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

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Taylor Guitars purchased an ebony mill in Cameroon to ensure corporate social and environmental responsibility (CSER) in sourcing, and shared the responsibly-sourced supply of ebony with competitors through horizontal sourcing. Inspired by this case, we investigate vertical integration as an alternative strategy for CSER in sourcing in which a firm can vertically integrate with its supplier in order to ensure responsible practices in the supply chain. In a competitive setting, an exposed CSER violation in one supply chain may increase the competing supply chain’s demand (positive externalities) due to substitution, or decrease the competing supply chain’s demand (negative externalities) due to the public’s suspicion about an industry’s social and environmental practices. Furthermore, NGOs’ scrutiny and reporting policies may influence the likelihood of a violation exposure, as well as demand externalities between the competing supply chains. We examine horizontal sourcing as a potential strategy for mitigating the impact of a CSER externality from a competing supply chain. When horizontal sourcing is infeasible, we find that higher violation exposure externalities better induce CSER, but overly intensive violation scrutiny alongside strongly negative externalities may backfire and impede CSER. By contrast, when horizontal sourcing is feasible, intensive violation scrutiny better induces CSER, but strongly positive externalities may impede industry-wide CSER. These findings have instructive implications for firms pursuing CSER in their supply chain, as well as for NGOs’ violation scrutiny and reporting policies.

Key words: responsible sourcing, CSER, NGO, demand externalities

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 sales decreasing and stock price dropping 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 the collapse, Rana plaza was housing 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 grow more extended, complex, and globalized, ensuring CSER is becoming 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 lead to widespread illegal and unsustainable ebony harvesting practices. Gibson Guitar, 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 criticisms from environmental and industry groups (Sasso 2011). To avoid such 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 the sourcing of ebony from Crelicam (White 2012).

Taylor Guitars had to navigate Cameroon’s complex and often obscure regulations to obtain all required permits. They then went on to carefully inspect and rectify irresponsible practices in the day-to-day operations at Crelicam. During this process, they discovered a prevalent yet disturbing practice in ebony harvesting. Not all ebony trees have pitch-black wood inside, but the guitar industry had traditionally valued pitch-black ebony wood for aesthetic reasons. As a result, ebony suppliers had been cutting down an average of ten ebony trees just to find one with pitch-black wood, leaving nine downed trees to rot. Becoming aware of this practice, Taylor Guitars decided to use non-pitch-black ebony in their guitars, and launched campaigns to raise consumer awareness of the state of ebony and promoted the use of non-pitch-black ebony by other guitar makers. Taylor Guitars also doubled worker wages and made sure that Crelicam operates in alignment with Cameroon and US Labor Laws. In addition, Taylor Guitars plans to make investments and train workers so that Crelicam can further process ebony into semi-finished products. This will create more jobs and allow the Cameroonian people to reap greater economic benefits from their
native resource (Arnseth 2013, White 2012, Taylor Guitars 2012). Interestingly, Taylor Guitars is willing to share its responsibly sourced ebony with competitors through horizontal sourcing. It now 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. Its effectiveness has been documented by practitioners and studied by academicians (Gayathri 2013, Chen et al. 2015, Xu et al. 2015, Caro et al. 2015). However, due to auditing’s sampling nature, suppliers can sometimes find ways to cheat the procedures. For example, some suppliers build showroom factories for audits while subcontracting or carrying out production at different sites (Mitchell 2012). In other cases, fake factory books were made to conceal unethical practices (Chu 2012). Plambeck and Taylor (2015) show analytically that auditing may cause suppliers to hide violations rather than rectify their practices. These risks are further magnified in complex supply chains that extend beyond countries and oceans; the geographic distance limits the frequency and secrecy of audits, and the cultural and language barriers create more potential loopholes. In fact, after the Rana Plaza disaster, Walmart, Gap, Nike and several other firms acknowledged that “audits alone are not doing enough” (The Economist 2013). Locke et al. (2007) also find empirically that Nike’s audits had not improved suppliers’ labor standards.

