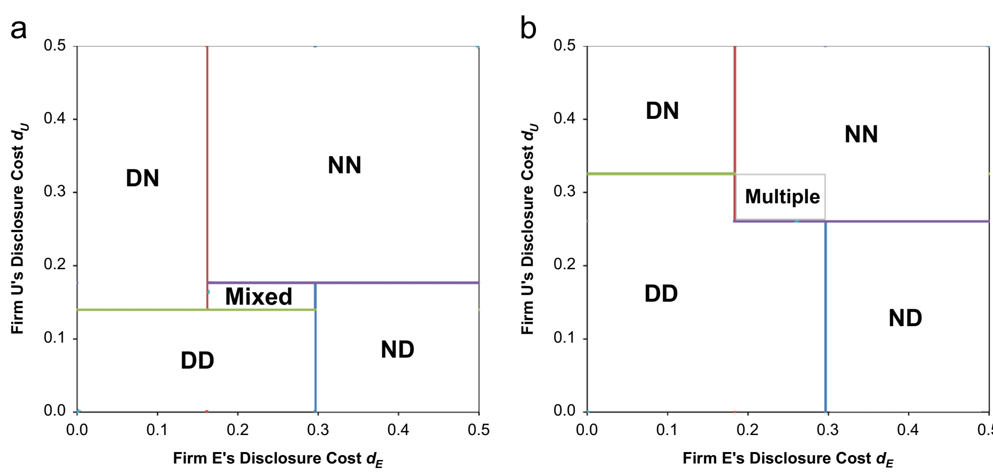

Fig. 1. Equilibrium regions in disclosure costs. (a) $\theta<\overline{\theta}$. (b) $\theta>\overline{\theta}$.

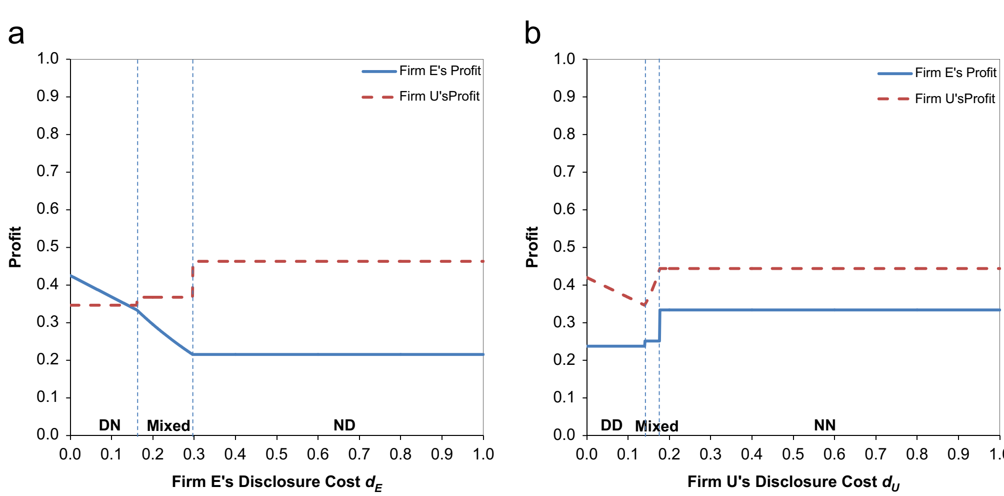

Fig. 2. Sensitivity of profit to disclosure cost. (a) Firm E's disclosure cost. (b) Firm U's disclosure cost.

in which neither firm discloses because in the case of DD, both firms earn less. This may present an opportunity for government action to change the desired equilibrium to DD, perhaps by subsidizing disclosure costs.

What are the effects on profit, as the disclosure costs change? Fig. 2(a) and (b) shows what happens to profit for each firm, when disclosure costs are in the range that result in a mixed strategy (as in that region in Fig. 1(a)). In the example depicted in Fig. 2(a), with d_U set at 0.15, both profit curves are monotone and piecewise continuous, but move in opposite directions. That is, firm E's profit falls as its disclosure cost rises (in the DN and mixed strategy regions), then levels off when it does not disclose but its competitor does (ND). On the other hand, firm U's profit rises as the disclosure cost of its competitor rises, and then levels off. We see from this that firm U benefits from its competitor's higher disclosure cost, particularly at the thresholds $d_E = d_E^I = 0.30$ and $d_E = d_E^{II} = 0.16$, where firm U loses less of its market share to its competitor. Note: the relative magnitude of these and other figures is an artifact of the numbers used to generate the example; other examples might show a different relationship between the magnitude of profit of each firm.

On the other hand, as firm U's disclosure cost rises (see Fig. 2(b), with d_E=0.25), it moves from disclosing (as does its competitor; DD) through mixed strategy, and then profit levels off as both firms decide not to disclose (NN). Firm E's profit rises, and then levels off, moving through the same regions. As the disclosure cost for the unethical firm rises (after 0.18 in this example), firm U decides not to disclose because of rising cost, while firm E saves the cost of disclosing because of its rival's non-disclosure. Interestingly, firm U's profit curve is no longer monotonic, since it decreases in DD and then increases in the mixed-strategy region, because when the probability of firm E disclosing is lower, it relieves firm U from the pressure to conduct costly disclosure.

Another contrast worth noting between the results of increasing d_E and d_U in these two figures is that the two firms choose opposite disclosing strategies (DN-mixed-ND) as d_E rises but the same strategy (DD-mixed-NN) as d_U increases. Looking at the last region for each, in Fig. 2(a), firm U retains more market share (and profit) by disclosing, given that firm E does not disclose (ND); in Fig. 2(b), firm E saves cost by not disclosing, given that firm U does not disclose (NN).

Proposition 2 characterizes the dependence of the Nash equilibria on the incremental changes in market share (Δ_E and Δ_U) that result from the disclosing behavior of the two firms.

Proposition 2. *For $\Delta_E > 0$ and $\Delta_U > 0$, let*

$$\Delta_E^I = \frac{d_E\left(\delta_{ND} + \frac{m}{1-m}\right)}{p_E - c_E - d_E} \tag{13}$$

$$\Delta_E^{II} = \frac{d_E\left[\theta(\delta_{ND} + \Delta_U) + \frac{m}{1-m}\right]}{\theta(p_E - c_E - d_E)} \tag{14}$$

$$\Delta_U^I = \frac{d_U}{(p_U - c_U)\theta} + \left[\frac{1-\theta}{\theta} - \frac{d_U}{(p_U - c_U)\theta}\right](\delta_{ND} + \Delta_E) \tag{15}$$

$$\Delta_U^{II} = \frac{d_U}{(p_U - c_U)\theta} + \left[\frac{1-\theta}{\theta} - \frac{d_U}{(p_U - c_U)\theta}\right]\delta_{ND} \tag{16}$$

$$\overline{\overline{\theta}} = 1 - \frac{d_U}{p_U - c_U} \tag{17}$$

then

a. *When $\Delta_E^I > \Delta_E$ and $\Delta_U > \Delta_U^{II}$, ND is the unique equilibrium.*
b. *When $\Delta_E > \Delta_E^{II}$ and $\Delta_U^I > \Delta_U$, DN is the unique equilibrium.*
c. *If $\Delta_U^I > \Delta_U^{II}$ (i.e., $\theta < \overline{\overline{\theta}}$), then*
   (i) *When $\Delta_E > \Delta_E^I$ and $\Delta_U > \Delta_U^I$, DD is the unique equilibrium.*
   (ii) *When $\Delta_E < \Delta_E^{II}$ and $\Delta_U < \Delta_U^{II}$, NN is the unique equilibrium.*
   (iii) *When $\Delta_E^{II} > \Delta_E > \Delta_E^I$ and $\Delta_U^I > \Delta_U > \Delta_U^{II}$, a pure-strategy equilibrium does not exist. The unique mixed-strategy equilibrium is*

   firm E discloses with probability $\left[1 + \left(\frac{\Delta_U^I - \Delta_U}{\Delta_U - \Delta_U^{II}}\right)\right]^{-1}$ *and*

   firm U discloses with probability $\left[1 + \left(\frac{1}{\theta}\right)\left(\frac{\Delta_E - \Delta_E^I}{\Delta_E^{II} - \Delta_E}\right)\right]^{-1}$.

d. *If $\Delta_U^{II} > \Delta_U^I$ (i.e., $\theta > \overline{\overline{\theta}}$), then*
   (i) *When $\Delta_E > \Delta_E^I$ and $\Delta_U > \Delta_U^{II}$ OR $\Delta_E > \Delta_E^{II}$ and $\Delta_U > \Delta_U^I$, DD is the unique equilibrium.*
   (ii) *When $\Delta_E < \Delta_E^I$ and $\Delta_U < \Delta_U^{II}$ OR $\Delta_E < \Delta_E^{II}$ and $\Delta_U < \Delta_U^I$, NN is the unique equilibrium.*
   (iii) *When $\Delta_E^{II} > \Delta_E > \Delta_E^I$ and $\Delta_U^{II} > \Delta_U > \Delta_U^I$, DD and NN are pure-strategy equilibria and NN Pareto-dominates DD.*

Proposition 2 characterizes the disclosing game, providing thresholds for the incremental changes in market share that result from the disclosing behavior of the firms (see Lemma 1). When considering these market-share changes, the two risk-related scenarios are characterized by the relationship of the probability of discovery θ to a threshold $\overline{\overline{\theta}}$, which decreases as firm U's cost of disclosure increases, and increases as firm U's contribution margin increases (17). In other words, this threshold

