Article forthcoming in *Manufacturing & Service Operations Management*

Ensuring Corporate Social and Environmental Responsibility through Vertical Integration and Horizontal Sourcing

Adem Orsdemir
School of Business Administration, University of California Riverside, Riverside, CA 92521, adem.orsdemir@ucr.edu

Bin Hu
Naveen Jindal School of Management, University of Texas at Dallas, Dallas, TX 75080, bin.hu@utdallas.edu

Vinayak Deshpande
Kenan-Flagler Business School, University of North Carolina at Chapel Hill, Chapel Hill, NC 27599, vinayak_deshpande@kenan-flagler.unc.edu

Problem Definition: Firms have recently vertically integrated with suppliers to ensure corporate social and environmental responsibility (CSER) in sourcing. We investigate the conditions under which CSER concerns will drive vertical integration, and how actions of non-governmental organizations (NGOs) impact CSER.

Academic/Practical Relevance: This paper is inspired by Taylor Guitars' acquisition of an ebony mill in Cameroon to ensure CSER. Whereas the majority of the responsible sourcing literature focuses on auditing as a mechanism for addressing CSER, we study vertical integration as an alternative. Our analysis confirms that CSER can be a potential driver of vertical integration aside from other well-known drivers.

Methodology: We analyze game-theoretical models where a firm can vertically integrate to potentially eliminate CSER risks. Two innovative features of our models are *demand externalities*, namely a firm's CSER violation can positively or negatively affect its competitor's demand; and *horizontal sourcing*, namely a vertically integrated firm can sell responsibly sourced supply to a competitor.

Results: We show that a firm's CSER strategy depends on the risk of a CSER violation exposure, the level of demand externalities (positive or negative), and whether horizontal sourcing is feasible. We find that in industries where horizontal sourcing is unlikely, firms stay disintegrated under a low CSER violation exposure risk and vertically integrate under a moderate CSER violation exposure risk. Surprisingly, firms may stay disintegrated under a high CSER violation exposure risk combined with strongly negative demand externalities. In contrast, firms vertically integrate under moderate-to-high CSER violation exposure risk when horizontal sourcing is possible, but may not share responsibly sourced supply through horizontal sourcing under strongly positive demand externalities.

Managerial Implications: We show that firms should be conscious about demand externalities and the possibility of horizontal sourcing in the industry when considering vertical integration for CSER. We also provide guidance to NGOs interested in promoting CSER. When horizontal sourcing is unlikely, NGOs should specify both violating and non-violating firms in their reports, but not over-scrutinize firms; whereas when horizontal sourcing is possible, NGOs should allocate more resources for scrutinizing firms' CSER violations and create industry-wide violation reports, while avoiding naming specific firms in their reports.

Key words: responsible sourcing, CSER, NGO, demand externalities
History: Accepted for publication June 2018

Article forthcoming in *Manufacturing & Service Operations Management*

1. Introduction

In recent years, several corporate social and environmental responsibility (CSER) violations have come under public scrutiny. *Daily Mail* (2011) revealed that workers in Nike's Taiwanese-operated overseas plant were only paid 50 cents per hour, and were mentally and physically abused by their supervisors. Nike had faced similar controversies about their suppliers treating workers poorly since the 1990's. After these incidents, Nike saw its sales decrease and its stock price dropped due to the negative publicity (Wazir 2001). In 2013, Rana Plaza, a factory building in Bangladesh, collapsed and killed more than 1,000 workers, making it one of the deadliest industrial disasters in human history. A report revealed that despite clear evidence that the building was a safety hazard, workers were made to continue working there (Yardley 2013b). At the time of its collapse, Rana plaza housed several garment factories making clothing for well-known European and American brands, including Benetton, Bonmarche, the Children's Place, Mango, Primark, and Walmart. After the incident, these brands faced widespread protests (Greenhouse 2013). As supply chains have become more complex and globalized, managing CSER has become increasingly challenging.

Taylor Guitars, a high-end guitar manufacturer in the US, faced similar CSER challenges. High-end guitars are made from exotic woods for their acoustic and aesthetic qualities. One such wood is ebony, an endangered species mainly growing in West Africa, which is sought-after for its unique black color. Low supply and high demand led to widespread illegal and unsustainable ebony harvesting practices. Gibson, another major guitar manufacturer, was raided in 2009 and again in 2011 by federal marshals for trafficking in illegally-sourced woods including ebony (Havighurst 2011). These incidents cost the company $2 to $3 million (Poor 2011), and drew criticism from environmental and industry groups (Sasso 2011). To avoid similar legal ramifications and negative publicity, Taylor Guitars resorted to *vertical integration*. In 2011, Taylor Guitars purchased Crelicam, the largest ebony mill in Cameroon, and made great efforts to ensure CSER in its ebony sourcing from Crelicam (White 2012).

Taylor Guitars had to navigate Cameroon's complex and often obscure regulations to obtain all required permits. They also doubled worker wages and made sure that Crelicam operated in alignment with both Cameroon and U.S. Labor Laws. They went on to carefully inspect and rectify irresponsible practices in day-to-day operations at Crelicam. For example, they discovered a disturbing yet prevalent practice in ebony harvesting that loggers had been cutting down an average of ten trees to use just one, leaving nine downed trees to rot. This was because buyers traditionally expect pitch-black ebony wood, yet most ebony trees provide striped-wood on the inside. Becoming aware of this practice, Taylor Guitars decided to use striped ebony in its flagship guitars, and launched campaigns to raise consumer awareness and promote the use of striped ebony. In addition, Taylor Guitars plans to make investments and train workers so that Crelicam can further process ebony into semi-finished products which would create more jobs and allow the Cameroonian people to reap greater economic benefits from their native resources (Arnseth 2013, White 2012, *Taylor Guitars* 2012). Interestingly, Taylor Guitars is willing to share its responsibly-sourced ebony with competitors through *horizontal sourcing*. It supplies ebony obtained from Crelicam to other "instrument-making clients", and guarantees that the wood has been acquired legally and ethically, with a commitment to long-term sustainability (*Taylor Guitars* 2012). We learned about Taylor Guitars' responsible-sourcing endeavors first-hand from its Director of Supply Chain, Charlie Redden, who oversaw the Crelicam project, and were intrigued by Taylor Guitars' adoption of vertical integration for CSER and its openness to share responsibly-sourced supply with competitors.

Auditing is another popular strategy to manage CSER in sourcing (Gayathri 2013, Chen et al. 2015, Xu et al. 2017, Caro et al. 2015). Because auditing tends to be easier and cheaper to implement and manage than vertical integration, firms may first consider auditing for CSER in sourcing. However, auditing is not always effective. For example, Taylor Guitars found it practically impossible to verify a supplier's CSER status in Cameroon's legal, political, and economic environments. Plambeck and Taylor (2016) also find analytically that auditing may cause suppliers to hide violations rather than rectify their practices. In situations where auditing may be ineffective, vertical integration becomes a powerful alternative because it grants the buying firm full knowledge and control of the supplier's operations, and thus is less susceptible to risks that undermine auditing's effectiveness. While economic drivers of vertical integration have been studied in the literature, our first objective is to investigate whether and when CSER incentives may drive firms to vertically integrate with suppliers.

The other interesting observation is that Taylor Guitars is open to sharing responsible supply with competitors through horizontal sourcing (which is enabled by vertical integration). Horizontal sourcing is not uncommon in practice. For example, Samsung supplies iPhone chips and displays for Apple (Vance 2013), and Toyota's subsidiary Aisin supplies transmission modules to BMW, Chrysler, Volvo and other car manufacturers (*Aisin* 2015). In the above cases, horizontal sourcing is likely driven by direct cost considerations, but as we will explain later, CSER risks may also motivate horizontal sourcing.

A CSER violation exposed at a supplier impacts its clients' demands as consumers may forgo buying products tainted by the violation, but the impact is often not limited to the directly-involved firm. On one hand, negative publicity from a CSER violation may lead consumers to switch to competitors' products (Guo et al. 2016). We refer to this effect as a CSER violation's *positive externality* (because it increases competitors' demands). On the other hand, a CSER violation may also generate a *negative externality* and decrease competitors' demands by raising public suspicion about the industry's general practices. This is especially the case in industries where major suppliers are clustered in a geographic region. For instance, Yardley (2013a) reports that the collapse of Rana Plaza had "placed the entire global supply chain that delivers clothes from Bangladeshi factories to Western consumers under scrutiny." Therefore, it is plausible that a vertically-integrated firm may willingly share responsible supply with competitors in order to avoid negative externalities from competitors' potential violations, and the nature of CSER externalities in an industry (positive or negative) may affect firms' behavior in general. Accordingly, our second objective is to understand how CSER externalities affect a firm's vertical integration decisions, and whether the possibility of horizontal sourcing can mitigate externalities.

We also note that non-governmental organizations (NGOs) can influence firms' responsibility behavior in several ways. First, NGOs' scrutiny affects the likelihood of a CSER violation being exposed. It has been suggested that intense scrutiny deters CSER violations (Baron et al. 2011, Greenhouse 2013). Second, how NGOs report CSER violations may influence the violations' externalities. When a report broadly indicts an industry or a region, negative externalities are likely to ensue. An example is by *Greenpeace* (2009), which states that "the cattle sector in the Brazilian Amazon is the largest driver of deforestation in the world." Such a report may raise consumer suspicions against all Brazilian cattle ranches regardless of whether their actions directly damaged the Amazon rainforest. On the flip side, NGOs can be more specific about firms directly involved in a violation while exonerating uninvolved firms. For instance, *Greenpeace* (2012) ranks companies by their environmental performances. In this report, Wipro is ranked a top performer, whereas RIM, Toshiba and Sharp are found at the bottom and criticized for their lack of commitment to sustainability. Hence, our third objective is to analyze the impact of NGOs' CSER violation scrutiny and reporting policies on firms' vertical integration and horizontal sourcing decisions.

We study these research questions by modeling two competing firms, each with its own supplier and market share. One of the two firms is capable of vertically integrating with its supplier which would ensure CSER and eliminate its own risk of CSER violations. A disintegrated firm always faces the risk of a CSER violation exposure at its supplier which would reduce its demand, while the competing firm's demand might increase or decrease, capturing the possibly positive or negative violation externalities. We first consider industries where horizontal sourcing is unlikely, and show that firms stay disintegrated under low CSER violation exposure risk and vertically integrate under moderate CSER violation exposure risk, but surprisingly may stay disintegrated under high CSER violation exposure risk combined with strongly negative demand externalities. Next, we consider industries where horizontal sourcing is possible. In this case, firms vertically integrate under moderate-to-high CSER violation exposure risk, but may not share responsible supply through

	CSER violation exposure risk	*Demand Externality*
No Horizontal Sourcing	High CSER violation risk may impede vertical integration	High (positive) externalities encourages vertical integration
Possible Horizontal Sourcing	High CSER violation risk encourages vertical integration	High (positive) externalities may impede horizontal sourcing

Table 1 Summary of results

horizontal sourcing under strongly positive demand externalities. These results are summarized in Table 1 and shown to be robust to several extensions in Section 6 and Appendix A.

The above results have important practical implications. A firm in a developed economy integrating with a supplier in a developing economy not only improves CSER but can also lead to improved pay, added value and opportunities of economic growth in the region where the supplier is located. However, it typically requires fixed investments and leads to increased sourcing costs for the firm. Therefore, it is unclear whether vertical integration is an economically viable strategy to improve CSER and stimulate economic growth in developing economies. Our study shows that despite the costs, vertical integration for CSER can be economically viable, suggesting that NGOs may indeed promote vertical integration to improve CSER and the livelihood of people in developing economies. Specifically, our study informs a firm of vertical integration strategies for CSER and highlights the importance of recognizing whether a violation at a competing firm would likely benefit or hurt itself, and whether horizontal sourcing is possible in the industry. It also offers guidelines to NGOs aiming at exposing violations to promote CSER. When horizontal sourcing is unlikely in an industry, NGOs should issue targeted violation reports to foster positive demand externalities, but be cautious about overly intense scrutiny of CSER violations which may backfire and impede vertical integration. By contrast, when horizontal sourcing is possible, more intense CSER violation scrutiny improves CSER, but NGOs should refrain from being overly specific in their reports which may discourage the sharing of responsibly sourced supply.

The rest of this paper is organized as follows. In Section 2 we survey the related literature. The model is introduced in Section 3. It is first analyzed without horizontal sourcing in Section 4, then with this option in Section 5, where we also compare the two cases. We then drive additional insights in four extensions in Section 6 before concluding our findings in Section 7. Appendix A contains two more extensions. Appendix B contains all proofs.

2. Literature

A relatively new but rapidly growing literature exists on CSER in sourcing. Kraft et al. (2013a) and Kraft et al. (2013b) investigate the removal of a potentially hazardous substance from a product in a competitive environment respectively from the manufacturer's and NGOs' perspectives. They consider manufacturers with full control over all aspects of production, whereas we model full control of the supply chain as a costly decision by the manufacturer (through vertical integration). Belavina and Girotra (2015) study the role of supply network structure in responsible supplier behavior in a long-term relational sourcing setting. Whereas they consider the supply network structure as an exogenous input, we endogenize the supply chain structure decision. Lin et al. (2016) are similarly inspired by Taylor Guitars but investigate another aspect of Taylor's CSER endeavor—co-production. Agrawal and Lee (2016) study how competing manufacturers can use sourcing policies to influence their suppliers' adoption of sustainable practices. They implicitly assume that manufacturers can perfectly verify suppliers' sustainable practices, whereas we focus on situations where this cannot be done unless a supply chain is vertically integrated. Guo et al. (2016) study a buyer's sourcing decision between a responsible supplier and a supplier with CSER risks when selling to a socially-conscious market. Although this paper has similarities with our work, mainly in that a firm can choose whether to ensure CSER in sourcing, there are key differences. First, they consider an isolated supply chain whereas we consider two competing supply chains. Moreover, they assume a pre-existing responsible supplier, whereas we require vertical integration with a supplier to ensure CSER in sourcing. Finally, we consider horizontal sourcing which is irrelevant in an isolated supply chain.