Auditing is likely much easier and cheaper to implement and manage than vertical integration. Therefore, firms should first consider auditing for managing CSER in sourcing—which explains its popularity. Nevertheless, in situations where auditing may be ineffective, vertical integration becomes a powerful alternative. For example, Taylor Guitars’ Charlie Redden found it practically impossible to depend on a supplier itself to ensure CSER in Cameroon’s legal, political, and economic environments. Vertical integration allows the buying firm full knowledge and control of the supplier’s operations, thus is less susceptible to the risks that undermine audits’ effectiveness. In fact, Taylor Guitars is far from the only firm to adopt vertical integration for CSER. Tiffany has long been vertically integrated to ensure that its brand name is not connected to blood diamonds (Aston 2011). American Apparel proudly announces on its website that, through vertical integration, it can guarantee its products to be sweatshop-free.² Similarly, the State of Florida requires all medical

²https://www.americanapparel.net/aboutus/verticalint/
cannabis producers to be vertically integrated (Fountain 2015). While several economic drivers of vertical integration have been studied in the literature, we set out to understand whether and when vertical integration can be driven by incentives related to CSER, which is the first objective of this paper.

The other interesting observation is Taylor Guitars’ openness in sharing responsible supply with competitors through horizontal sourcing (which is enabled by vertical integration). Horizontal sourcing is a common sight in industry. 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 economic considerations, but as we will explain below, CSER risks may also motivate horizontal sourcing.

A CSER violation exposed at a supplier may impact its clients’ demands, as consumers may forgo purchasing products tainted by the violation. To provide a few examples, in the apparel industry, organized boycotts by universities affiliated with the Worker’s Rights Consortium (WRC) in 2000 threatened up to 20% of the revenue of Gear for Sports, an athletic apparel provider, and up to 1% of the revenue of Nike, following the revelation of labor violations by their suppliers (Guo et al. 2016). In 2008, after WRC exposed a labor right violation in Honduras by Russel Athletic, more than 100 universities decided not to renew their contracts for licensed goods with Russel (Anupindi and Hermelin 2014). Moreover, the impact of a CSER violation is often not limited to the directly involved firm. On the 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 a competitors’ demand). On the other hand, a CSER violation may also yield a negative externality. For instance, after a transportation contractor for the Newmont Mining Corporation caused a major mercury spill in Peru, the widespread protests and hostility toward the mining industry affected an unrelated mining company, BHP Billiton (Puffer and Wesley 2012). Similarly, Yardley (2013a) reports that the collapse of Rana Plaza has “placed the entire global supply chain that delivers clothes from Bangladeshi factories to Western consumers under scrutiny.” A CSER violation’s negative externality may be explained by the public’s suspicion about the industry’s general practices. In many cases, major suppliers in a particular industry are clustered in a geographic region. For instance, some of the world’s largest electronics manufacturers are concentrated around a few major cities in China (Liu 2013). Bangladesh supplies major European and American apparel brands, including but not limited to Gap, Calvin Klein, Tommy Hilfiger, H&M, and Zara (The Economist 2013). In these industries, a
CSER violation may raise suspicions about general practices in the region, and negatively impact the demands of other firms in the industry regardless of whether they engaged in malpractice. (A similar phenomenon called advertising spillover has been documented, where one firm’s advertising may increase competing firms’ demands because the advertisement reminds consumers of related products; see Perry 1989, Anderson and Simester 2013, Lewis and Nguyen 2014.) Therefore, it is plausible that a vertically integrated firm may willingly share responsible supply with competitors in order to avoid negative externalities resulting from competitor’s actions; and in general, the nature of CSER externalities in an industry (positive or negative) may affect firms’ behaviors. Accordingly, our second objective is to understand how CSER externalities affect a firm’s integration and responsibility strategies, and if horizontal sourcing can mitigate such externalities.