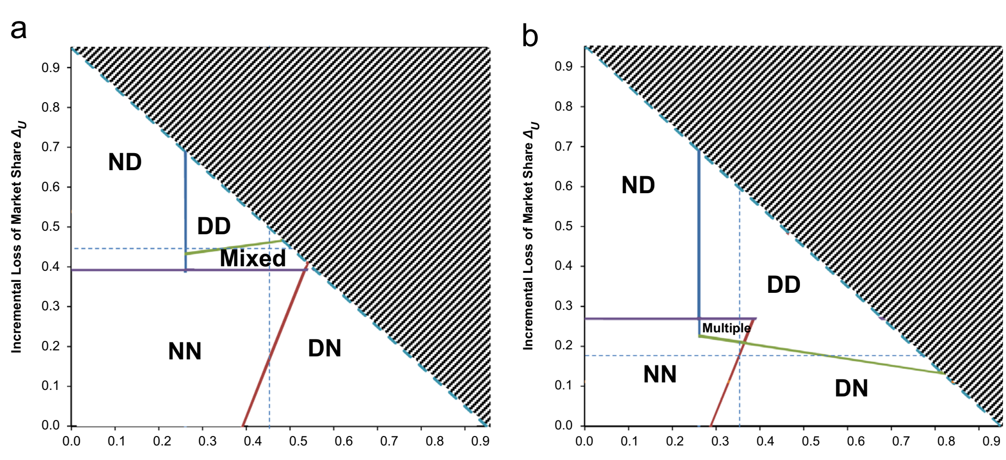

Fig. 3. Equilibrium regions in incremental market gain/loss. (a) $\theta < \overline{\overline{\theta}}$. (b) $\theta > \overline{\overline{\theta}}$.

is lower when firm U is paying more to disclose, relative to its revenues. When the probability of discovery is lower than this value, intermediate values of incremental market change result in a mixed strategy; when it is higher, they result in multiple equilibria (where the Pareto-optimal equilibrium is NN). Note that, to avoid trivial solutions, d_U must be less then $p_U - c_U$; otherwise this expression would yield a negative probability threshold $\overline{\overline{\theta}}$, implying that firm U would never choose to disclose in equilibrium.

Looking at the probabilities in c.(iii), firm E is more likely to disclose when firm U's incremental loss (Δ_U) is relatively higher, and firm U is more likely to disclose when firm E's incremental gain (Δ_E) is relatively lower, *and* the probability of discovery θ is higher. So the ethical firm takes advantage of the possibility of increasing its market share when its rival will lose more, and the unethical firm is motivated to disclose both by the probability of discovery (and market loss) and the proportion of the market that it can defend from its rival (Δ_U).

How does the reaction of the market influence the firm's decision to disclose? Fig. 3(a) provides a graphic display of a specific numerical example (p_E=1.00, c_E=0.25, d_E=0.20, p_U=0.90, c_U=0.10, d_U=0.20, m=0.40, d_{ND} = 0.05) when $\theta = 0.65 < \overline{\overline{\theta}} = 0.75$, and Fig. 3(b) when $\theta = 0.90 < \overline{\overline{\theta}}$. From Lemma 1, the largest proportion of market share lost by firm U is $\delta_{DN} = \delta_{DD} + \Delta_U = \delta_{ND} + \Delta_E + \Delta_U \le 1$ where the equalities hold because $\delta_{DN} - \delta_{DD} = \Delta_U$ and $\delta_{DD} - \delta_{ND} = \Delta_E$. This implies an upper bound on $\Delta_E + \Delta_U \le 1 - \delta_{ND} = 0.95$, which results in the blocked-out area in Fig. 3.

As noted previously in Fig. 1(a) and (b), Fig. 3(a) and (b) displays a similar structure, with slightly different shapes and different intermediate regions (mixed vs. multiple equilibria). Specifically, two of the four boundary lines are neither vertical nor horizontal because the corresponding two thresholds Δ_E^{II} and Δ_U^{I} vary as market gain/loss changes. As the incremental market share gained by firm E (Δ_E) increases with disclosure, (moving right on the x-axis), firm E will disclose whether or not its competitor discloses (DN). Similarly, as the market share lost by firm U (Δ_U) increases with non-disclosure (moving up on the y-axis), it will disclose (ND). Both firms disclose when the benefit of disclosing (to firm E) and loss by not disclosing (to firm U) rise (DD).

We look more closely at this example to understand how firms modify their strategy as the market structure changes. In Fig. 3(a), when $\Delta_E = 0.45$, as Δ_U increases, the equilibrium changes from *DN*, to *NN*, to mixed-strategy, and finally to *DD*. Notice that firm E discloses only for low and high Δ_U, and does not disclose for intermediate Δ_U, while firm U does *not* disclose for lower values of Δ_U. This represents a situation where the ethical firm responds to the incremental gain in market share from its competitor, as follows: when firm U does not disclose, firm E discloses even when that incremental gain is relatively low (DN); it also discloses when the incremental gain is high, *and* its competitor discloses (DD).

The unethical firm is motivated to disclose when its incremental market loss becomes high enough (DD). So when firm E decides to disclose (DD), it is reacting to the change in firm U's decision, while firm U's decision to disclose is motivated by its own incremental loss of market share. On the other hand, when $\Delta_U = 0.45$, as Δ_E increases, the equilibrium changes from *ND*, to *DD*, to mixed-strategy. So in this example, the unethical firm does disclose at all values of Δ_E, and the ethical firm moves from not disclosing to disclosing (ND to DD), as its incremental market share rises.

In Fig. 3(b), similarly, when $\Delta_E = 0.35$, as Δ_U increases, the equilibrium changes from *DN*, to *NN*, to Pareto *NN*, and finally to *DD* (firm E discloses only for low and high Δ_U, and does not disclose for intermediate Δ_U). Here the ethical firm discloses to gain additional market share when its rival has relatively low incremental loss of market share but does not disclose (DN), and also when its rival decides to disclose because of higher incremental market loss (DD). For the region of intermediate loss of market share when firm U does not disclose, the ethical firm may opt out of disclosing to save the cost, since it can still gain additional market share if its rival's sourcing is discovered.

On the other hand, when $\Delta_U = 0.18$, as Δ_E increases, the equilibrium changes from *NN*, to *DN*, to *DD* (firm U discloses only for high Δ_E). Again, the unethical firm is motivated to disclose when its rival's incremental gain in market share Δ_E increases.

How do these incremental changes in market share affect the profit of each firm? The example in Fig. 4(a) ($\Delta_U = 0.18$ and $\theta = 0.90 > \overline{\overline{\theta}}$) shows that when the incremental gain to the ethical firm for disclosing (Δ_E) is relatively low, profit is level since neither firm discloses (NN); in the intermediate region, only firm E discloses (DN), and its profit rises while firm U's profit falls. When firm E's incremental gain Δ_E is relatively higher, both firms disclose, with the profit trends remaining the same. So the ethical firm is motivated to disclose as its incremental gain in market share rises, and the unethical firm discloses at a higher value of Δ_E, that is, when it faces a larger incremental loss to its competitor. Note that when firm U switches from not disclosing to disclosing (DN to DD), there is a drop in firm E's profit (when $\Delta_E = 0.39$) because its incremental gain in market share decreases with firm U's disclosure.

On the other hand, as the incremental loss of market share Δ_U for the unethical firm increases, it moves from not disclosing

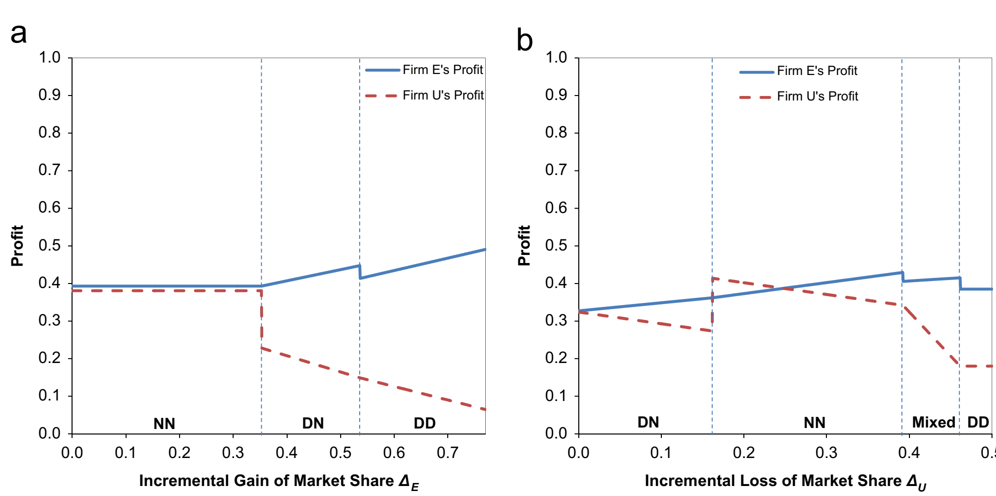

Fig. 4. Sensitivity of profit to incremental market gain/loss. (a) Incremental market gain for firm E. (b) Incremental market loss for firm U.

(DN, NN) to disclosing (mixed, DD) (Fig. 4(b), with $\Delta_E = 0.45$ and $\theta = 0.65 < \overline{\overline{\theta}}$; compare to Fig. 3(a) when $\Delta_E = 0.45$). Firm U's profit falls in each region where it does not disclose, as the loss grows (DN, NN) though it begins higher in NN (initial benefit of its competitor not disclosing). It falls through the mixed strategy area, and then levels off when both firms disclose (DD), and its incremental loss is highest. On the other hand, firm E's profit rises steadily as Δ_U increases, a reflection of firm E's incremental gain in market share when its competitor does not disclose (DN, NN); its profit is slightly lower in the region of mixed strategies and when both firms disclose (DD). Note that when firm E switches from disclosing to not disclosing (DN to NN) to save the cost of disclosure, there is an increase in firm U's profit which reflects the fact that firm U is losing less market share to its competitor.

Proposition 3 characterizes the dependence of the Nash equilibria on the *initial* market share m of the ethical firm, and the probability of discovery θ.