One important tool to mitigate CSER risks in sourcing is auditing. The literature has shown both its effectiveness and limitations. Plambeck and Taylor (2016) find that increasing auditing efforts may be detrimental due to suppliers' hiding efforts. Chen and Lee (2017) study a buyer's optimal contracting problem under different mitigation tools including auditing. Kim (2015) studies a manufacturer's disclosures of environmental noncompliance incidences when it is inspected by a regulatory body. Aral et al. (2014) study the value of third-party sustainability auditing in sourcing auctions, and conclude that the value of auditing does not necessarily increase for less sustainable supplier pools. Chen et al. (2015) study the interaction of whether a firm releases its supplier list with NGOs' auditing efforts and suppliers' compliance efforts. Caro et al. (2015) and Fang and Cho (2015) investigate joint and shared auditing. In contrast with these papers, we focus on vertical integration as an alternative tool to mitigate CSER risks when auditing may be ineffective.

Vertical integration as a strategy has been studied from various perspectives. Perry (1989) provides a comprehensive review and lists three main drivers of vertical integration: technological economies, transactional economies, and market imperfections. The first two reflect that vertical integration may generate some form of economies of scale. The third one reflects that vertical integration may improve efficiency by eliminating market imperfections such as information asymmetry. In our paper, we study a new driver of vertical integration, namely ensuring CSER in sourcing. In order to establish CSER as a new driver, we eliminate the aforementioned known drivers in our model: we do not assume economies of scale (in our model vertical integration causes sourcing costs to increase) or asymmetric information. Such a model allows us to conclude that CSER, independent of other known drivers, can drive vertical integration, thus contributing to the vertical integration literature. The only other paper to our knowledge that rigorously models CSER as a driver for vertical integration is by Fu et al. (2018), however they consider a monopolist manufacturer and do not incorporate several crucial elements in our model, such as violation externalities and horizontal sourcing.

3. Model

We model two competing firms selling products to their respective shares of the same market. Each firm has its own supplier, and the status quo is that neither supply chain is vertically integrated. We refer to a non-vertically-integrated firm as a buyer. We use A and B to respectively denote the two supply chains and their members. We assume that currently, each buyer can sell Q units of its product at exogenous retail price p. A unit of each buyer's product requires a unit of a critical component sourced from its supplier at exogenous wholesale price w. As explained in Section 1, we aim to study vertical integration as an alternative when conventional CSER risk mitigation tools such as auditing are ineffective. Accordingly, we assume that a supplier's compliance with CSER codes cannot be guaranteed unless a buyer obtains full control of the supplier through vertically integration. We denote by $\sigma \in (0,1)$ the probability that a CSER violation will be exposed at each supplier, and that the exposure probabilities for the two suppliers are independent (correlated exposure probabilities are investigated in Section 6.1). This parameter captures the CSER risks in the industry's conventional practices. All parties are risk-neutral.

If a violation is exposed at one supplier, its buyer's demand would be negatively affected. To be specific, we assume that the demand drops to $(1+\alpha)Q$, where $\alpha \in (-1,0)$ captures a violation's direct demand impact. Furthermore, as we discussed in Section 1, the CSER violation exposure may positively or negatively impact the competing firm's demand. Accordingly, we assume that the competing firm's demand becomes $(1+\beta)Q$, where $\beta \in (\alpha,-\alpha)$. The assumption that β may be positive or negative captures the possibly positive and negative externalities of exposed CSER violations. The assumption of $|\beta| < |\alpha|$ reflects the intuition that a violation exposure's direct impact should be stronger than its indirect impact. If violations are exposed at both suppliers, we assume both supply chains' demands are decreased to $(1+\alpha)Q$.

We make two notes about the demand model. First, we directly assume the demand changes after an exposed CSER violation instead of modeling market mechanisms that lead to such demand changes. We do so because market mechanisms behind the demand changes are not our focus, and that our model is simple yet general enough for our purpose. Such models have been adopted in the CSER literature (Boyaci and Gallego 2004, Kraft et al. 2013a,b); in particular, Fang and Cho (2015) adopt a setup very similar to ours to capture externalities of CSER violations. Second, we consider market sizes in terms of volume (demand) for simplicity, while keeping the retail price p exogenous—a setting adopted by Boyaci and Gallego (2004) and Huang et al. (2016), among others. In practice, firms may adjust their retail prices in response to exposed violations' demand impacts. However, even with responsive pricing, firms' revenue changes are likely qualitatively similar to the demand changes in our model, thus our structural results should not depend on this simplifying assumption. This intuition is confirmed in Appendix A.1 where we investigate an extension to endogenous retail prices.

Of the two buyers, we assume that only one can vertically integrate with its supplier for CSER. This assumption reflects the reality in many industries that vertical integration requires the buyer to have substantial knowledge about the supplier's operations and the environment wherein the supplier resides. For example, Taylor Guitars had many years of experience sourcing ebony from Cameroon before purchasing an ebony mill there (White 2012), and had the first and only (as of December 2013) vertically-integrated supply chain in the musical instrument industry (Arnseth 2013). (Furthermore, we investigate the case where both buyers can vertically integrate in Section 6.3 and obtain similar insights.) We assume that buyer A incurs a fixed cost f to integrate with supplier A and ensure CSER. (Along this line, the assumption that buyer B cannot integrate with supplier B may be interpreted as it having a prohibitively high fixed cost for integration.) Once buyer A integrates with supplier A to ensure CSER, the component sourcing cost becomes $c_r > w$. This assumption reflects that suppliers in developing economies often operate on thin margins and thus are economically unable to ensure CSER by themselves. The increased sourcing cost after vertical integration reflects the necessary investments and efforts to rectify irresponsible practices. For example, Taylor Guitars overcame great difficulties navigating a highly complex legal system to obtain all required permits, expanded power grid, and doubled worker salaries (White 2012). In return, firm A eliminates its own violation exposure risk (σ becomes 0). However, even in this case firm A may still be indirectly affected by an exposed violation at supplier B. This is because consumers may not be fully aware of a firm's CSER efforts, and may not trust a firm's CSER claims if a violation at a similar supplier has just been exposed.

An integrated firm A may set wholesale price w' to supply responsibly-sourced components to buyer B through horizontal sourcing, thus eliminating violation exposure risks at both supply chains. In this case, buyer B can choose to source components from either supplier B or firm A. (We investigate an extension where buyer B may dual-source from supplier B and firm A in Appendix A.2 and recover similar structural results.) Since horizontal sourcing is not ubiquitous

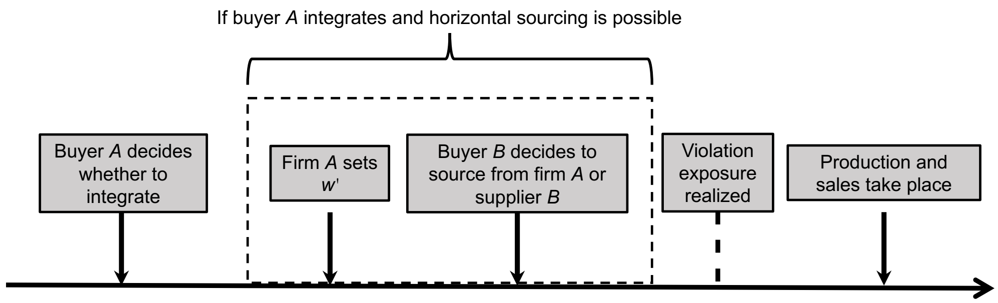


Figure 1 **Sequence of events in the model**

Symbol	Definition
$p > 0$	Retail price
$w > 0$	Component wholesale price from a supplier
$w' > 0$	Component wholesale price through horizontal sourcing (decision)
$c_r > w$	Unit cost of responsibly-sourced components
$f > 0$	Fixed cost of vertical integration
$Q > 0$	Current market size of each firm
$\alpha \in (-1, 0)$	Direct impact of an exposed violation
$\beta \in (\alpha, -\alpha)$	Indirect impact (externalities) of an exposed violation
$\sigma \in (0, 1)$	Probability of a violation exposure

Table 2 **Symbols in the main model**

in all industries, we first study a model assuming no horizontal sourcing in Section 4, and then allow this option in Section 5.

The sequence of events is presented in Figure 1. First, buyer A decides whether to vertically integrate with supplier A. Next, if horizontal sourcing is possible, a vertically-integrated firm A can set wholesale price w' for buyer B, who then decides to source from firm A or supplier B. Each disintegrated supplier is then exposed of a CSER violation with probability σ. Finally, the firms produce to satisfy demand. Table 2 lists all symbols in the main model.

4. Vertical integration without horizontal sourcing

We first analyze the model assuming no horizontal sourcing (i.e., an integrated firm A cannot supply buyer B). In practice, horizontal sourcing is not ubiquitous for a number of reasons. First, if a component is highly customized to a firm's specific requirements, it will be difficult for another firm to use the same component. Second, firms in industries where competition is intense may bear reluctance toward horizontal sourcing. For example, in recent years, Apple has sought to replace Samsung, a long-time supplier but also a major competitor in the smart phone and tablet markets, with other suppliers (Luk 2014). Therefore, it is important to analyze the model without horizontal sourcing. The analysis also serves as a basis of comparison with the model allowing horizontal sourcing in Section 5.

We use $\mathcal{I}$ and $\mathcal{D}$ to respectively denote buyer A's decision to integrate with supplier A and to stay disintegrated. Let π_X^i denote buyer i's expected profit when buyer A follows decision X. For example, $\pi_{\mathcal{I}}^B$ denotes buyer B's expected profit when buyer A is vertically integrated with supplier A. Below are the expressions of the expected profits:

$$\pi_{\mathcal{I}}^A = (p - c_r)Q[\sigma(1+\beta) + (1-\sigma)] - f,$$
$$\pi_{\mathcal{D}}^A = \pi_{\mathcal{D}}^B = (p-w)Q[\sigma^2(1+\alpha) + \sigma(1-\sigma)(1+\alpha) + (1-\sigma)\sigma(1+\beta) + (1-\sigma)^2],$$
$$\pi_{\mathcal{I}}^B = (p-w)Q[\sigma(1+\alpha) + (1-\sigma)].$$

We assume sufficiently small cost of responsibly-sourced component c_r and fixed cost f to eliminate uninteresting cases (the specific thresholds can be found in the proof of Proposition 1). The following proposition characterizes firm A's optimal strategy, which is visualized in Figure 2. Parameters used in generating the figure are $p = 2$, $w = 1/8$, $c_r = 1/4$, $Q = 4$, and $\alpha = -3/8$.

Proposition 1. *Assume no horizontal sourcing, and define* $\beta_1(f) = \frac{Q(c_r - w + \alpha(p-w)) + f}{Q(p - c_r)} < 0$.

1. *Firm A's optimal strategy is* $\mathcal{D}$*, if (i)* $\beta < \max(\alpha, \beta_2(f))$*; (ii)* $\max(\alpha, \beta_2(f)) < \beta < \beta_1(f)$ *and* $\sigma \in (0, \underline{\sigma}^R] \cup [\overline{\sigma}^R, 1)$*; or (iii)* $\beta_1(f) \le \beta$ *and* $\sigma \in (0, \underline{\sigma}^R]$.
2. *Firm A's optimal strategy is* $\mathcal{I}$*, if (i)* $\max(\alpha, \beta_2(f)) < \beta < \beta_1(f)$ *and* $\sigma \in (\underline{\sigma}^R, \overline{\sigma}^R)$*; or (ii)* $\beta_1(f) \le \beta$ *and* $\sigma \in (\underline{\sigma}^R, 1)$.

Furthermore, $\beta_2(f) > \alpha$ *if and only if* $f > f_1$*. The characterizations of* β_2*,* f_1*,* $\underline{\sigma}^R$ *and* $\overline{\sigma}^R$ *are found in the proof of the proposition.*

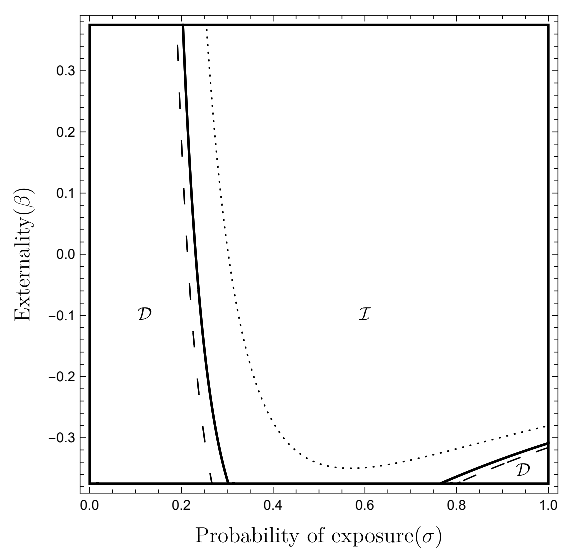


Figure 2 **Buyer A's optimal strategy assuming no horizontal sourcing (dashed boundary for $f = 0.10$, solid for $f = 0.15$, dotted for $f = 0.35$)**

Let us understand buyer A's optimal strategy. If the violation exposure probability is sufficiently low, firm A stays disintegrated and bears CSER violation risks, which is intuitive. This observation reflects the basic trade-off between avoiding one's own violation exposures and reducing sourcing costs. Less intuitive is the observation that, under strongly negative violation exposure externalities, high violation exposure probabilities can also drive firm A to stay disintegrated rather than to vertically integrate with supplier A to ensure CSER. The cause of this behavior is negative externalities. While an integrated firm A can eliminate its own violation risks through vertical integration, it is still susceptible to externalities if a violation is exposed at supplier B. When externalities are strongly negative and exposure probabilities are high, firm A's own CSER efforts become futile as its demand is likely to be negatively impacted by an exposed violation at supplier B anyway. As a result, firm A remains disintegrated.