Finally, we note that non-governmental organization (NGOs) can influence firms’ responsibility behaviors in several important ways. First, NGOs’ scrutiny efforts influence the likelihood of a CSER violation exposure; it has been suggested that tighter scrutiny deters CSER violations (Baron et al. 2011, Greenhouse 2013). Second, how NGOs publish CSER violations may influence their externalities for other firms in the industry. 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 incite global protests and boycotts against all Brazilian cattle ranches regardless of whether their actions directly damaged the Amazon rainforest. Another example is a list maintained by the US Department of Labor about goods that may be produced by child or forced labor on a country level, such as shrimps from Thailand.

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 scrutiny levels and reporting policies on inducing CSER.

We study these research questions by modeling an industry with two major competing firms. Each firm has its own supplier and market share. In the main model we assume that one of the two firms is capable of vertically integrating with its supplier at a fixed cost, which will ensure CSER and thus eliminate its own risk of CSER violations, at increased sourcing costs. (The case where both firms can vertically integrate yields similar insights and is included in Appendix 6.5.)

Since our goal is to study situations where conventional approaches such as auditing are ineffective,
we assume that a disintegrated firm always faces the risk of a CSER violation exposure. When a CSER violation is exposed at its supplier, the demand for the directly involved firm decreases. The competing firm’s demand may increase or decrease, capturing the possibly positive or negative violation externalities. We first assume no horizontal sourcing, and show that when combined with strongly negative externalities, NGOs’ overly intensive scrutiny may actually impede responsible sourcing. On the other hand, more positive externalities can better induce responsible sourcing.

Next, we allow the integrated firm to provide responsible supply to the competing firm through horizontal sourcing, which eliminates risks of violation exposures in both supply chains. With the possibility of horizontal sourcing, the firms’ behaviors become different. Now NGOs’ more intensive scrutiny always better induce responsible sourcing, but strongly positive externalities may drive the integrated firm away from sharing responsible supply, thus impeding industry-wide CSER. Comparing the two models, we find that in general, the possibility of horizontal sourcing greatly improves industry-wide CSER.

Our analyses show that NGOs’ scrutiny and reporting policies have a non-straightforward impact on a firms’ responsible sourcing behavior. NGOs should consciously consider whether their reports foster positive or negative externalities, and whether horizontal sourcing is feasible in the relevant industry to avoid unintended consequences. Our findings suggest that when horizontal sourcing is infeasible, NGOs should refrain from publishing broadly indicting reports that may yield highly negative externalities, and be cautious about overly intensive scrutiny. On the other hand, with the possibility of horizontal sourcing, more intensive scrutiny induces better CSER, but NGOs should refrain from being overly specific in their reports to avoid creating strongly positive externalities, which discourage the sharing of responsible supply.

A buying firm’s integration with a supplier 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 buying firm. Therefore, it is a priori unclear whether promoting vertical integration is a viable strategy by which NGOs may stimulate economic growth in developing nations. Our study shows that despite the costs, vertical integration for CSER can be economically justifiable for the buying firm, which suggests that NGOs may indeed promote vertical integration as an approach to improve the livelihood of people in developing nations.

The rest of this paper is organized as follows. In Section 2 we survey the related literature. The general 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 next investigate
several model extensions in Section 6.1 and confirm the robustness of the base model’s insights, before concluding our findings in Section 7. The Appendix contains additional results and all proofs.