Proposition 3. *For $\Delta_E > 0$ and $\Delta_U > 0$, let*

$$m^I = \frac{(\delta_{DD} - \delta_{ND})\frac{p_E - c_E}{d_E} - \delta_{DD}}{1 + (\delta_{DD} - \delta_{ND})\frac{p_E - c_E}{d_E} - \delta_{DD}} \tag{18}$$

$$m^{II} = \frac{\theta\left[(\delta_{DN} - \delta_{NN})\frac{p_E - c_E}{d_E} - \delta_{DN}\right]}{1 + \theta\left[(\delta_{DN} - \delta_{NN})\frac{p_E - c_E}{d_E} - \delta_{DN}\right]} \tag{19}$$

$$\theta^I = \left(\frac{1 - \delta_{DD}}{\delta_{DN}}\right)\left(\frac{d_U}{p_U - c_U}\right) + \frac{\delta_{DD}}{\delta_{DN}} \tag{20}$$

$$\theta^{II} = \left(\frac{1 - \delta_{ND}}{\delta_{NN}}\right)\left(\frac{d_U}{p_U - c_U}\right) + \frac{\delta_{ND}}{\delta_{NN}} \tag{21}$$

$$\overline{d}_U = \frac{\delta_{NN}\delta_{DD} - \delta_{DN}\delta_{ND}}{\delta_{NN}\delta_{DD} - \delta_{DN}\delta_{ND} + \delta_{DN} - \delta_{NN}}(p_U - c_U) \tag{22}$$

then

a. *When $m^I < m$ and $\theta > \theta^{II}$, ND is the unique equilibrium.*
b. *When $m < m^{II}$ and $\theta^I > \theta$, DN is the unique equilibrium.*
c. *If $\theta^I > \theta^{II}$ (i.e., $d_U < \overline{d}_U$), then*
  (i) *When $m < m^I$ and $\theta > \theta^I$, DD is the unique equilibrium.*
  (ii) *When $m > m^{II}$ and $\theta < \theta^{II}$, NN is the unique equilibrium.*
  (iii) *When $m^{II} < m < m^I$ and $\theta^I > \theta > \theta^{II}$, a pure-strategy equilibrium does not exist. The unique mixed-strategy equilibrium is firm E discloses with probability*

$$\left[1 + \frac{\delta_{DN}}{\delta_{NN}}\left(\frac{\theta^I - \theta}{\theta - \theta^{II}}\right)\right]^{-1} \quad \text{and}$$

firm U discloses with probability

$$\left[1 + \frac{1 + (\delta_{DD} - \delta_{ND})\frac{p_E - c_E}{d_E} - \delta_{DD}}{1 + \theta\left[(\delta_{DN} - \delta_{NN})\frac{p_E - c_E}{d_E} - \delta_{DN}\right]}\left(\frac{m^I - m}{m - m^{II}}\right)\right]^{-1}.$$

d. *If $\theta^{II} > \theta^I$ (i.e., $d_U > \overline{d}_U$), then*
  (i) *When $m < m^I$ and $\theta > \theta^{II}$ OR $m < m^{II}$ and $\theta > \theta^I$, DD is the unique equilibrium.*
  (ii) *When $m > m^I$ and $\theta < \theta^{II}$ OR $m > m^{II}$ and $\theta < \theta^I$, NN is the unique equilibrium.*
  (iii) *When $m^{II} < m < m^I$ and $\theta^{II} > \theta > \theta^I$, DD and NN are pure-strategy equilibria and NN Pareto-dominates DD.*

Proposition 3 characterizes the disclosing game, with regard to the *initial* market share m of the ethical firm, and the probability of discovery θ, and provides threshold values for initial market share, probability of discovery and cost of disclosure for the unethical firm. Fig. 5(a) presents an example of the firms' decisions with regard to initial market share and probability of discovery (p_E=1.00, c_E=0.25, d_E=0.20, p_U=0.90, c_U=0.10, $\delta_{DN} = 0.65$, $\delta_{DD} = 0.30$, $\delta_{NN} = 0.40$, $\delta_{ND} = 0.05$) when the disclosure cost for firm U is relatively low ($d_U = 0.10 < \overline{d}_U = 0.21$). In general, neither firm discloses when the probability of discovery is low (NN), and both disclose when the probability is high *and* the initial market share is relatively low (DD). However, firm E discloses and firm U does not (DN), in the triangular region where initial market share is relatively low, and the probability of discovery is less than 0.6 in this example.

Intermediate values of m and θ result in a mixed strategy. Looking at the probabilities in c.(iii), firm E is more likely to disclose when the probability of discovery θ is higher: the ethical firm will take advantage of its rival's risk of being found out. Firm U is more likely to disclose when the initial market share m of its rival is higher: this is a defensive move, to keep its relatively lower share of the market.

Fig. 5(b) presents the same example when the disclosure cost for firm U is relatively high ($d_U = 0.27 > \overline{d}_U$). The story is similar to the above, except that the region where neither disclose (NN) is

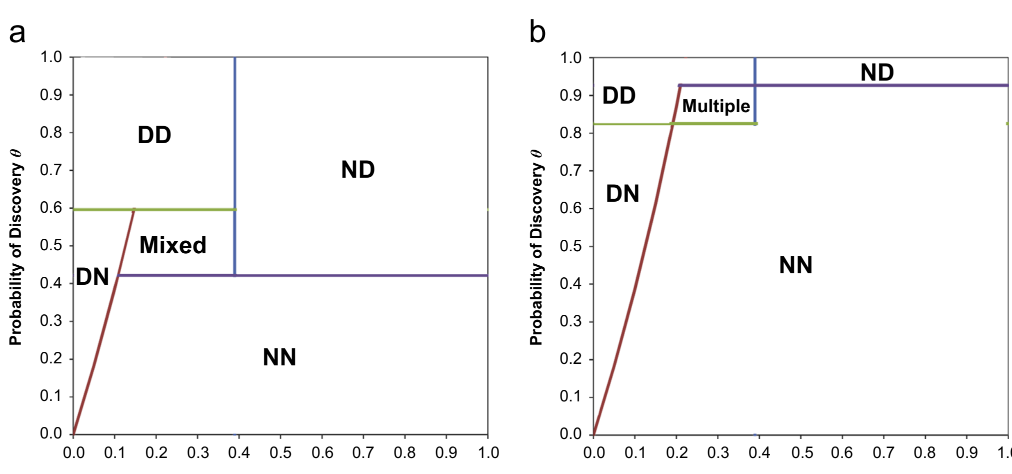

Fig. 5. Equilibrium regions in initial market share and probability of discovery. (a) $d_U < \overline{d}_U$. (b) $d_U > \overline{d}_U$.

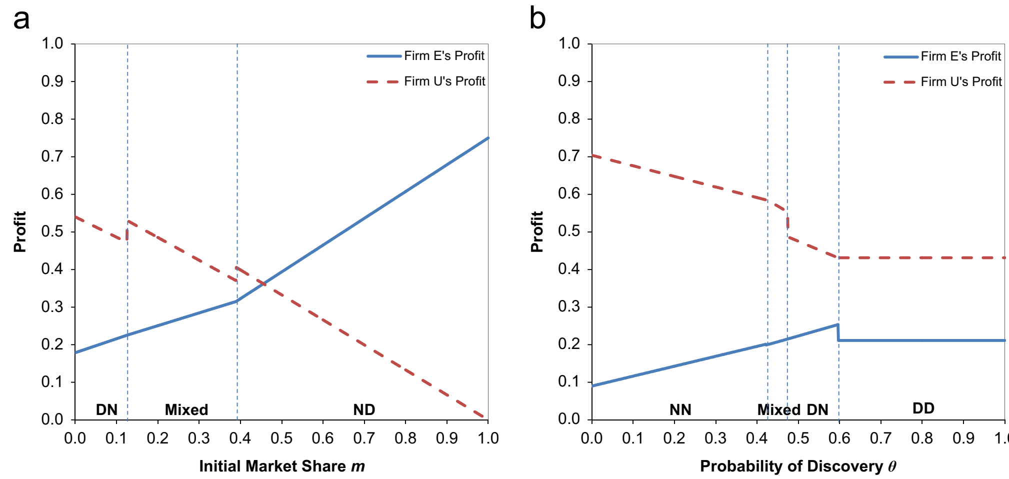

Fig. 6. Sensitivity of profit to initial market share and probability of discovery. (a) Initial market share. (b) Probability of discovery.

larger. So a higher disclosure cost for the unethical firm affects the behavior of its rival as well; the ethical firm feels less pressure to disclose if its rival does not.

How does initial market share affect profit? In the example in Fig. 6(a) ($\theta = 0.5$) we see that firm E's profit rises as its initial market share increases, and the reverse is true for firm U. When initial market share is relatively large (here, greater than 0.4), firm E does not disclose, while firm U does (ND). Conversely, firm U moves from not disclosing when its initial share is higher (lower values of m; DN), to a mixed strategy, to disclosing (ND), since it needs to defend market share from its competitor, when the latter begins with a higher proportion of it (higher m).

How does the probability of discovery affect profit? In the example in Fig. 6(b) ($m = 0.12$), we see that firm U's profit falls, and firm E's profit rises (and then both level off) as that probability increases. Both firms move from not disclosing (NN) to disclosing (DD), with an intermediate region where strategies are mixed, and then a region where firm E discloses but firm U does not (DN). This reflects the fact that the ethical firm realizes more benefits in market share by disclosing its sources (δ_{NN}, δ_{DN}), while the unethical firm can only be harmed by discovery. Once both disclose, discovery has no effect.

Proposition 4 characterizes the dependence of the Nash equilibria on contribution margins.