The above observations have managerial implications for NGOs promoting CSER. They can influence the violation exposure probabilities to some extent by adjusting the resources allocated to scrutinizing firms, and it is tempting to assume that more intense scrutiny is more likely to pressure firms into ensuring CSER in sourcing (Baron et al. 2011, Greenhouse 2013). Nevertheless, our analysis suggests that in scenarios where externalities are strongly negative, NGOs' scrutiny efforts may backfire and impede CSER.

On the other hand, note that the $\mathcal{I}$ region grows as the externalities become more positive. This observation is formalized in the following proposition.

Proposition 2. *Assume no horizontal sourcing. The range of exposure probabilities σ where buyer A's optimal strategy is $\mathcal{I}$ grows as externality β is increased.*

Recall our discussion in Section 1 that NGOs can influence violation exposure externalities by choosing how they report violations: a report can broadly indict an industry or a region to foster negative externalities, or focus on directly involved firms while exonerating uninvolved firms to foster positive externalities. Proposition 2 suggests that, assuming no horizontal sourcing, higher externalities may be more in line with NGOs' objective of inducing CSER. (Interestingly, if horizontal sourcing is possible, this is no longer the case; see Section 5.)

Next we investigate the firms' profits. One might intuitively think that for buyer B which sources from a conventional supplier and faces direct violation exposure risks, an increase in the exposure probability would decrease its profit. Interestingly, this is not always true, as presented in the next proposition.

Proposition 3. *Assume $\beta < 0$, and buyer A's optimal strategy is $\mathcal{D}$. Increasing σ by $\tau \in (\underline{\tau}^c, \overline{\tau}^c)$ shifts the optimal strategy to $\mathcal{I}$ and increases buyer B's profit. The characterizations of Δ_1, $\underline{\tau}^c$ and $\overline{\tau}^c$ are found in the proof of the proposition.*

Under negative violation exposure externalities, buyer B may actually benefit from an increased probability of a violation exposure, because when it pushes firm A to vertically integrate, buyer B will be free of negative externalities due to firm A's violations.

To summarize, assuming no horizontal sourcing, our analysis suggests that violation exposure externalities significantly influence firms' behavior. In general, a firm is more likely to ensure CSER through vertical integration under higher externalities, but with strongly negative externalities, overly intense scrutiny may backfire and impede vertical integration. These findings provide instructive implications for NGOs to strategically influence the externalities and violation exposure probabilities to improve CSER in sourcing.

5. Vertical integration with horizontal sourcing

In this section, we analyze the model assuming horizontal sourcing is possible. We continue to use the notations from Section 4, where $\mathcal{D}$ and $\mathcal{I}$ respectively represent buyer A's strategy of staying disintegrated and vertically integrating with supplier A. Additionally, we use subscripts S or N on $\mathcal{I}$ to respectively denote whether or not buyer B sources from integrated firm A through horizontal sourcing. Recall that w' denotes the horizontal sourcing wholesale price set by integrated firm A. Using backward induction, we solve the three-stage (integration, pricing, production) sequential game as in Figure 1. The following proposition characterizes the equilibrium.

Proposition 4. *Assume horizontal sourcing is possible. There exists a threshold* $0 \le \beta_3(f) < \frac{w-c_r-\alpha(p-w)}{p-c_r}$ *such that*

1. *The equilibrium is* $\mathcal{D}$*, if (i)* $\beta \le \beta_3(f)$ *and* $\sigma \in (0, \sigma_1]$*; (ii) if* $\beta_3(f) < \beta$ *and* $\sigma \in (0, \underline{\sigma}^R]$.
2. *The equilibrium is* $\mathcal{I}_N$*, if (i)* $\beta_3(f) < \beta < \frac{w-c_r-\alpha(p-w)}{p-c_r}$ *and* $\sigma \in (\underline{\sigma}^R, \sigma_2]$*;or (ii) if* $\frac{w-c_r-\alpha(p-w)}{p-c_r} \le \beta$ *and* $\sigma \in (\underline{\sigma}^R, 1)$.
3. *The equilibrium is* $\mathcal{I}_S$*, if (i)* $\beta \le \beta_3(f)$ *and* $\sigma \in (\sigma_1, 1)$*; or (ii) if* $\beta_3(f) < \beta < \frac{w-c_r-\alpha(p-w)}{p-c_r}$ *and* $\sigma \in (\sigma_2, 1)$.

The equilibrium horizontal sourcing wholesale price is $w' = w + \alpha\sigma(w - p)$*. The threshold* $\beta_3(f)$ *is continuous and increasing function of* f *characterized in the proof of the proposition. The characterization of* $\underline{\sigma}^R$ *is found in Proposition 1, and those of* σ_1 *and* σ_2 *are found in the proof of the proposition.*

Figure 3 illustrates the equilibria generated with the same parameters as in Figure 2. An immediate observation about Figure 3 is that higher violation exposure probabilities drive firm A to vertically integrate and ensure CSER. This is in contrast with the case without horizontal sourcing (Figure 2) where higher exposure probabilities may impede vertical integration. As we explained in Section 4, where horizontal sourcing is unlikely, scrutiny may impede firm A's CSER efforts

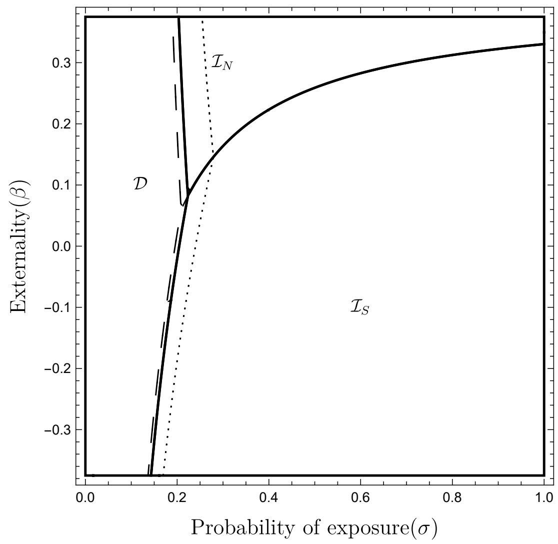


Figure 3 **Firms' equilibrium strategy allowing horizontal sourcing**
(dashed boundary for $f = 0.10$, solid for $f = 0.15$, dotted for $f = 0.35$)

because potential negative externalities of supplier B's violations may make the efforts futile. When horizontal sourcing is possible, however, firm A can eliminate negative externalities by sharing responsible supply with buyer B through horizontal sourcing, thus intense scrutiny always improves CSER. Furthermore, when firm A is integrated (the $\mathcal{I}$ regions), higher violation exposure probabilities induce firm A to share responsible supply with buyer B (equilibrium shifting from $\mathcal{I}_N$ to $\mathcal{I}_S$), expanding CSER to the entire industry. This is because under more intense scrutiny, buyer B is willing to pay more premium for responsible supply, strengthening firm A's incentive to share it.

We then investigate the impact of externalities. One can see in Figure 3 that higher violation exposure externalities cause the $\mathcal{D}$ and $\mathcal{I}_N$ regions to grow against the $\mathcal{I}_S$ region, which is formalized in the following proposition.

Proposition 5. *Assume horizontal sourcing is possible. The range of violation exposure probabilities σ where $\mathcal{I}_S$ is the equilibrium shrinks as externality β is increased.*

Furthermore, once again in contrast with the case without horizontal sourcing, strongly positive externalities may impede industry-wide CSER in sourcing: Proposition 5 and Figure 3 show that within the $\mathcal{I}$ regions where firm A is integrated, when externalities become strongly positive, firm A stops sharing responsible supply with buyer B (equilibrium shifting form $\mathcal{I}_S$ to $\mathcal{I}_N$). The reason is that with strongly positive externalities firm A actually benefits from supplier B's exposed violations. Therefore, while the possibility of horizontal sourcing resolves the complication that hinders the effectiveness of scrutiny, it creates a new complication in externalities' impacts on industry-wide CSER. These observations suggest that NGOs need to consciously consider whether horizontal sourcing is possible in the industry when choosing their scrutiny and reporting policies to avoid unintended consequences.

Next we investigate the firms' profits. Interestingly, we find that both firms may benefit from more intense scrutiny.

Proposition 6. *Assume $\beta < 0$ and $\sigma_1 - \Delta_2 < \sigma \leq \sigma_1$ so that the equilibrium is $\mathcal{D}$. Increasing σ by $\tau \in [\underline{\tau}^r, \overline{\tau}^r]$ shifts the equilibrium to $\mathcal{I}_S$ and increases both firm A and buyer B's profits. The characterizations of Δ_2, $\underline{\tau}^r$ and $\overline{\tau}^r$ are found in the proof of the proposition.*

Actually, in the case presented in Proposition 6, not only do both firms earn more profits, the industry is also transformed from fully conventional to fully responsible. Therefore, the society also benefits in terms of CSER, making this a win-win-win situation.

As a final note, we compare the CSER outcomes when horizontal sourcing is unlikely with those when horizontal sourcing is possible, and find that the possibility of horizontal sourcing strictly improves CSER (Proposition 7). Furthermore, when one compares Figures 2 and 3, it is apparent that the possibility of horizontal sourcing brings CSER to the entire industry in a significant parameter region. Therefore, the possibility of horizontal sourcing generally improves industry-wide CSER.

Proposition 7. $\mathcal{I} \subset \{\mathcal{I}_N \bigcup \mathcal{I}_S\}$.

To summarize, when horizontal sourcing is possible, intense scrutiny drives vertical integration, but strongly positive externalities may backfire and discourage an integrated firm from sharing responsible supply with competitors. These observations contrast starkly with those in Section 4 without horizontal sourcing, where higher externalities provide the right incentives, but overly intense scrutiny may backfire. Overall, the possibility of horizontal sourcing improves CSER.

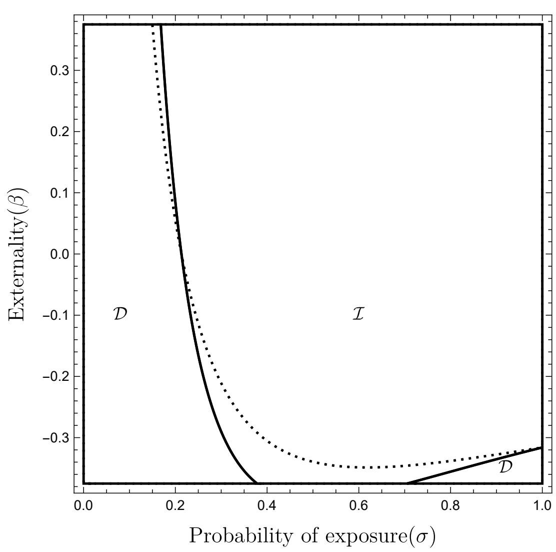
6. Extensions

In this section, we first study four extensions of the main model to drive additional insights, and then briefly discuss two additional extensions to confirm the robustness of our main results while relegating the analyses and more detailed discussions to Appendix A.

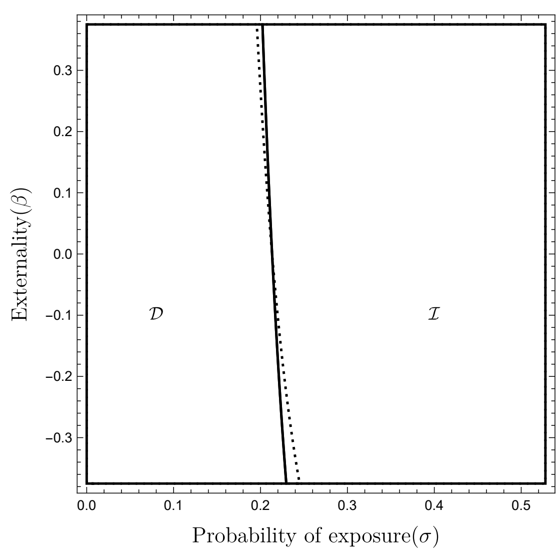
6.1. Correlated violation exposure risks

In the main model we have assumed independent violation exposure probabilities for the two suppliers. In practice, they may be correlated to some extent, either positively or negatively. Positive correlations may be due to that an exposed violation at a supplier draws more attention and scrutiny on other suppliers in the industry. On the other hand, observing an exposed violation at a supplier, other suppliers may take proactive measures to rectify and/or conceal malpractices, leading to negatively correlated violation exposure risks. Below we investigate the impact of correlated violation exposure probabilities by means of numerical studies.

Recall that in the main model each supplier faces an independent violation exposure probability σ. To introduce correlations without changing marginal probabilities (namely each supplier still has probability σ to be exposed of a violation), we adopt the correlated bi-variant Bernoulli model à la Hu and Kostamis (2015) as described below. We denote the joint probabilities of four possible exposure scenarios by q_{00}, q_{01}, q_{10} and q_{11} where 1 in the subscript represents a violation exposure and 0 represents no exposure at each supplier. For example, q_{10} represents the probability of a violation exposure at supplier A but not at supplier B. Using a parameter $r \in [-1,1]$ to indicate the correlation, we define $(q_{00},q_{01},q_{10},q_{11}) = (r\sigma(1-\sigma)+(1-\sigma)^2, (1-r)\sigma(1-\sigma), (1-r)\sigma(1-\sigma), r(1-\sigma)\sigma+\sigma^2)$ for $r \geq 0$, and $(q_{00},q_{01},q_{10},q_{11}) = (r\sigma^2+(1-\sigma)^2, \sigma-(r+1)\sigma^2, \sigma-(r+1)\sigma^2, (r+1)\sigma^2)$ for $r < 0$. As r is increased from -1 to 0 to 1, the two suppliers' violation exposure risks change from never occurring simultaneously ($q_{11} = 0$) to being independent to always occurring simultaneously ($q_{01} = q_{10} = 0$). Note that r is not the Pearson correlation coefficient but qualitatively similar.