2. Literature

A relatively new but rapidly growing literature exists on CSER in sourcing. Plambeck and Taylor (2015) investigate the mechanisms that may incentivize suppliers to comply with responsibility standards. Chen and Lee (2014) design contracts to screen and identify unethical suppliers. Kim (2014) studies a manufacturer’s disclosure decision for environmental noncompliance incidences. Alizamir and Kim (2015) investigate the asymmetric relationship between a supplier and a buyer in the event of a public disclosure. Xu et al. (2015) analyze policies that may discourage child labor. Lin (2016) are similarly inspired by Taylor Guitars and investigate co-production in a sustainability context. 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. These papers focus on mechanisms to induce CSER in a single decentralized supply chain. In comparison, we consider CSER in a market with two competitive supply chains. Kraft et al. (2013a) and Kraft et al. (2013b) investigate the removal of a potentially hazardous substance from a product in a competitive environment, from the manufacturer’s and NGOs’ perspectives, respectively. Their models assume that the manufacturer has full control over all aspects of production. By contrast, in our model whether to obtain full control of the supply chain is a costly decision by the manufacturer (through vertical integration). Belavina and Girotra (2014) study the role of supply network structure in responsible supplier behaviors. Our consideration of vertical integration is related to supply chain structures, but our model setting is vastly different from their relational (long-term) sourcing setting. In addition, Belavina and Girotra (2014) consider supply network structure as an exogenous input, whereas we endogenize the supply chain structure decision. Chen et al. (2015) study the interaction of whether a firm releases its supplier list with NGOs’ auditing efforts and suppliers’ compliance efforts, whereas we focus on vertical integration as an alternative strategy to auditing when the latter is ineffective. Agrawal and Lee (2015) 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. Caro et al. (2015) and Fang and Cho (2015) investigate two new types of auditing mechanisms, namely joint and shared audits. Particularly, Fang and Cho (2015) model positive and negative externalities of social responsibility violations similarly to our model.
The main difference is that these papers investigate auditing mechanisms, whereas we focus on situations where audits may be ineffective, and study vertical integration as an alternative strategy, thus complementing these papers. Guo et al. (2016) study a buyer’s sourcing decision between a responsible supplier and another supplier who poses potential CSER risks when selling to a socially conscious market segment. 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 before a firm can ensure CSER in sourcing. Finally, we consider a vertically integrated firm supplying a competing firm—a strategy irrelevant in an isolated supply chain.

Our work can be regarded as mitigating CSER violation risks, thus is remotely related to the literature on strategies to mitigate supply risks. Prominent examples of strategies considered in this literature include inventory (Tomlin 2006), financial mechanisms (Swinney and Netessine 2009, Babich 2010, Dong and Tomlin 2012), backup production capability (Yang et al. 2009), diversification (Tomlin 2009), and guaranteed delivery contracts (Hu and Kostamis 2015). Our work differs from this stream of literature in two significant ways. First, in these papers the risks impact the supply side, whereas in our paper the risk impacts the demand side (due to consumers response to exposed violations). Second, a key component of our model is the (possibly positive or negative) externalities of CSER violations, which are absent in the supply risk management setting.

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 captures that vertical integration may lead to various forms of economies of scale. The third one captures 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 that vertical integration may ensure a firm’s CSER in sourcing. In order to isolate CSER as a new driver, we eliminate the aforementioned known drivers of vertical integration in our model: we do not assume economies of scale (in our model vertical integration and ensuring CSER actually 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.

Finally, we discuss the connection and distinction between CSER and product quality management. A CSER violation by itself may not involve inferior product quality. For example, a guitar
built with illegally sourced wood can have the exact same quality as one built with responsibly-sourced wood. Therefore, product inspection, a popular tool for quality control, is not applicable to CSER; the latter requires proper management of the sourcing and production process. On the other hand, relatively minor quality issues may not have significant social impacts. For example, a low-quality component’s impact may be limited to increased warranty costs, but does not necessarily raise any concerns about the entire industry. However, serious quality issues, especially when threatening consumer health and safety, can have significant social impacts, in which case the quality issue escalates into a CSER violation. A case in point is the 2008 Chinese baby formula scandal, in which one company’s contaminated products caused 54,000 children to suffer from kidney stones (Mooney 2008). After the news broke out, consumers avoided all Chinese baby formula brands (Ramzy 2008). The majority of the product quality management literature does not consider the social impact of quality issues. For example, Chao et al. (2009) investigate how product recall cost sharing contracts between suppliers and buyers can induce improved product quality, and Babich and Tang (2012) explore deferred payment as a means to prevent suppliers from cutting corners. In comparison, we focus on the social impacts of CSER violations by modeling their (possibly positive and negative) externalities. To a certain extent, our research sheds light on product quality issues that are serious enough to have significant social impacts.