Proposition 4. *For $\Delta_E > 0$ and $\Delta_U > 0$, let*

$$(p_E - c_E)^I = \frac{\delta_{DD} + \frac{m}{1-m} d_E}{\delta_{DD} - \delta_{ND}} \quad (23)$$

$$(p_E - c_E)^{II} = \frac{\theta\delta_{DN} + \frac{m}{1-m} d_E}{\theta\delta_{DN} - \theta\delta_{NN}} \quad (24)$$

$$(p_U - c_U)^I = \frac{1 - \delta_{DD}}{\theta\delta_{DN} - \delta_{DD}} d_U \quad (25)$$

$$(p_U - c_U)^{II} = \frac{1 - \delta_{ND}}{\theta\delta_{NN} - \delta_{ND}} d_U \quad (26)$$

then

a. *When $(p_E - c_E)^I > p_E - c_E$ and $p_U - c_U > (p_U - c_U)^{II}$, ND is the unique equilibrium.*
b. *When $p_E - c_E > (p_E - c_E)^{II}$ and $(p_U - c_U)^I > p_U - c_U$, DN is the unique equilibrium.*
c. *If $(p_U - c_U)^I > (p_U - c_U)^{II}$ (i.e., $\theta < \overline{\theta}$), then*
   (i) *When $p_E - c_E > (p_E - c_E)^I$ and $p_U - c_U > (p_U - c_U)^I$, DD is the unique equilibrium.*
   (ii) *When $p_E - c_E < (p_E - c_E)^{II}$ and $p_U - c_U < (p_U - c_U)^{II}$, NN is the unique equilibrium.*
   (iii) *When $(p_E - c_E)^{II} > p_E - c_E > (p_E - c_E)^I$ and $(p_U - c_U)^I > p_U - c_U > (p_U - c_U)^{II}$, a pure-strategy equilibrium does not exist. The unique mixed-strategy equilibrium is:*

   firm E discloses with probability
   $$\left[1 + \left(\frac{\theta\delta_{DN} - \delta_{DD}}{\theta\delta_{NN} - \delta_{ND}}\right)\left(\frac{(p_U - c_U)^I - (p_U - c_U)}{(p_U - c_U) - (p_U - c_U)^{II}}\right)\right]^{-1} \text{ and}$$
   firm U discloses with probability
   $$\left[1 + \frac{1}{\theta}\left(\frac{\delta_{DD} - \delta_{ND}}{\delta_{DN} - \delta_{NN}}\right)\left(\frac{(p_E - c_E) - (p_E - c_E)^I}{(p_E - c_E)^{II} - (p_E - c_E)}\right)\right]^{-1}.$$

d. *If $(p_U - c_U)^{II} > (p_U - c_U)^I$ (i.e., $\theta > \overline{\theta}$), then*
   (i) *When $p_E - c_E > (p_E - c_E)^I$ and $p_U - c_U > (p_U - c_U)^{II}$ OR $p_E - c_E > (p_E - c_E)^{II}$ and $p_U - c_U > (p_U - c_U)^I$, DD is the unique equilibrium.*
   (ii) *When $p_E - c_E < (p_E - c_E)^I$ and $p_U - c_U < (p_U - c_U)^{II}$ OR $p_E - c_E < (p_E - c_E)^{II}$ and $p_U - c_U < (p_U - c_U)^I$, NN is the unique equilibrium.*
   (iii) *When $(p_E - c_E)^{II} > p_E - c_E > (p_E - c_E)^I$ and $(p_U - c_U)^{II} > p_U - c_U > (p_U - c_U)^I$, DD and NN are pure-strategy equilibria and NN Pareto-dominates DD.*

As for previous results, there are two risk-related scenarios, which depend on the same threshold ($\overline{\theta}$) for θ as did the results on disclosure costs (Proposition 1), and intermediate values result in mixed-strategy and multiple equilibria. Here the probabilities of disclosure for firm E in the mixed-strategy equilibrium rise as the contribution margin of firm U increases and for firm U, that probability rises as firm E's contribution margin decreases. This suggests that firm E should disclose to keep its market advantage when facing a stronger competitor, while firm U should disclose in order to defend its market share against a weaker competitor.

Proposition 5 characterizes the Nash equilibria, when *initial* market share m of the ethical firm is at its extreme points (monopoly cases), and also when discovery is either certain or impossible. Threshold values for contribution margin $(p_i - c_i)$ are as defined in Proposition 4.

Proposition 5. *For $\Delta_E > 0$ and $\Delta_U > 0$,*

a. *When $m=0$, DD is the unique equilibrium iff $d_U < d_U^I$ (or equivalently $\Delta_U > \Delta_U^I$, $\theta > \theta^I$, or $p_U - c_U > (p_U - c_U)^I$); otherwise, DN is the unique equilibrium.*
b. *When $m=1$, ND is the unique equilibrium iff $d_U < d_U^{II}$ (or equivalently $\Delta_U > \Delta_U^{II}$, $\theta > \theta^{II}$, $p_U - c_U > (p_U - c_U)^{II}$); otherwise, NN is the unique equilibrium.*
c. *When $\theta = 0$, NN is the unique equilibrium.*
d. *When $\theta = 1$, DD is the unique equilibrium iff $m < m^I$ (or equivalently $d_E < d_E^I$, $\Delta_E > \Delta_E^I$, or $p_E - c_E > (p_E - c_E)^I$); otherwise, ND is the unique equilibrium.*

Proposition 5(a) and (b) characterizes the monopolistic equilibria. When firm U begins as the monopolist ($m=0$, so $1-m=1$), it discloses if the cost of disclosure is low (or for high incremental market loss, high risk of discovery, or high margin). Interestingly, potential ethical start-ups who begin with no market share ($m=0$), such as Zady and Everlane (Tozzi, 2014), should always disclose their sources and be transparent about their supply chain regardless of what the current market leaders do. On the other hand, when firm E is the monopolist ($m=1$), it has no incentive to disclose.

Proposition 5(c) shows that neither firm discloses if there is no chance of discovery ($\theta = 0$), since firm E is never able to recoup its disclosing cost through a gain in market share, because firm U's unethical sourcing is never revealed. If discovery is certain ($\theta = 1$ as in Proposition 5(d)), both disclose (DD) if firm E's initial market share is low, so it still aims to gain market share from uncovering firm U's sourcing. But when firm E begins with sufficient market share, it has less incentive to disclose in order to take away customers from its rival; so only firm U discloses in order to retain as much market as it can (ND).

5. Discussion of results and conclusions

Our results provide insights into the conditions under which firms should disclose their sources, whether they have an ethical or unethical supply chain. We consider how the firms' decisions to disclose should be influenced by their cost of disclosure, gain or loss of market share, initial market share, probability of discovery and contribution margin. We find that those decisions should be motivated by the factors that affect each firm directly (for example, higher disclosure costs make it less likely that a firm should disclose its sources), but also by the characteristics and actions of the other firm. The type of firm (ethical or unethical) also makes a difference.

While the pure-strategy results confirm the aptness of our model, the mixed-strategy and multiple equilibria suggest how the firms' interactions with one another should influence their disclosure decisions. So the former provide assurance that the model conforms well to what we would expect, while the latter provide less obvious insights into a more complicated situation. This can be seen, for example, by the fact that the threshold values for each set of results are functions of multiple factors.

For intermediate values of disclosure costs, market share, or incremental market changes, a high probability of discovery leads to *multiple equilibria* while a low probability yields a *mixed-strategy equilibrium*. All multiple equilibria result in a situation in which both firms earn more profit when neither discloses. In the cases of mixed-strategy equilibria, we see that each firm is motivated by market characteristics which include actions and characteristics of the other firm, and the recommended course of action is different for each type. For instance, the ethical firm is more likely to improve its profit if it discloses its sources, when its competitor has lower disclosure costs, and the reverse is true for the unethical firm.

- *Cost of disclosure* is one of the major concerns for many firms when considering whether to disclose or not. Our first result is intuitive: we find that a firm, regardless of its type, should not disclose when it incurs a higher cost of doing so (all else equal). However, its reaction to its rival's increase in cost is very much dependent on its type: an unethical firm should disclose when its ethical rival does not disclose because of that firm's high cost; on the other hand, an ethical firm shouldn't disclose if its unethical competitor chooses not to disclose because of its own higher cost. An unethical firm's profit may even *increase* as its cost of disclosure increases, because its rival is less likely to disclose. The second and third results are not obvious, and so our analysis provides an insight into how a firm needs to consider more than simply cost when making disclosure decisions.
- *Market response to disclosure* reflects the pressure from consumers for a more transparent supply chain. Our analysis shows that the dynamics of gain and loss in market share are complicated and inter-dependent. The results suggest that an ethical firm should disclose if its unethical competitor would experience a loss in market share by not disclosing, but the decision depends on the size of that loss. In other words, as the unethical firm's incremental loss of market share increases, the ethical firm should move from disclosing to not disclosing (to save the cost of disclosure); but then it should *switch back* to disclosing, if its unethical rival chooses to disclose because of its own potential loss of market share. Here again, a firm's decision about disclosure should be based on the interaction of cost and market share, and also by whether its rival decides to disclose or not.
- *Initial market share*, as our results suggest, affects a firm's disclosure decision depending on its type: an ethical firm should disclose when its initial share is small, while an unethical firm should give more weight to the cost of disclosure than to market share. In the case of monopoly, there are three possible outcomes. When the ethical firm is a monopolist, it should never disclose since it gains no market share by doing so. When the unethical firm is a monopolist, the ethical firm should always disclose (in an attempt to gain market share), while the unethical firm should disclose only if its cost of doing so is low.
- *Probability of discovery* is also an effective driver for disclosing. Both firms should disclose when the likelihood of discovery is high. Examining the two extreme cases: if there is no chance of discovery, neither firm should disclose since the ethical firm will never gain and the unethical firm will never lose market share; when discovery is certain, both firms should disclose if the ethical firm starts with a relatively low market share; otherwise, only the unethical firm should disclose. This finding justifies the need for a transparent supply chain as advocated by New (2010): "Let your customers know everything about where your products come from - before they discover it first."
- *Contribution margin* may enable a firm to absorb the cost of disclosure. Therefore it affects the firm's disclosure decision in the opposite direction of cost. However, a firm's reaction to its rival's increase in profit margin depends its type. An unethical firm should disclose when its ethical rival does not disclose because of its low margin; on the other hand, an ethical firm should not disclose if its unethical competitor chooses not to disclose because of its own low margin. This result is not self evident. As we saw with regard to disclosure cost, the firm needs to consider more than simply its own contribution margin, when deciding whether or not to disclose.