(a) $r = 0.2$ and $r = 0.4$



(b) $r = -0.4$ and $r = -0.2$

Figure 4 **Buyer A's optimal strategy with correlated violation exposure probabilities, no horizontal sourcing (solid boundary for $r = 0.2$ in (a) and $r = -0.4$ in (b), dotted for $r = 0.4$ in (a) and $r = -0.2$ in (b))**

Figures 4 and 5 respectively depict buyer A's optimal strategies without and allowing horizontal sourcing for representative values of r. The other parameters are $p = 2$, $w = 1/8$, $c_r = 1/4$, $Q = 4$, $\alpha = -3/8$, and $f = 0.1$, as in previous figures. Case (a)'s of Figures 4 and 5 have positive correlations, and are structurally similar to Figure 2 and Figure 3, confirming that the insights from the main model continue to hold with positively correlated violation exposure risks. Case (b)'s of Figures 4 and 5 have negative correlations. In Figure 4, case (b) apparently does not share a similar structure as Figure 4, for the $\mathcal{D}$ region in the lower-right corner of Figure 2 does not exist in the lower panel of Figure 4. However, we note that case (b)'s do not cover the entire range of exposure probabilities, but are limited to $\sigma \lesssim 0.53$. This is because high marginal exposure probabilities cannot be negatively correlated. Therefore, case (b)'s of Figure 4 and 5 are not entirely comparable to Figure 2 and Figure 3; and where comparable ($\sigma \lesssim 0.53$), they are structurally similar. Finally, the boundaries between the $\mathcal{I}_N$ and $\mathcal{I}_S$ regions in Figure 5 remain unchanged for different values of r because in $\mathcal{I}$ regions firm A's exposure risks are eliminated, thus correlations become irrelevant.

An interesting question that would have important managerial implications is how correlations between violation exposure risks impact CSER outcomes. We find that with positive externalities, the regions where buyer A integrates with supplier A ($\mathcal{I}/\mathcal{I}_S/\mathcal{I}_N$) grow when the correlation is increased; and with negative externalities, these integration regions shrink when the correlation is increased (algebraically, rather than in absolute magnitude). The intuition is as follows. A higher correlation means that the world is less likely to be in the state where only one of the two suppliers is exposed of a violation. Consequently, a disintegrated buyer A is less likely to experience violation exposure externalities. Therefore, with positive (negative) externalities, higher correlation makes conventional practices less (more) attractive, causing the integration regions to grow (shrink). The above insight may be instructive for NGOs which can influence violation exposure correlations to some extent. For example, when a violation is exposed, NGOs can focus resources on the involved

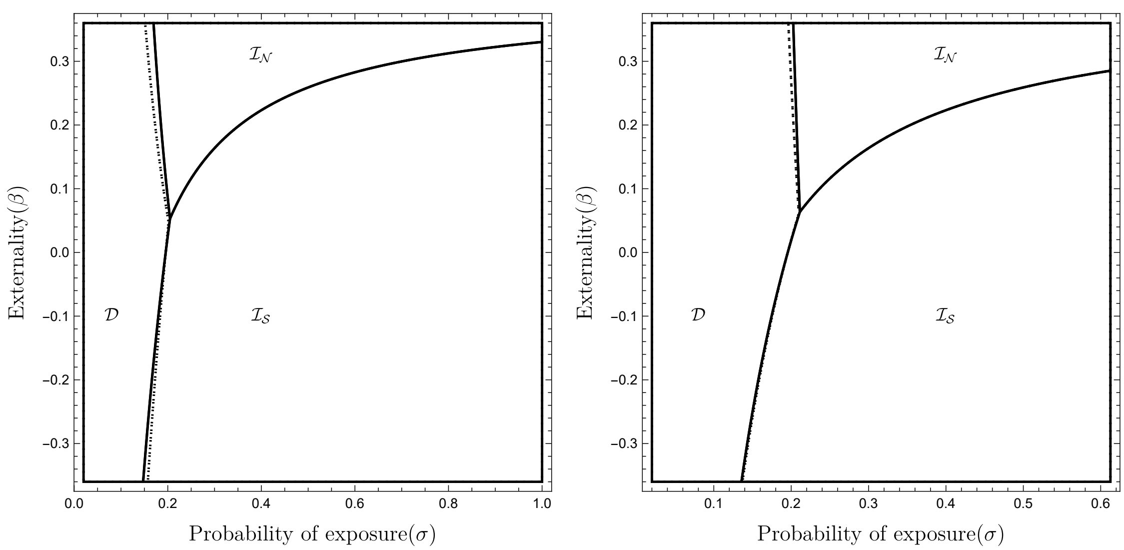


Figure 5 **Firms' equilibrium strategies with correlated violation exposure probabilities, with horizontal sourcing (solid boundary for $r = 0.2$ in (a) and $r = -0.4$ in (b), dotted for $r = 0.4$ in (a) and $r = -0.2$ in (b))**

supplier to reduce correlations, or allocate more resources for scrutinizing similar suppliers to increase correlations. Our results suggest that NGOs should consider the nature of externalities in the industry, and foster higher (lower) correlations with positive (negative) externalities.

6.2. Non-exclusive suppliers

In the main model we assumed that each buyer has its exclusive supplier. In this section, we extend the main model to allow buyers to choose one of two available suppliers (thus they may end up sourcing from a shared supplier). Specifically, if buyer A decides to stay disintegrated, both buyers simultaneously choose which of suppliers A and B to source from. In this case, if the buyers choose to source from a shared supplier, a violation exposure at this supplier affects both buyers' demands at the same time (i.e. both demands drop to $(1+\alpha)Q$). We denote the equilibrium where both buyers sharing a supplier by $\mathcal{D}_C$, and one where the buyers sourcing from different suppliers by $\mathcal{D}_U$. We present the case assuming no horizontal sourcing in Proposition 8 and Figure 6 which is generated with the same parameters as in Figure 2, and $f = 0.1$.

Proposition 8. *Assume no horizontal sourcing.*

1. *The equilibrium is* $\mathcal{D}_C$*, if (i)* $\beta \le \beta_1(f)$*; or (ii)* $\beta_1(f) < \beta < 0$ *and* $\sigma \in (0, \sigma_3]$*.*
2. *The equilibrium is* $\mathcal{D}_U$*, if* $0 \le \beta$ *and* $\sigma \in (0, \underline{\sigma}^R]$*.*
3. *The equilibrium is* $\mathcal{I}$*, if (i)* $\beta_1(f) < \beta < 0$ *and* $\sigma \in (\sigma_3, 1)$*; or (ii)* $0 \le \beta$ *and* $\sigma \in (\underline{\sigma}^R, 1)$*.*

The threshold σ_3 *is a continuous and decreasing function of* β *and its characterization is found in the proof of the proposition. The characterizations of* $\underline{\sigma}^R$ *and* $\beta_1(f)$ *are found in Proposition 1.*

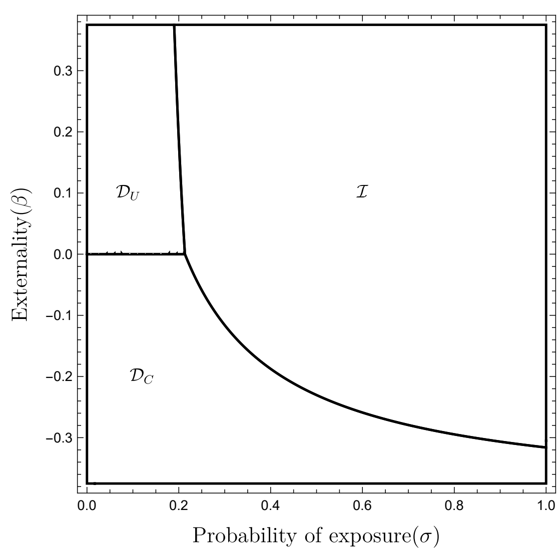


Figure 6 Firms' equilibrium strategies with non-exclusive suppliers, no horizontal sourcing

Note that with positive externalities, the buyers source from different suppliers and the equilibria are the same as in the main model. However, with negative externalities, the buyers source from a shared supplier, and the region where buyer A stays disintegrated for high probabilities of exposure in Proposition 1 (the $\mathcal{D}$ region in the lower right corner of Figure 2) disappears. The reason is that with strong negative externalities buyer A benefits more from sharing a supplier with buyer B and avoiding externalities than from integrating with its own supplier and facing strong negative externalities. Thus, with non-exclusive suppliers, high violation exposure probabilities always induce vertical integration, which is a new insight. As for the impact of externalities on the equilibrium structure, Proposition 8 shows that higher externalities always improve CSER. This trend is unchanged from the main model (Proposition 2).

Next, we present and illustrate the case allowing horizontal sourcing. Figure 7 is generated with the same parameters as in Figure 2, and $f = 0.1$.

PROPOSITION 9. *Assume horizontal sourcing is possible, and define* $\sigma_4 = \frac{2Q(c_r - w) + f}{2\alpha Q(w-p)}$.

1. *The equilibrium is* $\mathcal{D}_C$*, if* $\beta \le 0$ *and* $\sigma \in (0, \sigma_4]$.
2. *The equilibrium is* $\mathcal{D}_U$*, if (i)* $0 < \beta \le \beta_2(f)$ *and* $\sigma \in (0, \sigma_1]$*; (ii)* $\beta_2(f) < \beta$ *and* $\sigma \in (0, \underline{\sigma}^R]$.
3. *The equilibrium is* $\mathcal{I}_N$*, if (i)* $\beta_2(f) < \beta < \frac{w - c_r - \alpha(p-w)}{p - c_r}$ *and* $\sigma \in (\underline{\sigma}^R, \sigma_2]$*; or (ii)* $\frac{w - c_r - \alpha(p-w)}{p - c_r} \le \beta$ *and* $\sigma \in (\underline{\sigma}^R, 1)$.
4. *The equilibrium is* $\mathcal{I}_S$*, if (i)* $\beta \le 0$ *and* $\sigma \in (\sigma_4, 1)$*; (ii)* $0 < \beta \le \beta_2(f)$ *and* $\sigma \in (\sigma_1, 1)$*; or (iii)* $\beta_2(f) < \beta < \frac{w - c_r - \alpha(p-w)}{p - c_r}$ *and* $\sigma \in (\sigma_2, 1)$.

The equilibrium horizontal sourcing wholesale price is $w' = w + \alpha\sigma(w - p)$*. The characterizations of* $\beta_2(f)$*,* σ_1 *and* σ_2 *are found in Proposition 4, that of* $\underline{\sigma}^R$ *is found in Proposition 1.*

Similar to the case without horizontal sourcing, with positive externalities the buyers source from different suppliers and the equilibria are the same as in the main model, but with negative externalities they source from a shared supplier (if not vertically integrated). Overall, the trends in the main model are retained: high exposure probabilities always induce vertical integration, whereas strongly positive externalities may impede industry-wide CSER by discouraging integrated firm A from sharing its responsible supply with buyer B.

6.3. Both buyers can vertically integrate

In this extension we allow both buyers to vertically integrate with their suppliers to ensure CSER (or equivalently, both buyers have low fixed costs for integration.) Let tuple $(k;l)$ denotes that buyer A plays strategy k and buyer B plays strategy l; e.g., $(\mathcal{I};\mathcal{D})$ denotes that only buyer A is vertically integrated. When both buyers can vertically integrate, horizontal sourcing becomes unnecessary. Therefore, we do not consider horizontal sourcing in this extension.

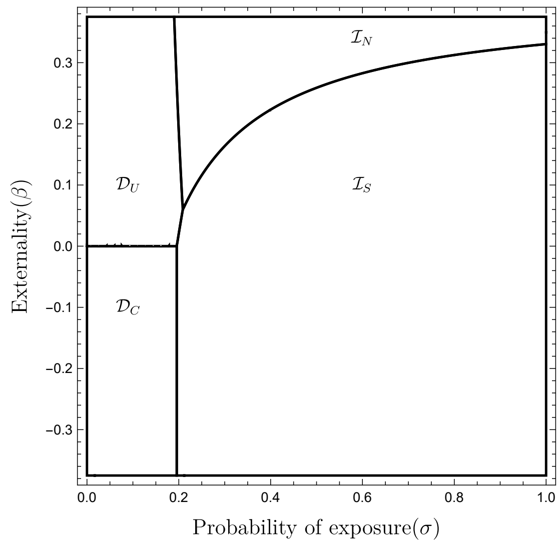


Figure 7 Firms' equilibrium strategies with non-exclusive suppliers, allowing horizontal sourcing

Proposition 10. *Assume both firms can vertically integrate and no horizontal sourcing.*

1. $(\mathcal{D},\mathcal{D})$ *is an equilibrium, if (i)* $\beta \le \max(\alpha,\beta_2(f))$*; (ii)* $\max(\alpha,\beta_2(f)) < \beta < \beta_1(f)$ *and* $\sigma \in (0,\underline{\sigma}^R] \cup [\overline{\sigma}^R,1)$*; (iii)* $\beta_1(f) \le \beta$ *and* $\sigma \in (0,\underline{\sigma}^R]$.
2. $(\mathcal{I},\mathcal{I})$ *is an equilibrium, if (i)* $\max(\alpha,\beta_2(f)) < \beta < \beta_1(f)$ *and* $\sigma \in (\underline{\sigma}^R,\overline{\sigma}^R)$*; (ii)* $\beta_1(f) \le \beta \le 0$ *and* $\sigma \in (\underline{\sigma}^R,1)$*; and (iii)* $0 < \beta$ *and* $\sigma \in (\sigma_7,1)$.
3. $(\mathcal{I},\mathcal{D})$ *or* $(\mathcal{D},\mathcal{I})$ *is an equilibrium, if* $0 < \beta$ *and* $\sigma \in (\underline{\sigma}^R,\sigma_7]$.