Our analysis shows that, in a competitive market, a firm's decisions about whether or not to disclose its sources should be based on its type, and the actions of its competitors, as well as its own cost and market structure. Sometimes, the outcome may not be desirable from a societal perspective, such as the multiple-equilibria conditions under which both firms do better not to disclose. This presents an opportunity for government agencies (led by U.S. and European Union legislation) or non-government organizations (e.g., Greenpeace and the Fair Labor Association), which can effectively maneuver the equilibrium by utilizing various instruments: helping to lower disclosure costs (subsidizing), raising customer awareness in terms of higher incremental market gain/loss (educating), or mandating supply chain transparency (regulating).

Our focus on a duopolistic environment, and some of our assumptions, suggest several directions for future research. First, the model might be extended to other competitive scenarios, such as oligopoly or perfect competition; the intensity of competition may affect the equilibrium outcome. Next, some of the exogenous factors in our models may be interdependent. It is likely that a firm may pass some of its cost of disclosure to customers by increasing its price. How would such dependence change our results? Also, since full disclosure may be costly, we might consider the extent of disclosure (full, partial, or no disclosure).

Acknowledgments

We thank the University Research Council at Cleveland State University for a Graduate Faculty Travel Grant in support of this project.

Appendix A

Proof of Lemma 1.

$$d_E^{II} = \frac{\theta\delta_{DN} - \theta\delta_{NN}}{\theta\delta_{DN} + \dfrac{m}{1-m}}(p_E - c_E) = \frac{\delta_{DD} - \delta_{ND}}{\delta_{DN} + \dfrac{m}{1-m}\dfrac{1}{\theta}}(p_E - c_E) < \frac{\delta_{DD} - \delta_{ND}}{\delta_{DD} + \dfrac{m}{1-m}} \times (p_E - c_E) = d_E^{I}$$

where the second equality holds because $\delta_{DD} - \delta_{ND} = \delta_{DN} - \delta_{NN} = \Delta_U > 0$, and the inequality holds because $\delta_{DN} - \delta_{DD} > 0$. Similarly,

$$d_U^{I} = \frac{\theta\delta_{DN} - \delta_{DD}}{1-\delta_{DD}}(p_U - c_U) = \frac{\theta(\delta_{NN} - \delta_{ND}) - (1-\theta)\delta_{DD}}{1-\delta_{DD}}(p_U - c_U) < \frac{\theta(\delta_{NN} - \delta_{ND}) - (1-\theta)\delta_{ND}}{1-\delta_{ND}}(p_U - c_U) = d_U^{II}$$

where the second equality holds because $\delta_{DN} - \delta_{DD} = \delta_{NN} - \delta_{ND} > 0$, and the inequality holds iff $\theta < 1/(1+\Delta_U)$ implying

$$\frac{d}{d\delta}\left(\frac{\theta\Delta_U - (1-\theta)\delta}{1-\delta}\right) = \frac{(1+\Delta_U)\theta - 1}{(1-\delta)^2} < 0$$

(otherwise, $d_U^{I} > d_U^{II}$). □

Proof of Proposition 1. From Lemma 1, there are total 18 possible cases of d_E and d_U with respect to the thresholds. In the enumeration below, cases [1]–[10] and [12]–[17] follow directly from the definitions of threshold values (Eqs. (1)–(8)).

a.] [1] When $d_E^{II} < d_E^{I} < d_E$ and $d_U < d_U^{I} < d_U^{II}$, $\pi_E^{ND} > \pi_E^{DD}$ and $\pi_U^{ND} > \pi_U^{NN}$, so ND is the unique equilibrium.
[2] When $d_E^{II} < d_E^{I} < d_E$ and $d_U^{I} < d_U < d_U^{II}$, $\pi_E^{ND} > \pi_E^{DD}$ and $\pi_U^{ND} > \pi_U^{NN}$, so ND is the unique equilibrium.
[3] When $d_E^{II} < d_E^{I} < d_E$ and $d_U < d_U^{II} < d_U^{I}$, $\pi_E^{ND} > \pi_E^{DD}$ and $\pi_U^{ND} > \pi_U^{NN}$, so ND is the unique equilibrium.

b.] [4] When $d_E < d_E^{II} < d_E^{I}$ and $d_U^{I} < d_U < d_U^{II}$, $\pi_E^{DN} > \pi_E^{NN}$ and $\pi_U^{DN} > \pi_U^{DD}$, so DN is the unique equilibrium.
[5] When $d_E < d_E^{II} < d_E^{I}$ and $d_U^{I} < d_U^{II} < d_U$, $\pi_E^{DN} > \pi_E^{NN}$ and $\pi_U^{DN} > \pi_U^{DD}$, so DN is the unique equilibrium.
[6] When $d_E < d_E^{II} < d_E^{I}$ and $d_U^{II} < d_U^{I} < d_U$, $\pi_E^{DN} > \pi_E^{NN}$ and $\pi_U^{DN} > \pi_U^{DD}$, so DN is the unique equilibrium.

c.] If $\theta < \overline{\theta}$
[7] When $d_E < d_E^{II} < d_E^{I}$ and $d_U < d_U^{I} < d_U^{II}$, $\pi_E^{DD} > \pi_E^{ND}$ and $\pi_U^{DD} > \pi_U^{DN}$, so DD is the unique equilibrium.
[8] When $d_E^{II} < d_E < d_E^{I}$ and $d_U < d_U^{I} < d_U^{II}$, $\pi_E^{DD} > \pi_E^{ND}$ and $\pi_U^{DD} > \pi_U^{DN}$, so DD is the unique equilibrium.
[9] When $d_E^{II} < d_E < d_E^{I}$ and $d_U^{I} < d_U^{II} < d_U$, $\pi_E^{NN} > \pi_E^{DN}$ and $\pi_U^{NN} > \pi_U^{ND}$, so NN is the unique equilibrium.
[10] When $d_E^{II} < d_E^{I} < d_E$ and $d_U^{I} < d_U^{II} < d_U$, $\pi_E^{NN} > \pi_E^{DN}$ and $\pi_U^{NN} > \pi_U^{ND}$, so NN is the unique equilibrium.
[11] When $d_E^{II} < d_E < d_E^{I}$ and $d_U^{I} < d_U < d_U^{II}$, $\pi_E^{DD} > \pi_E^{ND}$, $\pi_E^{NN} > \pi_E^{DN}$, $\pi_U^{DN} > \pi_U^{DD}$ and $\pi_U^{ND} > \pi_U^{NN}$, so there exists no pure-strategy equilibrium.

For the mixed-strategy Nash equilibria in case [11], assume that firm E and firm U disclose with probability r and q respectively. Then firm E's expected profit is as follows:

$$\begin{aligned}\mathbb{E}[\pi_E] &= r(1-q)\pi_E^{DN} + rq\pi_E^{DD} + (1-r)(1-q)\pi_E^{NN} + (1-r)q\pi_E^{ND} \\ &= (1-q)\pi_E^{NN} + q\pi_E^{ND} + r[(1-q)(\pi_E^{DN} - \pi_E^{NN}) + q(\pi_E^{DD} - \pi_E^{ND})]\end{aligned}$$

From the definitions of the payoff functions (Eqs. (9)–(12)) :

$$\begin{aligned}&= (1-q)\pi_E^{NN} + q\pi_E^{ND} \\ &\quad + r[(1-q)\{[m + (1-m)\delta_{DN}\theta](p_E - c_E - d_E) \\ &\quad - [m + (1-m)\delta_{NN}\theta](p_E - c_E)\} \\ &\quad + q\{[m + (1-m)\delta_{DD}](p_E - c_E - d_E) \\ &\quad - [m + (1-m)\delta_{ND}](p_E - c_E)\}] \\ &= (1-q)\pi_E^{NN} + q\pi_E^{ND} + r[(1-q)\{(1-m)\theta(\delta_{DN} - \delta_{NN})(p_E - c_E) \\ &\quad - [m + (1-m)\delta_{DN}\theta]d_E\} + q\{(1-m)(\delta_{DD} - \delta_{ND})(p_E - c_E) \\ &\quad - [m + (1-m)\delta_{DD}]d_E\}] \\ &= (1-q)\pi_E^{NN} + q\pi_E^{ND} + r\big[(1-q)[m + (1-m)\delta_{DN}\theta] \\ &\quad \times \left(\frac{(1-m)\theta(\delta_{DN} - \delta_{NN})}{m + (1-m)\delta_{DN}\theta}(p_E - c_E) - d_E\right) \\ &\quad + q[m + (1-m)\delta_{DD}]\left(\frac{(1-m)(\delta_{DD} - \delta_{ND})}{m + (1-m)\delta_{DD}}(p_E - c_E) - d_E\right)\bigg]\end{aligned}$$

From the definitions of the thresholds d_E^{I} *and* d_E^{II} (Eqs. (9)–(12)):

$$\begin{aligned}&= (1-q)\pi_E^{NN} + q\pi_E^{ND} \\ &\quad + r[(1-q)[m + (1-m)\delta_{DN}\theta](d_E^{II} - d_E) \\ &\quad + q[m + (1-m)\delta_{DD}](d_E^{I} - d_E)] \\ &= (1-q)\pi_E^{NN} + q\pi_E^{ND} \\ &\quad + r \cdot [m + (1-m)\delta_{DN}\theta](d_E - d_E^{II}) \\ &\quad \left[-(1-q) + q\left(\frac{m + (1-m)\delta_{DD}}{m + (1-m)\theta\delta_{DN}}\right)\left(\frac{d_E^{I} - d_E}{d_E - d_E^{II}}\right)\right] \\ &= (1-q)\pi_E^{NN} + q\pi_E^{ND} \\ &\quad + r \cdot [m + (1-m)\delta_{DN}\theta](d_E - d_E^{II}) \\ &\quad \left\{q\left[1 + \left(\frac{m + (1-m)\delta_{DD}}{m + (1-m)\theta\delta_{DN}}\right)\left(\frac{d_E^{I} - d_E}{d_E - d_E^{II}}\right)\right] - 1\right\}\end{aligned}$$

Thus firm E's expected profit is increasing in r if

$$q > \left[1 + \left(\frac{m + (1-m)\delta_{DD}}{m + (1-m)\theta\delta_{DN}}\right)\left(\frac{d_E^{I} - d_E}{d_E - d_E^{II}}\right)\right]^{-1} \equiv \hat{q},$$

decreasing in r if $q<\hat{q}$, or constant in r if $q=\hat{q}$. So firm E's best response correspondence is

$$r^*(q)=\begin{cases}1 & \text{if } q>\hat{q}\\ [0,1] & \text{if } q=\hat{q}\\ 0 & \text{if } q<\hat{q}\end{cases} \quad \text{(A.1)}$$

Similarly, firm U's expected profit is as follows:

$$\begin{aligned}\mathbb{E}[\pi_U]&=r(1-q)\pi_U^{DN}+rq\pi_U^{DD}+(1-r)(1-q)\pi_U^{NN}+(1-r)q\pi_U^{ND}\\&=(1-r)\pi_U^{NN}+r\pi_U^{DN}+q[(1-r)(\pi_U^{ND}-\pi_U^{NN})+r(\pi_U^{DD}-\pi_U^{DN})]\end{aligned}$$

From the definitions of the payoff functions on (Eqs. (9)–(12)) :

$$\begin{aligned}&=(1-r)\pi_U^{NN}+r\pi_U^{DN}\\&\quad+q[(1-r)(1-m)\{(1-\delta_{ND})(p_U-c_U-d_U)-[(1-\delta_{NN})\theta\\&\quad+(1-\theta)](p_U-c_U)\}+r(1-m)\{(1-\delta_{DD})(p_U-c_U-d_U)\\&\quad-[(1-\delta_{DN})\theta+(1-\theta)](p_U-c_U)\}]\\&=(1-r)\pi_U^{NN}+r\pi_U^{DN}\\&\quad+q(1-m)[(1-r)\{(\theta\delta_{NN}-\delta_{ND})(p_U-c_U)-(1-\delta_{ND})d_U\}\\&\quad+r\{(\theta\delta_{DN}-\delta_{DD})(p_U-c_U)-(1-\delta_{DD})d_U\}]\\&=(1-r)\pi_U^{NN}+r\pi_U^{DN}\\&\quad+q(1-m)\left[(1-r)(1-\delta_{ND})\left(\frac{\theta\delta_{NN}-\delta_{ND}}{1-\delta_{ND}}(p_U-c_U)-d_U\right)\right.\\&\quad\left.+r(1-\delta_{DD})\left(\frac{\theta\delta_{DN}-\delta_{DD}}{1-\delta_{DD}}(p_U-c_U)-d_U\right)\right]\end{aligned}$$

From the definitions of the thresholds d_U^I and d_U^{II} (Eqs. (9)−(12)):

$$\begin{aligned}&=(1-r)\pi_U^{NN}+r\pi_U^{DN}\\&\quad+q(1-m)[(1-r)(1-\delta_{ND})(d_U^{II}-d_U)+r(1-\delta_{DD})(d_U^{I}-d_U)]\\&=(1-r)\pi_U^{NN}+r\pi_U^{DN}\\&\quad+q(1-m)(1-\delta_{ND})(d_U^{II}-d_U)\left[(1-r)-r\left(\frac{1-\delta_{DD}}{1-\delta_{ND}}\right)\left(\frac{d_U-d_U^I}{d_U^{II}-d_U}\right)\right]\\&=(1-r)\pi_U^{NN}+r\pi_U^{DN}\\&\quad+q\cdot(1-m)(1-\delta_{ND})(d_U^{II}-d_U)\left\{1-r\left[1+\left(\frac{1-\delta_{DD}}{1-\delta_{ND}}\right)\left(\frac{d_U-d_U^I}{d_U^{II}-d_U}\right)\right]\right\}\end{aligned}$$

Thus firm U's expected profit is increasing in q if

$$r<\left[1+\left(\frac{1-\delta_{DD}}{1-\delta_{ND}}\right)\left(\frac{d_U-d_U^I}{d_U^{II}-d_U}\right)\right]^{-1}\equiv\hat{r}, \text{decreasing in } q \text{ if } r>\hat{r},$$

or constant in q if $r=\hat{r}$. So firm U's best response correspondence is

$$q^*(r)=\begin{cases}0 & \text{if } r>\hat{r}\\ [0,1] & \text{if } r=\hat{r}\\ 1 & \text{if } r<\hat{r}\end{cases} \quad \text{(A.2)}$$

The two correspondences intersect only at $(r^*,q^*)=(\hat{r},\hat{q})$ and hence it is the only mixed-strategy Nash equilibrium.

d. If $\theta>\overline{\theta}$,

[12] When $d_E<d_E^{II}<d_E^I$ and $d_U<d_U^{II}<d_U^I$, $\pi_E^{DD}>\pi_E^{ND}$ and $\pi_U^{DD}>\pi_U^{DN}$, so DD is the unique equilibrium.

[13] When $d_E<d_E^{II}<d_E^I$ and $d_U^{II}<d_U<d_U^I$, $\pi_E^{DD}>\pi_E^{ND}$ and $\pi_U^{DD}>\pi_U^{DN}$, so DD is the unique equilibrium.

[14] When $d_E^{II}<d_E<d_E^I$ and $d_U<d_U^{II}<d_U^I$, $\pi_E^{DD}>\pi_E^{ND}$ and $\pi_U^{DD}>\pi_U^{DN}$, so DD is the unique equilibrium.

[15] When $d_E^{II}<d_E^I<d_E$ and $d_U^{II}<d_U<d_U^I$, $\pi_E^{NN}>\pi_E^{DN}$ and $\pi_U^{NN}>\pi_U^{ND}$, so NN is the unique equilibrium.

[16] When $d_E^{II}<d_E^I<d_E$ and $d_U^{II}<d_U^I<d_U$, $\pi_E^{NN}>\pi_E^{DN}$ and $\pi_U^{NN}>\pi_U^{ND}$, so NN is the unique equilibrium.

[17] When $d_E^{II}<d_E<d_E^I$ and $d_U^{II}<d_U^I<d_U$, $\pi_E^{NN}>\pi_E^{DN}$ and $\pi_U^{NN}>\pi_U^{ND}$, so NN is the unique equilibrium.

[18] When $d_E^{II}<d_E<d_E^I$ and $d_U^{II}<d_U<d_U^I$, $\pi_E^{DD}>\pi_E^{ND}$, $\pi_U^{DD}>\pi_U^{DN}$, $\pi_E^{NN}>\pi_E^{DN}$ and $\pi_U^{NN}>\pi_U^{ND}$, so DD and NN are the two pure-strategy equilibria.

The unique Pareto-dominant equilibrium of the two Nash equilibria DD and NN in case [18] is NN, because of the following. To show that $\pi_E^{DD}<\pi_E^{NN}$ in case [18], recall that $\pi_E^{DD}>\pi_E^{NN}$ iff

$$d_E<\frac{\delta_{DD}-\theta\delta_{NN}}{\delta_{DD}+\frac{m}{1-m}}(p_E-c_E).$$

Notice that

$$d_E^I>d_E>d_E^{II}=\frac{\theta\delta_{DN}-\theta\delta_{NN}}{\theta\delta_{DN}+\frac{m}{1-m}}(p_E-c_E)>\frac{\delta_{DD}-\theta\delta_{NN}}{\delta_{DD}+\frac{m}{1-m}}(p_E-c_E),$$

where the inequality holds because $\theta\delta_{DN}>\delta_{DD}$ for any $d_U^I>0$. This is a contradiction, and so $\pi_E^{DD}<\pi_E^{NN}$.