Furthermore, $\beta_2(f) > \alpha$ *if and only if* $f > f_1$*. The characterizations of* $\underline{\sigma}^R$*,* $\overline{\sigma}^R$*,* β_1 *and* β_2 *are found in Proposition 1 and that of* σ_7 *is found in the proof of the proposition.*

Proposition 10 bears a structural similarity to Proposition 1 where only buyer A can vertically integrate. In addition, the result that high externalities induce vertical integration through vertical integration (Proposition 2) also carries over in Proposition 11. Therefore, all main insights of Section 4 continue to hold when both buyers can vertically integrate.

Proposition 11. *In the equilibrium described in Proposition 10, the range of* σ *where at least one firm plays the strategy* $\mathcal{I}$ *grows as* β *is increased.*

6.4. Suppliers' responsibility decisions

In this extension we allow all disintegrated suppliers to simultaneously decide whether to ensure CSER by themselves after buyer A's vertical integration decision. If a supplier ensures CSER, the unit production cost of the component is increased to $c_s < w$ (otherwise a supplier would never ensure CSER). While a supplier may ensure CSER, verifiability is a separate issue. For example, Taylor Guitars was unable to verify its Cameroonian supplier's CSER status (even with proper licenses) in an environment where corruption is rampant and survival far outweighs conservation.

Consistent with this observation, we assume that a buyer cannot verify its supplier's CSER status, thus continues to assume the same violation exposure probability even when the supplier ensures CSER. Therefore, buyer A's integration decision remains unchanged from the main model.

We use subscript (i,j), where $i,j \in \{Re, Co\}$, on $\mathcal{D}$ to denote the suppliers' responsibility decisions in the equilibrium (Re for responsible, Co for conventional). For instance, $\mathcal{D}_{ReCo}$ means in the equilibrium supplier A ensures CSER whereas supplier B remains conventional. The next proposition presents our results.

PROPOSITION 12. *Suppose each supplier can decide whether to ensure CSER, and firm A stays disintegrated.*

1. $\mathcal{D}_{ReRe}$ *is an equilibrium, if* $\sigma \geq -\frac{c_s}{w\alpha}$.
2. $\mathcal{D}_{CoCo}$ *is an equilibrium, if* $\nu(\sigma,\beta,c_s,w,\alpha) \leq 0$.
3. $\mathcal{D}_{ReCo}$ *or* $\mathcal{D}_{CoRe}$ *is an equilibrium, if* $\sigma < -\frac{c_s}{w\alpha}$, $\nu(\sigma,\beta,c_s,w,\alpha) > 0$ *and* $\beta > 0$.

The characterization of ν *is found in the proof of the proposition.*

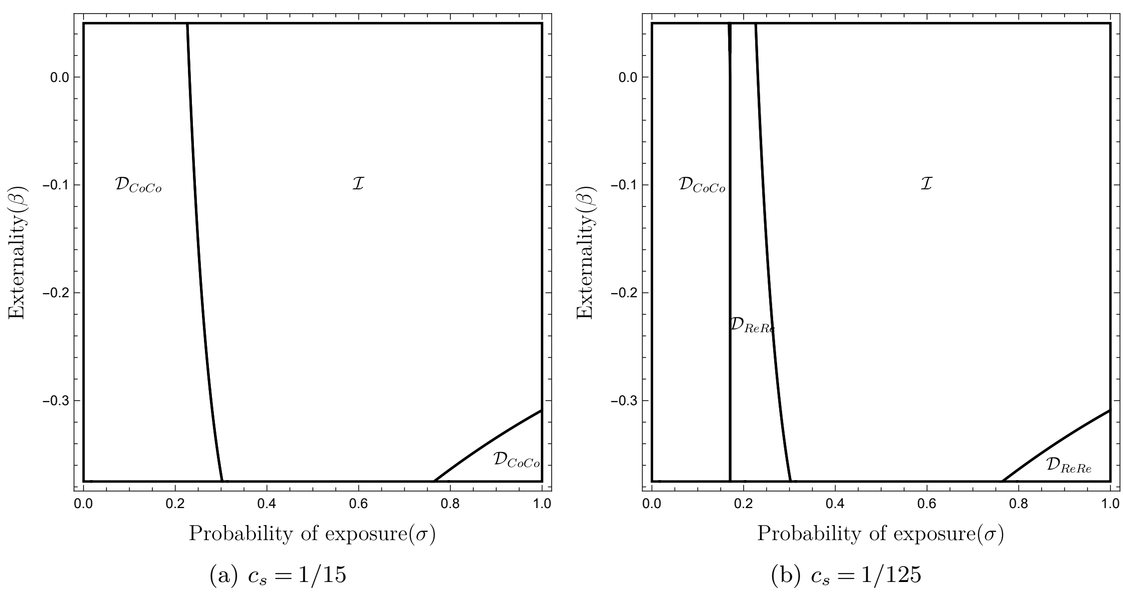
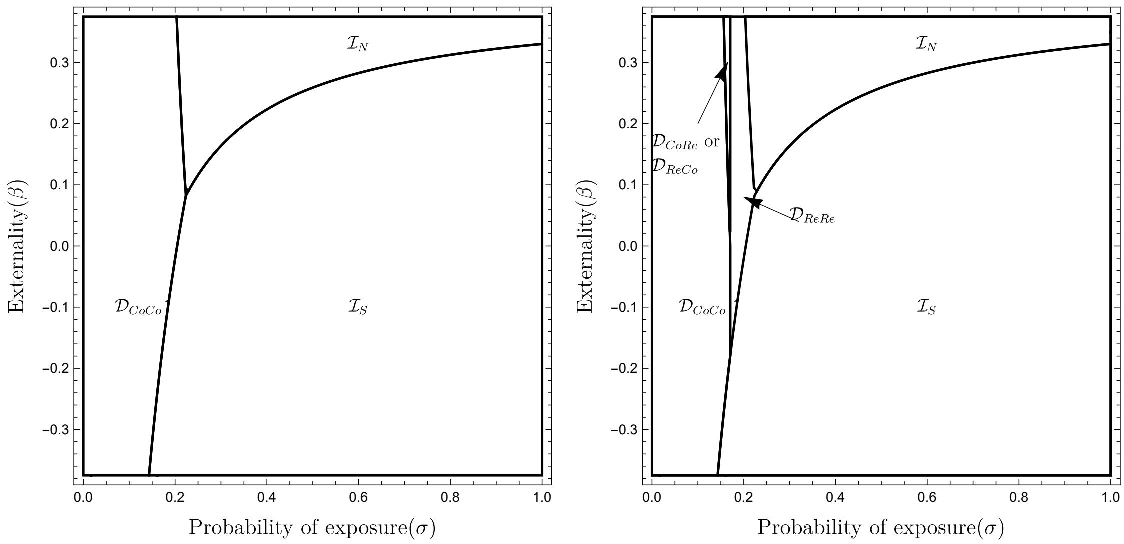


Figure 8 Firms' equilibrium strategy with suppliers' responsibility decisions, no horizontal sourcing

Note that this proposition holds regardless of whether horizontal sourcing is possible. Figures 8 and 9 illustrate this proposition for the same parameters $p = 2$, $w = 1/8$, $c_r = 1/4$, $Q = 4$, $\alpha = -3/8$ and $f = 0.15$ as in previous figures, while varying c_s. We resolve the issue of multiple equilibria by choosing the Pareto efficient equilibrium.

One can see that for large c_s values (i.e., 1/15), suppliers do not ensure CSER by themselves and the equilibrium is the same as in the main model. As c_s is decreased, a $\mathcal{D}_{ReRe}$ region invades



(a) $c_s = 1/15$ (b) $c_s = 1/125$

Figure 9 Firms' equilibrium strategy with suppliers' responsibility decisions, allowing horizontal sourcing

the $\mathcal{D}_{CoCo}$ region. The reason why a supplier may ensure CSER even if the buyer could not verify it is that a supplier eliminating its own violation exposure risks will statistically improve its customer's demand, which leads to a statistically larger sourcing quantity for itself. From the buyers' perspective, though, the suppliers' responsibility decisions do not change its strategies, thus the main insights regarding buyer A's vertical integration decision is unaffected.

6.5. Other extensions

We briefly discuss two additional extensions to test the robustness of our main results. The analyses and more detailed discussions are relegated to Appendix A. In Appendix A.1, we allow endogenous retail prices and adopt a differentiated Bertrand competition market model. Numerical studies confirm that our main structural results continue to hold. In Appendix A.2, we assume that firm A does not have enough supply capacity to fully satisfy buyer B's demand through horizontal sourcing, and thus buyer B must dual-source from firm A and supplier B. We find that as firm A's supply capacity gradually increases, the equilibrium structure transitions from resembling that in the main model without horizontal sourcing to that in the main model allowing horizontal sourcing, which confirms and generalizes the insights from the main model.

7. Conclusion

In an increasingly socially- and environmentally-conscious world, when a supplier is exposed of a CSER violation, its customers often bear market consequences. In addition, competing firms may benefit from the exposure because of substitution, or suffer from it because of consumer suspicion about general practices in the industry. Rapid globalization makes managing CSER in sourcing ever more challenging, and in some cases conventional approaches such as auditing may be ineffective.

On the other hand, many NGOs attempt to promote CSER through the combined power of media and markets by exposing violations to socially- and environmentally-conscious consumers. In this process, they can choose amount of resources allocated to scrutinizing suppliers, as well as the way violations are reported. The former choice affects the likelihood of a violation being exposed, whereas the latter choice influences whether an exposed violation benefits or hurts competing firms. The complex interactions make it non-straightforward for NGOs in determining what violation scrutiny and reporting policies best induce CSER in the industry.

Inspired by the case of Taylor Guitars, we investigated vertical integration as an alternative strategy for CSER in sourcing where conventional approaches such as auditing are ineffective. We modeled two competing firms, one of which may vertically integrate with its supplier to ensure CSER. An exposed violation reduces the demand of the directly-involved firm, and also positively or negatively impacts that of the competing firm. We first investigated the model assuming no horizontal sourcing, and then allowed horizontal sourcing through which a vertically-integrated firm can provide responsible supply to the competitor. We also compared the results of the two models.

Our analysis reveals that firms' optimal/equilibrium integration decisions are non-trivial, and differ based on whether horizontal sourcing is possible. In general, we confirmed CSER to be a potential driver for vertical integration aside from other well-known drivers. Specifically, in industries where horizontal sourcing is unlikely, firms stay disintegrated under low CSER violation exposure risk and vertically integrate under moderate CSER violation exposure risk, but surprisingly may stay disintegrated under high CSER violation exposure risk combined with strongly negative demand externalities. By contrast, where horizontal sourcing is possible, firms vertically integrate under moderate-to-high CSER violation exposure risk, but may not share responsible supply through horizontal sourcing under strongly positive demand externalities. These results mean that firms should be conscious about externalities and the possibility of horizontal sourcing in the industry when considering vertical integration for CSER. They also provide guidance for NGOs' violation scrutiny and reporting policies for firms that may adopt vertical integration and horizontal sourcing for CSER. Where horizontal sourcing is unlikely, NGOs should specify both violating and non-violating firms specifically in their reports, but not over-scrutinize firms; whereas when horizontal sourcing is possible, NGOs should allocate more resources to scrutinizing firms' CSER violations, and should create industry-wide violation reports while avoiding naming specific firms.

Our findings also have socioeconomic implications. As is in the case of Taylor Guitars, a major OEM's integration with a supplier in a developing nation for CSER often leads to improved pay, added value and opportunities of economic growth in an underdeveloped region. However, it typically requires fixed investments and leads to increased sourcing costs for the OEM. Therefore, it is unclear whether NGOs can realistically promote vertical integration by OEMs to stimulate economic growth in developing nations. Our study shows that despite the costs, vertical integration for CSER can be economically justifiable, suggesting that NGOs may indeed promote vertical integration by OEMs to improve the livelihood of people in developing nations.

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Appendices

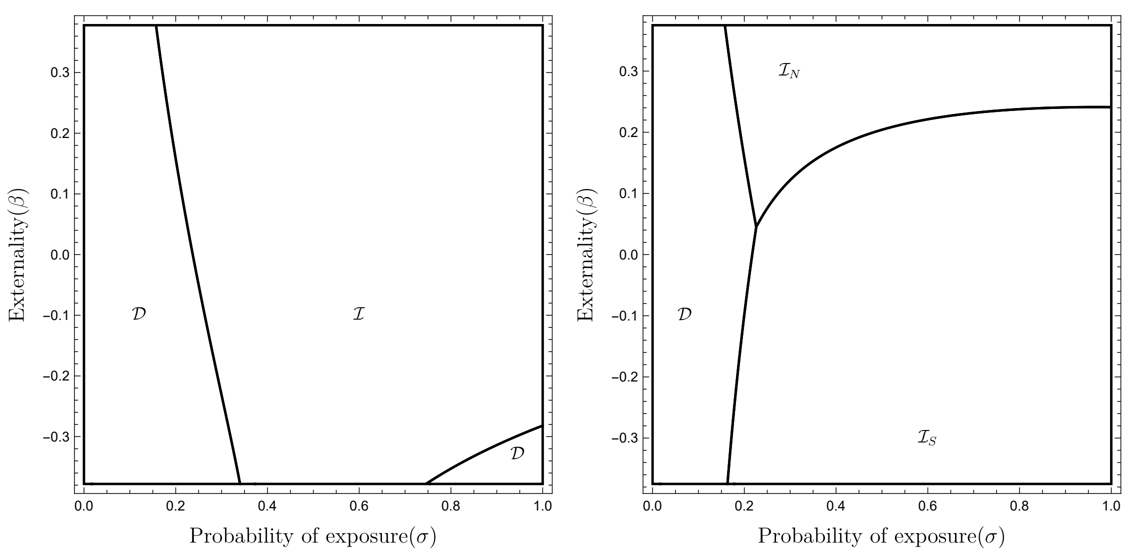
A. Additional Extensions

In this appendix we investigate two additional extensions and show that our main insights are robust to relaxed model assumptions.

A.1. Endogenous retail prices

Below we extend the main model's assumption of an exogenous retail price. For $i, j = A, B, i \neq j$, we assume buyer i's demand to be $Q_i = \theta_i - \gamma p_i + \epsilon p_j$ based on the two firms' endogenous retail prices p_i and p_j, where θ_i can take one of three values 1, $1+\alpha$, and $1+\beta$, for the cases of no violation is exposed, a violation is exposed at supplier i, and a violation is exposed at supplier j, respectively. Here the parameters α and β carry similar meanings as in the main model. The parameters γ and ϵ respectively measure a product's demand sensitivities to its own price and the competing product's price.

Due to this model's complexity, we resort to numerical studies. We focus on non-trivial cases where both buyers have positive demands, and consistently observe that the model behaves qualitatively similar to the main model. This is evident in the representative examples (with and without the possibility of horizontal sourcing) in Figure A1, which are generated with parameters $\alpha = -3/8$, $w = 1/8$, $c_r = 1/4$, $\gamma = 0.6$, $f = 0.1$, and $\epsilon = 0.1$. Therefore, the main model's insights are robust under endogenous retail prices.



(a) no horizontal sourcing (b) allowing horizontal sourcing

Figure A1 Firms' equilibrium strategies with endogenous retail prices

A.2. Capacitated horizontal sourcing

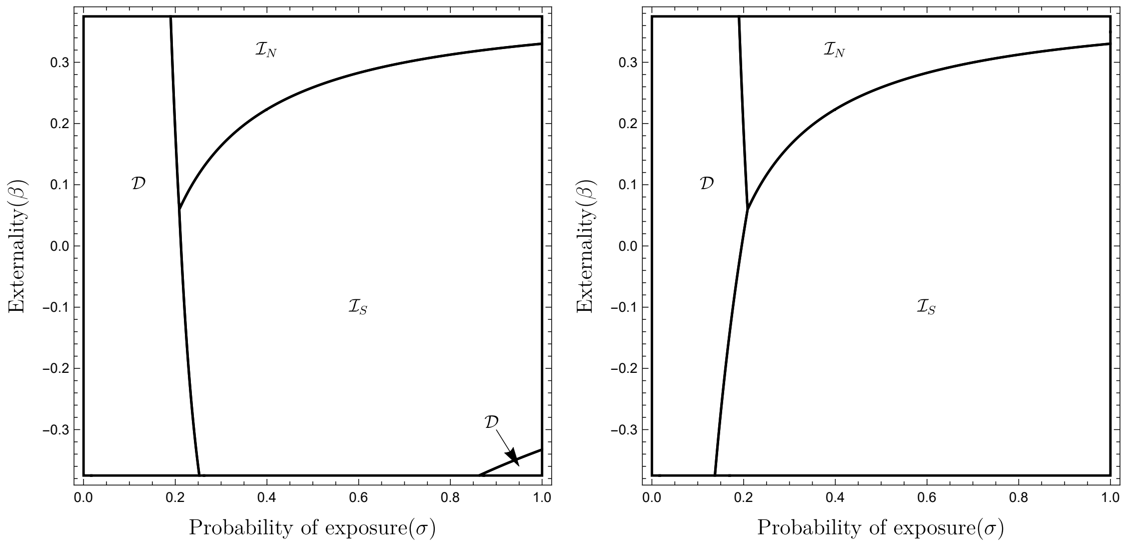
In this extension we consider the possibility that the integrated firm A has enough supply capacity C for its own demand but not enough to satisfy buyer B's entire demand through horizontal sourcing, namely $Q < C < 2Q$. As such, in equilibrium $\mathcal{I}_S$, buyer B sources $C - Q$ units of (responsible) supply from firm A and the rest $2Q - C$ units from (conventional) supplier B to fulfill demand Q. Recall that with probability σ a violation may be exposed at supplier B, thus in equilibrium $\mathcal{I}_S$ buyer B still faces violation exposure probability σ. However, the demand impact of such a violation exposure may be lower because only a portion of buyer B's products are affected. To model this effect, we define proportional direct and indirect demand impact parameters respectively as $\alpha_s = (2Q - C)\alpha/Q$ and $\beta_s = (2Q - C)\beta/Q$. We also define $k = C - Q$ as firm A's supply capacity in excess of its own demand that can be used to supply buyer B. Proposition A1 characterizes the equilibria of this model extension.

PROPOSITION A1. *Assume horizontal sourcing is possible and $f < f_2$. There exist thresholds $\beta_4(f)$ and $k_1(f,\beta)$ satisfying $\underline{\beta}(f) < \beta_4(f) < \overline{\beta}(f) < 0$ and $\underline{k}(\beta,f) < k_1(f,\beta) < \overline{k}(\beta,f)$, such that*

1. *The equilibrium is $\mathcal{D}$, if (i) $\beta < \beta_4(f)$, $k < k_1(f,\beta)$ and $\sigma \in (0,\sigma_5] \cup [\sigma_6,1)$; (ii) $\beta < \beta_4(f)$, $k \geq k_1(f,\beta)$ and $\sigma \in (0,\sigma_5]$; (iii) $\beta_4(f) \leq \beta \leq \beta_3(f)$ and $\sigma \in (0,\sigma_5]$; (iv) $\beta_3(f) < \beta$ and $\sigma \in (0,\underline{\sigma}^R]$.*
2. *The equilibrium is $\mathcal{I}_N$, if (i) $\beta_3(f) < \beta < \frac{w-c_r-\alpha(p-w)}{p-c_r}$ and $\sigma \in (\underline{\sigma}^R,\sigma_2]$; or (ii) $\frac{w-c_r-\alpha(p-w)}{p-c_r} \leq \beta$ and $\sigma \in (\underline{\sigma}^R,1)$.*
3. *The equilibrium is $\mathcal{I}_S$, if (i) $\beta < \beta_4(f)$, $k < k_1(f,\beta)$ and $\sigma \in (\sigma_5,\sigma_6)$; (ii) $\beta < \beta_4(f)$, $k \geq k_1(f,\beta)$ and $\sigma \in (\sigma_5,1)$; (iii) $\beta_4(f) \leq \beta \leq \beta_3(f)$ and $\sigma \in (\sigma_5,1)$; or (iv) $\beta_3(f) < \beta < \frac{w-c_r-\alpha(p-w)}{p-c_r}$ and $\sigma \in (\sigma_2,1)$.*

The equilibrium horizontal sourcing wholesale price is $w' = w + \alpha\sigma(w-p)$. The characterizations of $\beta_3(f)$ and σ_2 are found in Proposition 4, that of $\underline{\sigma}^R$ is found in Proposition 1, and those of σ_5, σ_6, $\underline{\beta}$, $\overline{\beta}$, $\underline{k}$ and $\overline{k}$ are found in the proof of the proposition.

Figure A2, generated with the same parameters as before (i.e., $p = 2$, $w = 1/8$, $c_r = 1/4$, $Q = 4$, and $f = 0.1$), illustrates Proposition A1 with low and high capacities. When firm A's supply capacity is low, horizontal sourcing does not substantially reduce buyer B's violation exposure risks. As such, the equilibrium structure of Figure A2(a) resembles that of Figure 2 without horizontal sourcing, particularly the $\mathcal{D}$ region in the lower-right corner. On the other hand, when firm A's supply capacity is high enough to meaningfully reduce buyer B's violation exposure risks through horizontal sourcing, the equilibrium structure of Figure A2(b) resembles that of Figure 3 allowing horizontal sourcing. This means that the main insights generally apply even with limited supply capacity of firm A.



(a) $C = 4.1$ (b) $C = 7.9$

Figure A2 Firms' equilibrium strategies with limited supply capacity of firm A

B. Proofs

This appendix contains proofs of all results in the paper.

Proof of Proposition 1: As discussed in the paper, we assume $c_r < -[\alpha(p-2w) + 2\left(1-\sqrt{\alpha+1}\right)(p-w)]/\alpha$ and $f < Q\left(\frac{\alpha(p-w)^2}{\mathrm{cr}-2p+w} - \mathrm{cr} + w\right)$ to eliminate uninteresting cases. To prove the proposition, we first define difference functions of profits for different scenarios and then investigate the behavior of these difference functions. Define $\Delta^{\mathcal{I}}_{\mathcal{D}} = \pi^A_I - \pi^A_D$. Because $\mathrm{d}\Delta^{\mathcal{I}}_{\mathcal{D}}/\,\mathrm{d}\sigma = -Q\left(\beta c_r + p(\alpha - 2\beta\sigma) - w(\alpha - 2\beta\sigma + \beta)\right)$, $\Delta^{\mathcal{I}}_{\mathcal{D}}$ is an increasing function if and only if $\beta > \frac{\alpha(w-p)}{c_r-2p+w}$. In addition, $\Delta^{\mathcal{I}}_{\mathcal{D}}(\sigma=0) < 0$ always holds. When $f=0$, $\Delta^{\mathcal{I}}_{\mathcal{D}}(\sigma=1) < 0$ if and only if $\beta < \frac{c_r+\alpha p-(\alpha+1)w}{p-c_r}$ (Note that $\frac{c_r+\alpha p-(\alpha+1)w}{p-c_r} < \frac{\alpha(w-p)}{c_r-2p+w}$). Because of the assumption that $f < Q\left(\frac{\alpha(p-w)^2}{\mathrm{cr}-2p+w} - \mathrm{cr} + w\right) = \Delta^{\mathcal{I}_N}_{\mathcal{D}}(\sigma = 1, \beta = \frac{\alpha(p-w)}{-c_r+2p-w})$ and the fact that $\mathrm{d}\Delta^{\mathcal{I}_N}_{\mathcal{D}}/\,\mathrm{d}\beta > 0$, there exists a $\beta_1(f) \in (\frac{c_r+\alpha p-(\alpha+1)w}{p-c_r}, \frac{\alpha(w-p)}{c_r-2p+w})$ such that when $\beta > \beta_1$ a unique probability of exposure $\underline{\sigma}^R$ satisfies $\Delta^{\mathcal{I}}_{\mathcal{D}}(\underline{\sigma}^R) = 0$, and $\mathcal{I}$ is the optimal strategy if and only if $\sigma \in (\underline{\sigma}^R, 1)$. The threshold β_1 is defined by $\Delta^{\mathcal{I}}_{\mathcal{D}}(\sigma = 1, \beta_1) = 0$ and its expression is given in the proposition.

On the other hand, when $\beta < \beta_1$, there may be two cases: $\Delta^{\mathcal{I}}_{\mathcal{D}}$ intersects with the σ axis either twice or never depending on the value of f. It can be shown that when $f < f_1 = \max_\sigma(\Delta^{\mathcal{I}}_{\mathcal{D}}(\beta = \alpha))$, $\Delta^{\mathcal{I}}_{\mathcal{D}}$ intersects with the σ axis at two σ values $\underline{\sigma}^R$ and $\overline{\sigma}_R$ satisfying $\underline{\sigma}^R < \overline{\sigma}_R$. This is the case for any $\beta < \beta_1$. However, when $f > f_1$, there exists a $\beta_2 < \beta_1$ satisfying $\max_\sigma \Delta^{\mathcal{I}}_{\mathcal{D}}(\beta_2, \sigma) = 0$ such that when $\beta < \beta_2$, $\Delta^{\mathcal{I}}_{\mathcal{D}} < 0$ always hold (namely $\mathcal{D}$ is optimal regardless of σ). It is straightforward from the definition of f_1 that β_2 exists if and only if $f > f_1$.

Assuming $\beta < \beta_1$, when $\Delta^{\mathcal{I}}_{\mathcal{D}}$ intersects with the σ axis at $\underline{\sigma}^R$ and $\overline{\sigma}_R$, the optimal strategy is $\mathcal{D}$ if $\sigma \in (0, \underline{\sigma}^R] \cup [\overline{\sigma}_R, 1)$, and $\mathcal{I}$ if $\sigma \in (\underline{\sigma}^R, \overline{\sigma}_R)$, because $\Delta^{\mathcal{I}}_{\mathcal{D}}$ is a concave function of σ for $\beta < \beta_1$. $\square$

Proof of Proposition 2. To prove the proposition, we need to show that as β increases, the σ thresholds that characterize the $\mathcal{I}$ region (defined in the proof of Proposition 1) increase or decrease in a way that expands the $\mathcal{I}$ region. In other words, the followings must hold: 1) $\mathrm{d}\overline{\sigma}^R/\mathrm{d}\beta > 0$ when $\overline{\sigma}^R \in (0,1)$; and 2) $\mathrm{d}\underline{\sigma}^R/\mathrm{d}\beta < 0$.

From the implicit function theorem, $\frac{\mathrm{d}\overline{\sigma}_R}{\mathrm{d}\beta} = -\frac{\partial\Delta^{\mathcal{I}}_{\mathcal{D}}/\partial\beta}{\partial\Delta^{\mathcal{I}}_{\mathcal{D}}/\partial\sigma}\bigg|_{\overline{\sigma}_R}$. From the proof of Proposition 1 we know that when $\beta < \beta_1$, $\Delta^{\mathcal{I}}_{\mathcal{D}}$ is a concave function of σ with two roots satisfying $\underline{\sigma}_R < \overline{\sigma}_R$. Additionally, $\lim_{\sigma\to 0}\Delta^{\mathcal{I}}_{\mathcal{D}} < 0$ and $\lim_{\sigma\to 1}\Delta^{\mathcal{I}}_{\mathcal{D}} < 0$. Therefore $\partial\Delta^{\mathcal{I}}_{\mathcal{D}}/\partial\sigma|_{\sigma=\overline{\sigma}_R} < 0$. As a result, $\mathrm{d}\overline{\sigma}_R/\mathrm{d}\beta$ and $\partial\Delta^{\mathcal{I}}_{\mathcal{D}}/\partial\beta|_{\sigma=\overline{\sigma}_R} = Q\sigma\left(-c_r + p\sigma - \sigma w + w\right)$ have the same sign. It is easy to see that $\overline{\sigma}_R > \frac{c_r-w}{p-w}$, hence $\mathrm{d}\overline{\sigma}_R/\mathrm{d}\beta > 0$.