Similarly, to show that $\pi_U^{DD}<\pi_U^{NN}$ in case [18], recall that $\pi_U^{DD}>\pi_U^{NN}$ iff

$$d_U<\frac{\theta\delta_{NN}-\delta_{DD}}{1-\delta_{DD}}(p_U-c_U).$$

Notice that

$$d_U^I>d_U>d_U^{II}=\frac{\theta\delta_{NN}-\delta_{ND}}{1-\delta_{ND}}(p_U-c_U)>\frac{\theta\delta_{NN}-\delta_{DD}}{1-\delta_{DD}}(p_U-c_U),$$

where the inequality holds because $\delta_{DD}>\delta_{ND}$. This is a contradiction, and so $\pi_U^{DD}<\pi_U^{NN}$. Because $\pi_E^{DD}<\pi_E^{NN}$ and $\pi_U^{DD}<\pi_U^{NN}$, NN is the unique Pareto-dominant equilibrium. □

Proof of Proposition 2. Notice that the structure of Proposition 2 is parallel to that of Proposition 1, and the equilibrium regions are analogous. So it is sufficient to show that the conditions are equivalent. First notice (from Lemma 1) that $\delta_{DD}=\delta_{ND}+\Delta_E$, $\delta_{NN}=\delta_{ND}+\Delta_U$, and also $\delta_{DN}=\delta_{ND}+\Delta_E+\Delta_U$ because

$$\begin{aligned}\delta_{DN}-\delta_{DD}=\Delta_U\Rightarrow\delta_{DN}&=\delta_{DD}+\Delta_U\\&=\delta_{DD}+\delta_{NN}-\delta_{ND}\\&=\delta_{DD}+\delta_{NN}-\delta_{ND}+\delta_{ND}-\delta_{ND}\\&=\delta_{DD}-\delta_{ND}+\delta_{NN}-\delta_{ND}+\delta_{ND}\\&=\Delta_E+\Delta_U+\delta_{ND}\end{aligned}$$

Next we substitute these expressions into the conditions of Proposition 1. For example, to show that the first condition in part a of Proposition 1 ($d_E^I<d_E$) is equivalent to the corresponding condition in Proposition 2 ($\Delta_E^I>\Delta_E$),

$$\begin{aligned}d_E^I&=\frac{\delta_{DD}-\delta_{ND}}{\delta_{DD}+\dfrac{m}{1-m}}(p_E-c_E)\\&=\frac{\Delta_E}{\delta_{ND}+\Delta_E+\dfrac{m}{1-m}}(p_E-c_E)<d_E\Longleftrightarrow\\ \Delta_E&<\frac{d_E\left(\delta_{ND}+\dfrac{m}{1-m}\right)}{p_E-c_E-d_E}\equiv\Delta_E^I\end{aligned}$$

The equivalent conditions involving thresholds Δ_E^{II}, Δ_U^I and Δ_U^{II} can be similarly derived from the conditions $d_E<d_E^{II}$, $d_U<d_U^I$ and $d_U<d_U^{II}$, respectively. To show that $\Delta_U^I<\Delta_U^{II}\Longleftrightarrow\theta>\overline{\overline{\theta}}$:

$$\begin{aligned}\Delta_U^I-\Delta_U^{II}&=\frac{d_U}{(p_U-c_U)\theta}+\left[(1-\theta)-\frac{d_U}{(p_U-c_U)}\right]\frac{\delta_{ND}+\Delta_E}{\theta}\\&\quad-\frac{d_U}{(p_U-c_U)\theta}+\left[(1-\theta)-\frac{d_U}{(p_U-c_U)}\right]\frac{\delta_{ND}}{\theta}\\&=\left[(1-\theta)-\frac{d_U}{(p_U-c_U)}\right]\frac{\Delta_E}{\theta}>0\Longleftrightarrow\end{aligned}$$

$$(1-\theta)-\frac{d_U}{(p_U-c_U)}>0 \iff$$
$$\theta<1-\frac{d_U}{(p_U-c_U)}\equiv\overline{\overline{\theta}}$$

The derivation of the disclosing probabilities for the mixed-strategy equilibrium, and the proof of Pareto dominance for the region with multiple probabilities, are also analogous to Proposition 1. □

Proof of Proposition 3. As above, the structure of Proposition 3 is parallel to that of Proposition 1, and the equilibrium regions are analogous. So it is sufficient to show that the conditions are equivalent.

For example, to show that the first condition in part a of Proposition 1 ($d_E^I<d_E$) is equivalent to the corresponding condition in Proposition 3 ($m^I<m$),

$$d_E>d_E^I=\frac{\delta_{DD}-\delta_{ND}}{\delta_{DD}+\frac{m}{1-m}}(p_E-c_E) \iff$$
$$\frac{m}{1-m}>\frac{\delta_{DD}-\delta_{ND}}{d_E}(p_E-c_E)-\delta_{DD} \iff$$
$$m>\frac{(\delta_{DD}-\delta_{ND})\frac{p_E-c_E}{d_E}-\delta_{DD}}{1+(\delta_{DD}-\delta_{ND})\frac{p_E-c_E}{d_E}-\delta_{DD}}\equiv m^I$$

The equivalent conditions involving thresholds m^{II}, θ^I and θ^{II} can be similarly derived from the conditions $d_E<d_E^{II}$, $d_U<d_U^I$ and $d_U<d_U^{II}$, respectively. To show that $\theta^I>\theta^{II} \iff d_U<\overline{d_U}$:

$$\theta^I-\theta^{II}=\left(\frac{1-\delta_{DD}}{\delta_{DN}}\right)\left(\frac{d_U}{p_U-c_U}\right)+\frac{\delta_{DD}}{\delta_{DN}}-\left(\frac{1-\delta_{ND}}{\delta_{NN}}\right)\left(\frac{d_U}{p_U-c_U}\right)-\frac{\delta_{ND}}{\delta_{NN}}$$
$$=\frac{1}{\delta_{DN}\delta_{NN}}\Big[(\delta_{NN}-\delta_{NN}\delta_{DD})\frac{d_U}{p_U-c_U}+\delta_{NN}\delta_{DD}$$
$$-(\delta_{DN}-\delta_{DN}\delta_{ND})\frac{d_U}{p_U-c_U}-\delta_{DN}\delta_{ND}\Big]$$
$$=\frac{1}{\delta_{DN}\delta_{NN}}\Big[(\delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND})-(\delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND}$$
$$+\delta_{DN}-\delta_{NN})\frac{d_U}{p_U-c_U}\Big]>0$$
$$\Rightarrow \delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND}>(\delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND}+\delta_{DN}-\delta_{NN})\frac{d_U}{p_U-c_U}$$
$$\Rightarrow \frac{\delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND}}{\delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND}+\delta_{DN}-\delta_{NN}}>\frac{d_U}{p_U-c_U}$$
$$\Rightarrow \frac{\delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND}}{\delta_{NN}\delta_{DD}-\delta_{DN}\delta_{ND}+\delta_{DN}-\delta_{NN}}(p_U-c_U)\equiv\overline{d_U}>d_U$$

The derivation of the disclosing probabilities for the mixed-strategy equilibrium, and the proof of Pareto dominance for the region with multiple probabilities, are also analogous to Proposition 1. □

Proof of Proposition 4. As above, the structure of Proposition 4 is parallel to that of Proposition 1, and the equilibrium regions are analogous. So it is sufficient to show that the conditions are equivalent.

For example, to show that the first condition in part a of Proposition 1 ($d_E^I<d_E$) is equivalent to the corresponding condition in Proposition 4 ($(p_E-c_E)^I>p_E-c_E$), notice that

$$d_E>d_E^I=\frac{\delta_{DD}-\delta_{ND}}{\delta_{DD}+\frac{m}{1-m}}(p_E-c_E) \iff p_E-c_E<\frac{\delta_{DD}+\frac{m}{1-m}}{\delta_{DD}-\delta_{ND}}d_E\equiv(p_E-c_E)^I.$$

The equivalent conditions involving thresholds $(p_E-c_E)^{II}$, $(p_U-c_U)^I$ and $(p_U-c_U)^{II}$ can be similarly derived from the conditions $d_E<d_E^{II}$, $d_U<d_U^I$ and $d_U<d_U^{II}$, respectively. To show that $(p_U-c_U)^I>(p_U-c_U)^{II} \iff \theta<\overline{\theta}$:

$$(p_U-c_U)^1>(p_U-c_U)^{II} \iff \frac{1-\delta_{DD}}{\theta\delta_{DN}-\delta_{DD}}d_U>\frac{1-\delta_{ND}}{\theta\delta_{NN}-\delta_{ND}}d_U$$
$$\Rightarrow \frac{\theta\delta_{NN}-\delta_{ND}}{1-\delta_{ND}}>\frac{\theta\delta_{DN}-\delta_{DD}}{1-\delta_{DD}}$$
$$\Rightarrow \frac{d_U^{II}}{(p_U-c_U)}>\frac{d_U^I}{(p_U-c_U)}$$
$$\Rightarrow \theta<\overline{\theta}$$

by Lemma 1 and the definitions of d_U^I and d_U^{II}.

The derivation of the disclosing probabilities for the mixed-strategy equilibrium, and the proof of Pareto dominance for the region with multiple probabilities, are also analogous to Proposition 1. □

Proof of Proposition 5.

a. If $m=0$ and $\theta>\theta^I$, then the conditions for Proposition 3.c (i) and d(i) are met, since $m=0<m^I$ and $m=0<m^{II}$. If $\theta<\theta^I$, the conditions for Proposition 3.b are met.
b. If $m=1$ and $\theta>\theta^{II}$, then the conditions for Proposition 3.a are met, since $m=1>m^I$. If $\theta<\theta^{II}$, the conditions for Proposition 3.c(ii) and d(ii) are met, since $m=1>m^I$ and $m=1>m^{II}$.
c. If $\theta=0$, the conditions for Proposition 3.c(ii) and d(ii) are met, since $\theta=0<\theta^I$ and $\theta=0<\theta^{II}$, and also $m^{II}=0<m$.
d. If $\theta=1$ and $m<m^I$, the conditions for Proposition 3.c(i) and d.(i) are met, since $\theta=1>\theta^I$ and $\theta=1>\theta^{II}$. If $\theta=1$ and $m>m^I$, the conditions for Proposition 3.a are met. □

References

Ackerman, A., 2014. US Appellate Faults SEC's 'Conflict Minerals Arguments' Rule. Wall Street Journal, April 14.
Andersen, M., Skjoett-Larsen, T., 2009. Corporate social responsibility in global supply chains. Supply Chain Manag.: Int. J. 14 (2), 75–86.
Anonymous, 2010. Suppliers Need to Prove Green Credentials. Logistics Manager, March.
Awaysheh, A., Klassen, R.D., 2010. The impact of supply chain structure on the use of supplier socially responsible practices. Int. J. Oper. Prod. Manag. (12), 1246–1268.
Ayogu, M., Lewis, Z., 2011. Conflict Minerals: An Assessment of the Dodd-Frank Act. ⟨http://www.brookings.edu/research/opinions/2011/10/03-conflict-minerals-ayogu⟩. Online [accessed 22-04-14].
Belavina, E., Girotra, K., 2014. Supply Networks for Relational Sourcing. Technical Report, INSEAD. Working Paper.
Bellman, E., 2012. Paper maker sows greener image. Wall Street J. (September (4)), B.10.
Bradshaw, J., 2011. Conflict mineral law is helping Congolese. Wall Street J. (July 23), A.12.
Castka, P., Balzarova, M.A., 2008. ISO 26000 and supply chains—on the diffusion of the social responsibility standard. Int. J. Prod. Econ. 111, 274–286.
Chasan, E., 2012. CFO journal: the big number. Wall Street J. (October (9)), B.7.
Chasan, E., Schectman, J., 2014. CFO journal: war and the supply chain—companies unearth few answers about whether vendors used 'conflict minerals'. Wall Street J. (May (20)), B.8.
Clark, D., 2014. Intel Documents Conflict-free Minerals Claim. ⟨http://blogs.wsj.com/riskandcompliance/2014/05/22/intel-documents-conflict-free-minerals-claim⟩. Online [accessed 25-05-14].
Dam, L., Petkova, B., 2014. The impact of environmental supply chain sustainability programs on shareholder wealth. Int. J. Oper. Prod. Manag. 34 (5), 586–609.
Davidoff, S.M., 2014. Apple says war zones don't ship its supplies. New York Times (February (14)), B.7.
de Brito, M.P., Carbone, V., Blanquart, C.M., 2008. Towards a sustainable fashion retail supply chain in Europe: organisation and performance. Int. J. Prod. Econ. 114, 534–553.

DiPietro, B., 2014a. Appeals Court Hears Conflict Minerals Arguments. ⟨http://blogs.wsj.com/riskandcompliance/2014/01/07/appeals-court-hears-conflict-minerals-arguments/⟩. Online [accessed 29-05-14].
DiPietro, B., 2014b. Automakers Face 'Herculean' Task in Implementing Supply Chain Guidelines. ⟨http://blogs.wsj.com/riskandcompliance/2014/05/28/automakers-face-herculean-task-in-implementing-supply-chain-guidelines/⟩. Online [accessed 31-05-14].
Doorey, D., 2011. The transparent supply chain: from resistance to implementation at Nike and Levi-Strauss. J. Bus. Ethics 103, 587–603.
European Commission, 2014. Non-financial Reporting. ⟨http://ec.europa.eu/internal_market/accounting/non-financial_reporting/index_en.htm⟩. Online [accessed 19-09-14].
European Parliament, 2013. Report on Corporate Social Responsibility: Accountable, Transparent and Responsible Business Behaviour and Sustainable Growth. ⟨http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A7-2013-0017+0+DOC+XML+V0//EN⟩. Online [accessed 19-09-14].
Fair Labor Association, 2014. Improving Workers' Lives Worldwide. ⟨http://www.fairlabor.org/⟩ Online [accessed 26-09-14].
Gallear, D., Ghobadian, A., Chen, W., 2012. Corporate responsibility, supply chain partnership and performance: an empirical examination. Int. J. Prod. Econ. 140, 83–91.
Garry, M., 2013. Safeway tackles issue of slavery in supply chain. Supermark. News 61 (8), 26–27.
Gilbert, D., 2014. Exxon to Disclose `Emissions Risk. Wall Street J. (March 20), B1.
Gimenez, C., Tachizawa, E.M., 2012. Extending sustainability to suppliers: a systematic literature review. Supply Chain Manag.: Int. J. 17 (5), 531–543.
Goodman, J., 2012. Watch Conflict Minerals Rule, PE CCOs Warned. Compliance Reporter (October 22).
Greenpeace, 2012. People! Zara Commits to go Toxic-Free. ⟨http://www.greenpeace.org/international/en/news/features/Zara-commits-to-go-toxic-free/⟩. Online [accessed 19-09-14].
Greenpeace, 2013. Japan's Uniqlo Adds Detox Commitment to Springs Wardrobe Essentials. ⟨http://www.greenpeace.org/international/en/news/Blogs/makingwaves/japans-uniqlo-adds-detox-commitment-to-spring/blog/43593/⟩. Online [accessed 19-09-14].
Guo, R., Lee, H., Swinney, R., 2013. The Impact of Supply Chain Structure on Responsible Sourcing. Technical report, Stanford University. Working Paper.
Harbert, T., 2010. Conflict-minerals law spotlights electronics supply chain. EDN (October 7), 85.
H&M, 2014. Our Supplier List. ⟨http://sustainability.hm.com/en/sustainability/downloads-resources/resources/supplier-list.html⟩ Online [accessed 19-09-14].
Hochfelder, B., 2014. Preparing for the conflict mineral rule. Supply Demand Chain Execut. (March), 12–16.
Holmes, E., 2014. Fashion brands- message for fall shoppers: buy less, spend more. Wall Street J. (September 3).
Holzer, J., 2012. Wal-Mart, Target avoid mining rule—big U.S. retailers are expected to escape Dodd-Frank 'conflict mineral' disclosure requirement. Wall Street J. (August 23).
Hsueh, C.-F., 2014. Improving corporate social responsibility in a supply chain through a new revenue sharing contract. Int. J. Prod. Econ. 151, 214–222.
Hwang, J.S., 2013. Conflict minerals: a snapshot. SMT Mag. (March), 8–12.
Jena, S.K., Sarmah, S.P., 2014. Price competition and co-operation in a duopoly closed-loop supply chain. Int. J. Prod. Econ. 156, 214–222.
Jira, C., Toffel, M.W., 2014. Engaging supply chains in climate change. Manufact. Serv. Oper. Manag. 15 (54), 346–360.
Kim, S.-H., 2013. Time to come clean? Disclosure and Inspection Policies for Green Production. Technical report, Yale University. Working Paper.
King, I., 2014. Intel Endures Resistance Starving Africa's Militia Mines. ⟨http://www.bloomberg.com/news/2014-05-27/intel-endures-resistance-starving-africa-s-militia-mines.html⟩. [Online; accessed 27-May-2014].
Lenovo Group, 2014. 2012/2013 Lenovo Sustainability Report. ⟨www.lenovo.com/social_responsibility/us/en/FY2013_Lenovo_Sustainability_Report.pdf⟩. Online [accessed 19-09-14].
Lezhnev, S., Hellmuth, A., 2012. Taking Conflict Out of Consumer Gadgets. http://www.enoughproject.org/reports? Online [accessed 18-04-14].
Marti, J.M.C., Seifert, R.W., 2013. Assessing the comprehensiveness of supply chain environmental strategies. Bus. Strat. Environ. 22, 339–356.
Meleske, M., 2011. Heavy metals: Dodd–Frank's provisions addressing conflict minerals present a complex, costly challenge to companies. Inside Counsel 1 (December), 28–29.
Mont, J., 2012. Legal challenge delays conflict minerals rule. Compliance Week (December), 12–13 [Online; accessed 18-April-2014].
New, S., 2010. The transparent supply chain. Harv. Bus. Rev. (October), 76–82.
Ni, D., Li, K.W., 2012. A game-theoretic analysis of social responsibility conduct in two-echelon supply chains. Int. J. Prod. Econ. 138, 303–313.
Okongwu, U., Morimoto, R., Lauras, M., 2013. The maturity of supply chain sustainability disclosure from a continuous improvement perspective. Int. J. Prod. Perform. Manag. 62 (8), 827–855.
O'Rourke, D., 2014. The science of sustainable supply chains. Science 344 (6188), 1124–1127.
Pearson, M., 2013. The business value of supply chain sustainability. Logist. Manag. (June), 20–21.
Pedersen, E.R.G., Gwozdz, W., 2013. From resistance to opportunity-seeking: strategic responses to institutional pressures for corporate social responsibility in the Nordic fashion industry. J. Bus. Ethics 119, 245–264.
Plambeck, E.L., Taylor, T.A., 2014. Supplier Evasion of a Buyer's Audit: Implications for Motivating Compliance with Labor and Environmental Standards. Technical report. Working Paper.
Plambeck, E.L., Lee, H.L., Yatsko, P., 2012. Improving environmental performance in your Chinese supply chain. MIT Sloan Manag. Rev. (Winter), 43–51.
Schuh, C., Strohmer, M., 2012. Conflict Minerals: Yet Another Supply Chain Challenge. Technical report, A.T. Kearney. Online [accessed 25-05-14].
Tang, C., 2010. A review of marketingoperations interface models: from co-existence to coordination and collaboration. Int. J. Prod. Econ. 125, 22–40.
Topping, N., 2012. How does sustainability disclosure drive behavior change? J. Appl. Corp. Finance 24 (2), 45–48.
Tozzi, J., 2014 Selling Ethical Fashion to the Whole Foods Set. ⟨http://www.businessweek.com/articles/2014-04-17/ethical-clothing-startups-sell-socially-responsible-apparel⟩. Online [accessed 29-04-14].
Wakabayashi, D., 2014. Apple says suppliers forgo a disputed metal. Wall Street J. (February (13)), B.6.
Winter, C., 2013. Why It's Hard to Make An Ethically Sourced Smartphone. ⟨http://www.businessweek.com/printer/articles/154388-why-its-hard-to-make-an-ethically-sourced-smartphone⟩. Online [accessed 14-05-14].
Ye, G., Mukhopadhyay, S.K., 2013. Role of demand-side strategy in quality competition. Int. J. Prod. Econ. 145, 696–701.
Zhen, L., 2012. An analytical study on service-oriented manufacturing strategies. Int. J. Prod. Econ. 39, 220–228.
Zweig, J., 2011. The intelligent investor: can annual reports save lives?. Wall Street J. (December (17)), B1.