The proof of $\mathrm{d}\underline{\sigma}^R/\mathrm{d}\beta < 0$ is similar and omitted. □

Proof of Proposition 3. We first show how firm B's profit behaves as a function of σ and derive the condition for firm B's profit to increase with σ. Note that $\mathrm{d}\pi^B_{\mathcal{D}}/\mathrm{d}\sigma = Q\alpha(p-w) < 0$, $\mathrm{d}\pi^B_{\mathcal{I}}/\mathrm{d}\sigma = Q(p-w)(\alpha - 2\beta\sigma + \beta) < 0$, and $\pi^B_{\mathcal{I}} - \pi^B_{\mathcal{D}} = \beta Q(\sigma-1)\sigma(p-w) > 0$ when $\beta < 0$. Therefore π^B jumps higher when buyer A switches from strategy $\mathcal{D}$ to $\mathcal{I}$ and $\beta < 0$ at $\underline{\sigma}^R$ (defined in the proof of Proposition 1). Define $\Delta_1 > 0$, $\underline{\tau}^c > 0$ and $\overline{\tau}_c > 0$ as determined by $\pi^B_{\mathcal{D}}(\underline{\sigma}^R - \Delta_1) = \pi^B_{\mathcal{I}}(\underline{\sigma}^R)$, $\underline{\tau}^c = \underline{\sigma}^R - \sigma$ and $\pi_{\mathcal{D}}(\sigma) = \pi_{\mathcal{I}}(\sigma + \overline{\tau}_c)$, respectively. To see the existence of Δ_1 and $\overline{\tau}_c$, note that $\lim_{\sigma\to 0}\pi^B_{\mathcal{D}} = \lim_{\sigma\to 0}\pi^B_{\mathcal{I}}$ and $\lim_{\sigma\to 1}\pi^B_{\mathcal{D}} = \lim_{\sigma\to 1}\pi^B_{\mathcal{I}}$. Since at $\underline{\sigma}^R$ the profit jump higher, firm B's profit increases with increasing σ so long as $\tau \in (\underline{\tau}^c, \overline{\tau}_c)$. □

Proof of Proposition 4 To find the subgame-perfect Nash equilibrium, we first investigate buyer B's decision of whether to source from its competitor. It is easy to see that buyer B sources from firm A if and only if $\pi^B_{\mathcal{D}} \le \pi^B_{\mathcal{I}_S}$. Therefore, firm A should offer a price w' that makes buyer B indifferent between sourcing from firm A or supplier B, namely $\pi^B_{\mathcal{I}_S} = \pi^B_{\mathcal{D}} \Leftrightarrow Q(p-w') = Q((\alpha+1)\sigma - \sigma + 1)(p-w) \Leftrightarrow w' = \alpha\sigma(w-p) + w \Rightarrow \pi^A_{\mathcal{I}_S} = Q\left(-c_r - \alpha\sigma(p-w) + w\right) + Q\left(p - c_r\right) - f$.

Next, define $\Delta^{\mathcal{I}_S}_{\mathcal{D}} = Q\left(-2c_r + \sigma(2\alpha+\beta)(w-p) + \beta\sigma^2(p-w) + 2w\right) - f$, $\Delta^{\mathcal{I}_S}_{\mathcal{I}_N} = (\beta\sigma - 1)c_r - p\sigma(\alpha+\beta) + \alpha\sigma w + w$, and $\Delta^{\mathcal{I}_N}_{\mathcal{D}} = (\beta\sigma-1)c_r - p\sigma(\alpha+\beta) + \alpha\sigma w + w$, where $\Delta^i_j = \pi^A_i - \pi^A_j$. Note that $\Delta^{\mathcal{I}_N}_{\mathcal{D}}$ is same as $\Delta^{\mathcal{I}}_{\mathcal{D}}$ investigated in the proof of Proposition 1, and thus we only need to investigate $\Delta^{\mathcal{I}_S}_{\mathcal{I}_N}$ and $\Delta^{\mathcal{I}_S}_{\mathcal{D}}$. Note that $\Delta^{\mathcal{I}_S}_{\mathcal{I}_N}$ is a linear function of σ and its value at $\sigma = 0$ is $w - c_r < 0$. In addition, its value at $\sigma = 1$ is $(\beta-1)c_r - p(\alpha+\beta) + (\alpha+1)w$ which is positive if and only if $\beta < \frac{c_r + \alpha p - (\alpha+1)w}{c_r - p}$. Therefore, when $\beta \ge \frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$, $\mathcal{I}_S$ cannot be an equilibrium, and consequently the equilibrium structure is same as that in Proposition 1. When $\beta < \frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$, $\Delta^{\mathcal{I}_S}_{\mathcal{I}_N}$ has a unique root $\sigma_2 = \frac{c_r - w}{\beta c_r - p(\alpha+\beta) + \alpha w}$.

Considering $\mathrm{d}^2\Delta^{\mathcal{I}_S}_{\mathcal{D}}/\mathrm{d}\sigma^2 = 2\beta(p-w)$, $\Delta^{\mathcal{I}_S}_{\mathcal{D}}$ is convex for $\beta > 0$, concave for $\beta < 0$, and linear for $\beta = 0$. It is easy to show that $\Delta^{\mathcal{I}_S}_{\mathcal{D}}(\sigma = 0) < 0$ and $\Delta^{\mathcal{I}_S}_{\mathcal{D}}(\sigma = 1) > 0$. Therefore, there exists a unique root to $\Delta^{\mathcal{I}_S}_{\mathcal{D}}(\sigma) = 0$. Denote this root with σ_1. The next lemma is needed for the remainder of the proof. The proof follows straightforwardly from the implicit function theorem and is omitted.

LEMMA 1. *The following properties hold:* $\mathrm{d}\underline{\sigma}^R/\mathrm{d}\beta < 0$, $\mathrm{d}\sigma_1/\mathrm{d}\beta > 0$, $\mathrm{d}\sigma_2/\mathrm{d}\beta > 0$. *When* $\beta = 0$ *and* $f = 0$, $\underline{\sigma}^R = \sigma_1 = \sigma_2$.

We consider two different cases: $0 \le \beta < \frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$ and $\beta < 0$.

Case 1: $0 \le \beta < \frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$. Suppose $f = 0$. We first show $\underline{\sigma}^R < \sigma_1 < \sigma_2$ which means that for low (high) σ's, $\mathcal{D}$ ($\mathcal{I}_S$) is the equilibrium; and for medium σ's, $\mathcal{I}_N$ is the equilibrium. Following straightforward algebra one can see that $\Delta_{\mathcal{D}}^{\mathcal{I}_S}(\sigma_2) > 0$ if and only if $\beta > 0$. This proves the ordering when $f = 0$. Figure A3 illustrates this case for the same parameters as in Figure 2 and $f = 0$.

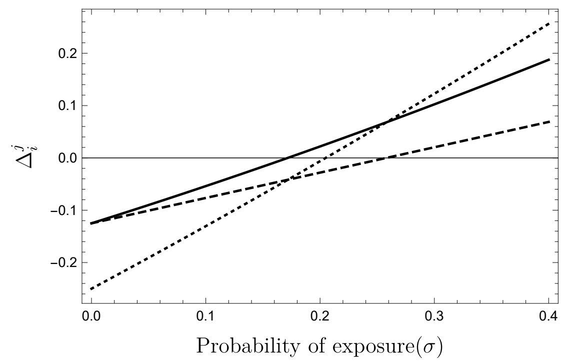


Figure A3 Difference functions (solid for $\Delta_{\mathcal{D}}^{\mathcal{I}_N}$, dashed for $\Delta_{\mathcal{I}_N}^{\mathcal{I}_S}$, dotted for $\Delta_{\mathcal{I}_N}^{\mathcal{I}_S}$)

Now suppose $f > 0$. Note that $\mathrm{d}\sigma_1/\mathrm{d}f > 0$, $\mathrm{d}\underline{\sigma}^R/\mathrm{d}f > 0$ and $\mathrm{d}\sigma_2/\mathrm{d}f = 0$. These properties alongside Lemma 1 and the upper bound on f defined in the proof of Proposition 1 imply $\beta_3 \in (0, \frac{c_r+\alpha p-(\alpha+1)w}{c_r-p})$ and it satisfies $\sigma_1(\beta_3) = \sigma_2(\beta_3) = \underline{\sigma}^R(\beta_3)$. It is easy to show that β_3 is a continuous and increasing function of f.

Case 2: $\beta < 0$. When $\beta < 0$, Lemma 1 implies $\sigma_2 < \sigma_1 < \underline{\sigma}^R$, and thus $\mathcal{I}_N$ cannot be an equilibrium. As a result, the equilibrium is determined by $\Delta_{\mathcal{D}}^{\mathcal{I}_S}$, which is positive if and only if $\sigma > \sigma_1$, hence the result. Combining Cases 1,2 and $\beta \ge \frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$ yields the proposition. □

Proof of Proposition 5. The following properties are implied by Lemma 1: 1. $\mathrm{d}\sigma_1/\mathrm{d}\beta > 0$, whenever $\mathcal{D}$ and $\mathcal{I}_S$ have a shared boundary; 2. $\mathrm{d}\sigma_2/\mathrm{d}\beta > 0$, whenever $\mathcal{I}_N$ and $\mathcal{I}_S$ have a shared boundary; hence the proposition. □

Proof of Proposition 6. When $\beta < 0$, $\mathrm{d}\pi_{\mathcal{D}}^A/\mathrm{d}\sigma < 0$, $\mathrm{d}\pi_{\mathcal{I}_S}^A/\mathrm{d}\sigma > 0$, $\mathrm{d}\pi_{\mathcal{D}}^B/\mathrm{d}\sigma < 0$ and $\mathrm{d}\pi_{\mathcal{I}_S}^B/\mathrm{d}\sigma < 0$. Furthermore, $\pi_{\mathcal{I}_S}^B - \pi_{\mathcal{D}}^B = \beta Q(\sigma - 1)\sigma(p - w) > 0$ and $\pi_{\mathcal{D}}^A(\sigma_1) = \pi_{\mathcal{I}_S}^A(\sigma_1)$. Therefore, buyer B's profit jumps higher at σ_1 when the equilibrium switches from $\mathcal{D}$ to $\mathcal{I}_S$ and buyer A's profit is continuous at σ_1. Figure A4 illustrates both profit functions.

Define $\sigma_c > \sigma_1$ such that $\pi_{\mathcal{I}_S}^A(\sigma_c) = \pi_{\mathcal{I}_S}^B(\sigma_c)$. Such σ_c exists because $\pi_{\mathcal{D}}^A(\sigma_1) < \pi_{\mathcal{D}}^B(\sigma_1)$ and $\pi_{\mathcal{D}}^A(1) > \pi_{\mathcal{D}}^B(1)$, and the profits are linear functions of σ when $\sigma > \sigma_1$. Define $\sigma_x \in (0, \sigma_1)$ such that $\pi_{\mathcal{D}}^A(\sigma_x) = \pi_{I_S}^A(\sigma_c)$; if such σ_x does not exist, let $\sigma_x = 0$. For any given $\sigma \in (\sigma_x, \sigma_1)$, define $\sigma_z^A \in (\sigma_1, 1)$ such

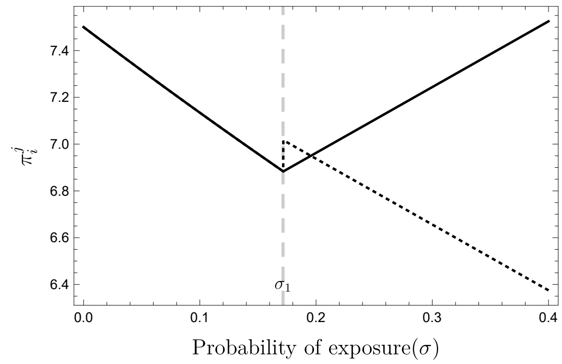


Figure A4 **Profit functions (solid for buyer A, dotted for buyer B)**

that $\pi^A_{\mathcal{D}}(\sigma) = \pi_{\mathcal{I}_S}(\sigma_z^A)$. Define $\sigma_z^B \in (\sigma_1, 1)$ such that $\pi^B_{\mathcal{D}}(\sigma) = \pi^B_{I_S}(\sigma_z^B)$; if such σ_z^B does not exist, let $\sigma_z^B = 1$. Then, $\sigma_1 - \sigma_x = \Delta_2$, $\overline{\tau}^r = \sigma_z^B - \sigma$ and $\underline{\tau}_r = \sigma_z^A - \sigma$. □

Proof of Proposition 7. Note that $\mathcal{I}_S$ being the equilibrium implies $\pi^A_{\mathcal{I}_S} > \pi^A_{\mathcal{I}_N}$, and thus the $\mathcal{I}$ region without horizontal sourcing is always contained in the $\mathcal{I}_S \cup \mathcal{I}_N$ region when horizontal sourcing is possible. □

Proof of Proposition 8. We first compare the profits when the buyers share and not share suppliers, i.e., $\pi^i_{\mathcal{D}_C}$ and $\pi^i_{\mathcal{D}_U}$. Note that $\pi^i_{\mathcal{D}_U} = \pi^i_{\mathcal{D}}$ which is defined in Section 3 and used in Sections 4 and 5. When the buyers share suppliers, their profits are $\pi^i_{\mathcal{D}_C} = Q(\alpha\sigma + 1)(p - w)$. Furthermore, $\pi^i_{\mathcal{D}_U} - \pi^i_{\mathcal{D}_C} = \beta(-Q)(\sigma - 1)\sigma(p - w) > 0 \Leftrightarrow \beta > 0$. Therefore, when $\beta > 0$, the equilibrium is the same as that in Proposition 1 because if buyer A decides to stay disintegrated, the buyer's would choose separate suppliers. On the other hand, when $\beta < 0$, we need to compare $\pi^A_{\mathcal{D}_C}$ and $\pi^A_{\mathcal{I}_S}$. The comparison is straightforward since $\pi^A_{\mathcal{D}_C} - \pi^A_{\mathcal{I}_S}$ is a quadratic function with at most one root, defined as σ_3, for $\sigma \in (0,1)$; details are omitted. □

Proof of Proposition 9. Due to the proof of Proposition 8, $\mathcal{D}_U$ ($\mathcal{D}_C$) is the equilibrium if and only if $\beta \le 0$ ($\beta > 0$). Using this result and comparing profits under strategies $\mathcal{I}_N$, $\mathcal{I}_S$, $\mathcal{D}_U$ and $\mathcal{D}_C$, we can obtain the equilibrium. Details are similar to the proof of Proposition 4 and omitted. □

Proof of Proposition A1. Note that the capacity constraint may change the profit functions of buyers A and B only under equilibrium $\mathcal{I}_S$. The wholesale price w' set by buyer A is determined by $\pi^B_{\mathcal{I}_S} = (p - w)(\alpha\sigma(Q - k) + Q) + k(w - w') = (\alpha + 1)Q\sigma(p - w) + Q(1 - \sigma)(p - w) = \pi^B_{\mathcal{D}} \Rightarrow w' = \alpha\sigma(w - p) + w$. This leads to $\pi^A_{\mathcal{I}_S} = \beta\sigma(k - Q)(c_r - p) - kc_r - Qc_r + k(\alpha\sigma(w - p) + w) + pQ - f$. Define $f_2 = \lim_{\beta\to\alpha} \max_\sigma \Delta^{\mathcal{I}_N}_{\mathcal{D}}(\sigma)$, and define the difference function $\Delta^{\mathcal{I}_S}_{\mathcal{I}_N} = \pi^A_{\mathcal{I}_S} - \pi^A_{\mathcal{I}_N} = k((\beta\sigma - 1)c_r - p\sigma(\alpha + \beta) + \alpha\sigma w + w)$. Note that the capacity constraint does not change the roots of this function, and thus the comparison of buyer A's profits under $\mathcal{I}_N$ and $\mathcal{I}_S$ is same as in the main model. The comparison of buyer A's profits for $\mathcal{I}_N$ and $\mathcal{D}$ is also the same as in the main model. Therefore, the boundaries between $\mathcal{I}_N$ and $\mathcal{I}_S$, and $\mathcal{I}_N$ and $\mathcal{D}$ remain unchanged from the main model. However, the boundary between $\mathcal{I}_S$ and $\mathcal{D}$ may change from the main model. To this end, we investigate $\beta < \frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$ in two case: $0<\beta<\frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$ and $\beta \le 0$. Define $\pi^A_{\mathcal{I}_S} - \pi^A_{\mathcal{D}} = \Delta^{\mathcal{I}_S}_{\mathcal{D}} = \sigma\left(\beta\left(c_r(k-Q)-kp+Qw\right)-\alpha(k+Q)(p-w)\right)-(k+Q)\left(c_r-w\right)-f+\beta Q\sigma^2(p-w)$.

Case 1: $0<\beta<\frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$. Suppose $f=0$. In this case, $\Delta^{\mathcal{I}_S}_{\mathcal{D}}(0)<0$, $\Delta^{\mathcal{I}_S}_{\mathcal{D}}(1)>0$ and $\mathrm{d}\Delta^{\mathcal{I}_S}_{\mathcal{D}}/\mathrm{d}\sigma>0$, and thus $\Delta^{\mathcal{I}_S}_{\mathcal{D}}$ has a unique root; denote it by σ_5. Following straightforward algebra, one can verify that $\Delta^{\mathcal{I}_S}_{\mathcal{D}}(\sigma_2)>0$, which implies $\underline{\sigma}^R<\sigma_5<\sigma_2$. Also note $\lim_{\beta\to 0}\underline{\sigma}^R=\lim_{\beta\to 0}\sigma_5=\lim_{\beta\to 0}\sigma_2$. Lastly, $\mathrm{d}\Delta^{\mathcal{I}_N}_{\mathcal{D}}(\sigma_2(\beta),\beta)/\mathrm{d}\beta>0$. This property follows from $\frac{\mathrm{d}\Delta^{\mathcal{I}_N}_{\mathcal{D}}(\sigma_2(\beta),\beta)}{\mathrm{d}\beta}=\frac{\partial\Delta^{\mathcal{I}_N}_{\mathcal{D}}(\sigma,\beta)}{\partial\sigma}\frac{\partial\sigma_2}{\partial\beta}+\frac{\partial\Delta^{\mathcal{I}_N}_{\mathcal{D}}(\sigma,\beta)}{\partial\beta}$, $\partial\Delta^{\mathcal{I}_N}_{\mathcal{D}}/\partial\sigma>0$ (due to the proof Proposition 1), $\partial\sigma_2/\partial\beta>0$ (due to Lemma 1), and $\frac{\partial\Delta^{\mathcal{I}_N}_{\mathcal{D}}}{\partial\beta}=Q\sigma(-c_r+p\sigma-\sigma w+w)|_{\sigma_2}>0$. The above three properties alongside the fact that $\Delta^{\mathcal{I}_N}_{\mathcal{D}}$ and $\Delta^{\mathcal{I}_S}_{\mathcal{D}}$ decrease with f imply that for any $f>0$, there exists a unique $\beta'\in(0,\frac{c_r+\alpha p-(\alpha+1)w}{c_r-p})$ such that $\Delta^{\mathcal{I}_N}_{\mathcal{D}}(\sigma_2,\beta')=0$ (which means $\beta'=\beta_3$), and the following is true: when $\beta'<\beta<\frac{c_r+\alpha p-(\alpha+1)w}{c_r-p}$, if $\sigma\in(0,\underline{\sigma}^R]$, the equilibrium is $\mathcal{D}$. If $\sigma\in(\underline{\sigma}^R,\sigma_2]$, it is $\mathcal{I}_N$. If $\sigma\in(\sigma_2,1)$, it is $\mathcal{I}_S$. On the other hand, when $\beta'\ge\beta>0$, if $\sigma\in(0,\sigma_5]$, the equilibrium is $\mathcal{D}$. If $\sigma\in(\sigma_5,1)$, it is $\mathcal{I}_S$.

Case 2: $\beta\le 0$. Suppose $f=0$. In this case, since $\mathrm{d}\Delta^{\mathcal{I}_S}_{\mathcal{D}}/\mathrm{d}k>0$, due to Proposition 1, $\mathcal{I}_N$ cannot be an equilibrium. Therefore we only need to compare buyer A's profits in $\mathcal{I}_S$ and $\mathcal{D}$; if $\Delta^{\mathcal{I}_S}_{\mathcal{D}}>(\le)0$, $\mathcal{I}_S(\mathcal{D})$ is the equilibrium. Note that

$$\lim_{\sigma\to 1}\mathrm{d}\Delta^{\mathcal{I}_S}_{\mathcal{D}}/\mathrm{d}\sigma<0\Leftrightarrow\beta<\frac{\alpha(p-w)}{-c_r+2p-w}=\overline{\beta}\text{ and }k<\frac{Q\left(\beta\left(c_r+w\right)+p(\alpha-2\beta)+\alpha(-w)\right)}{\beta c_r-p(\alpha+\beta)+\alpha w}=\overline{k},\quad(1)$$

$$\lim_{\sigma\to 1}\Delta^{\mathcal{I}_S}_{\mathcal{D}}<0\Leftrightarrow\beta<\frac{-c_r-\alpha p+\alpha w+w}{c_r-p}=\underline{\beta}\text{ and }k<\frac{Q\left(\beta c_r+c_r+\alpha p-\beta p-(\alpha+1)w\right)}{(\beta-1)c_r-p(\alpha+\beta)+(\alpha+1)w}=\underline{k}.\quad(2)$$

In addition, it can be shown that when $\lim_{\sigma\to 1}\Delta^{\mathcal{I}_S}_{\mathcal{D}}\ge 0$, either $\Delta^{\mathcal{I}_S}_{\mathcal{D}}$ has a unique root σ_5 where $\Delta^{\mathcal{I}_S}_{\mathcal{D}}$ is positive if and only if $\sigma>\sigma_5$, or it has two roots σ_5 and σ_6 where $\Delta^{\mathcal{I}_S}_{\mathcal{D}}$ is positive if and only if $\sigma\in(\sigma_5,\sigma_6)$. Furthermore, $\lim_{\sigma\to 1}\mathrm{d}\Delta^{\mathcal{I}_S}_{\mathcal{D}}/\mathrm{d}\beta>0$ and $\lim_{\sigma\to 1}\mathrm{d}\Delta^{\mathcal{I}_S}_{\mathcal{D}}/\mathrm{d}k>0$. These properties alongside (1) and (2) imply the proposition, where β_4 and k_1 are defined by $\lim_{k\to 0,\sigma\to 1}\Delta^{\mathcal{I}_S}_{\mathcal{D}}(\beta_4,k,f)=0$ and $\lim_{\sigma\to 1}\Delta^{\mathcal{I}_S}_{\mathcal{D}}(\beta,k_1(\beta),f)=0$ for $f>0$. □

Proof of Proposition 10. Four equilibria are possible: $(\mathcal{I};\mathcal{I})$, $(\mathcal{I};\mathcal{D})$, $(\mathcal{D};\mathcal{I})$ and $(\mathcal{D};\mathcal{D})$, with corresponding profits $\pi^i_{(\mathcal{I};\mathcal{I})}=(p-c_r)Q-f$, $\pi^A_{(\mathcal{I};\mathcal{D})}=\pi^B_{(\mathcal{D};\mathcal{I})}=(p-c_r)\left(\beta\sigma+1\right)Q-f$, and $\pi^i_{(\mathcal{D};\mathcal{D})}=p(\sigma(\alpha-\beta\sigma+\beta)+1)Q$. Define $\Delta_r=\pi^A_{(\mathcal{I};\mathcal{I})}-\pi^A_{(\mathcal{D};\mathcal{I})}=\pi^B_{(\mathcal{I};\mathcal{I})}-\pi^B_{(\mathcal{I};\mathcal{D})}=Q\left(-c_r+\alpha\sigma(w-p)+w\right)-f$ and $\Delta_c=\pi^A_{(\mathcal{I};\mathcal{D})}-\pi^A_{(\mathcal{D};\mathcal{D})}=\pi^B_{(\mathcal{D};\mathcal{I})}-\pi^B_{(\mathcal{D};\mathcal{D})}=\Delta^{\mathcal{I}}_{\mathcal{D}}$, where $\Delta^{\mathcal{I}}_{\mathcal{D}}$ is as defined in the proof of Proposition 1. When $\beta<\beta_1$, Δ_c has two roots $0<\underline{\sigma}^R<\overline{\sigma}^R<1$, and $\Delta_c>0$ if and only if $\sigma\in(\underline{\sigma}^R,\overline{\sigma}^R)$. When $\beta\ge\beta_1$, $0<\underline{\sigma}^R<1$ but $\overline{\sigma}^R\le 0$, and $\Delta_c>0$ if and only if $\sigma>\underline{\sigma}^R$. Equation Δ_r has a unique root $\sigma=-\frac{Qc_r+f-Qw}{\alpha Q(p-w)}=\sigma_7$ and $\Delta_r>0$ if and only if $\sigma>\sigma_7$. Furthermore, $\sigma_7<\underline{\sigma}^R$ if and only if $\beta<0$.

Next we solve the equilibrium for $\beta>0$ (the other cases are similar and omitted). Note that in this case $\underline{\sigma}^R<\sigma_7$. Suppose $\sigma>\sigma_7$. In $(\mathcal{D};\mathcal{D})$ firm A would deviate to $(\mathcal{I};\mathcal{D})$ because $\Delta_c>0$. Similarly in $(\mathcal{I};\mathcal{D})$ $((\mathcal{D};\mathcal{I}))$ firm B (A) would deviate to $(\mathcal{I};\mathcal{I})$ because $\Delta_r>0$. The unique equilibrium is

$(\mathcal{I};\mathcal{I})$ where neither firm would deviate. When $\underline{\sigma}^R < \sigma \le \sigma_7$, in $(\mathcal{I};\mathcal{I})$ each firm would deviate to $\mathcal{D}$ because $\Delta_r < 0$. In $(\mathcal{D};\mathcal{D})$ each firm would deviate to $\mathcal{I}$ because $\Delta_c > 0$. In $(\mathcal{I};\mathcal{D})$ and $(\mathcal{D};\mathcal{I})$, neither firm would deviate, and thus they are the equilibria. When $\sigma \le \underline{\sigma}^R$, in $(\mathcal{I};\mathcal{I})$, $(\mathcal{D};\mathcal{I})$ and $(\mathcal{I};\mathcal{D})$ at least one firm would deviate to $\mathcal{D}$, and thus the unique equilibrium is $(\mathcal{D};\mathcal{D})$. □

Proof of Proposition 11. Note that the thresholds $\underline{\sigma}^R$ and $\overline{\sigma}^R$ are the same as in Proposition 1. Additionally, in Proposition 2 we show that as β increases, these thresholds change in a way that expands the $\mathcal{I}$ region (i.e., $\mathrm{d}\underline{\sigma}^R/\mathrm{d}\beta < 0$ and $\mathrm{d}\overline{\sigma}^R/\mathrm{d}\beta > 0$ for $\overline{\sigma}^R \in (0,1)$). This combined with the fact that $cr/(-\alpha p)$ does not change with β imply the proposition. □

Proof of Proposition 12. Denote the suppliers' profits by $\pi^{Si}_{m,n}$, where $i \in \{A,B\}$ and $m,n \in \{Re,Co\}$. Define $\eta = \pi^{SA}_{ReRe} - \pi^{SA}_{CoRe} = \pi^{SB}_{ReRe} - \pi^{SB}_{ReCo}$ and $\nu = \pi^{SA}_{ReCo} - \pi^{SA}_{CoCo} = \pi^{SB}_{CoRe} - \pi^{SB}_{CoCo}$. Noting that the root of η is $-c_s/w\alpha$, the proposition straightforwardly follows. □