3. Model

We model two competing firms selling products in 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 a fixed retail price $p$. Each unit of a buyer’s product requires one unit of a critical component sourced from its supplier at market wholesale price $w$. As explained in Section 1, we aim to study vertical integration as an alternative when conventional approaches, 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 and ensures CSER. 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 single parameter captures the CSER risks embedded in this industry’s current common practices. All parties are risk-neutral.

3 There are two sources of uncertainty contributing to a violation exposure: whether a supplier violates CSER codes, and whether the violation gets exposed. Our parameter $\sigma$ captures their combined effect.
If a violation is exposed at one supplier, its buyer’s demand would be negatively affected (see the examples in Section 1). 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 $\beta$ may be positive or negative captures the possibly positive and negative externalities of a CSER violation exposure. The assumption of $|\beta| < |\alpha|$ reflects the intuition that a violation exposure’s direct impact should be stronger than its indirect impact. Finally, if violations are exposed at both suppliers, we assume both supply chains’ demands decrease to $(1 + \alpha)Q$.

We offer two notes about the demand model before moving on. First, we directly assume the demand changes after a CSER violation exposure instead of modeling consumer behavior which leads to such demand changes. We do so because the exact market mechanism behind the demand changes is not our focus, and that a descriptive model is simple yet general enough for us to study our problem. Such descriptive models are often 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 the market size in terms of volume (demand) for simplicity, while keeping the retail price $p$ fixed—a setting also adopted by Boyaci and Gallego (2004) and Huang et al. (2015), among others. In practice, firms may adjust their retail prices to mitigate a violation exposure’s demand impacts. However, even with responsive pricing, the 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.

Of the two buyers, we make the assumption in the main model that only one can ensure CSER by vertically integrating with its supplier. (In Section 6.5, we investigate the case where both firms can vertically integrate, and obtain similar insights to those from the main model. We have also analyzed a model where ensuring CSER is an option after integration, and found that all important structural results are retained. The analysis is available from the authors.) The assumption that only one buyer can integrate with its supplier 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 had many years of experience sourcing ebony from Cameroon before purchasing its own mill there (White 2012), and remained the first and only (as of December 2013) vertically integrated supply chain in the musical instrument industry (Arnseth 2013). 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 $B$ can be interpreted as it having a prohibitively high fixed cost for integration.) Furthermore, consistent with the case of Taylor Guitars, once buyer $A$ integrates with supplier $A$ and ensures CSER, the component sourcing cost becomes $c_r > w$. This assumption reflects that suppliers in developing economies often depend on very thin margins which make it economically infeasible to ensure CSER and improve worker conditions by themselves. The increased sourcing cost after vertical integration and ensuring CSER reflects the necessary investments and efforts to rectify irresponsible practices, which often improve the local residents’ livelihood. In Taylor Guitars’ case, they overcame great difficulties navigating a highly complex legal system to obtain all required permits, expanded power grid, and doubled worker salaries (White 2012). In exchange, firm $A$ eliminates its own violation exposure risk ($\sigma = 0$). 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 aware of a firm’s CSER efforts, and furthermore may not trust a firm’s CSER claims if a violation at a similar supplier has just been exposed.

Finally, 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 (see Section 1 for relevant examples). In the base model, we assume that buyer $B$ can choose to source components from either supplier $B$ or firm $A$, but not both. (In Section 6.4 we relax this assumption and show that all important structural results are retained.) Since horizontal sourcing is not ubiquitous in all industries, we first study the model without horizontal sourcing in Section 4 then with this option in Section 5 which also allows us to compare these two cases.

The general sequence of events is presented in Figure 1. First, buyer $A$ decides whether to ensure CSER by vertically integrating with supplier $A$. Next, if horizontal sourcing is feasible, a vertically
Table 1 Parameters and Decision Variables

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
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<tbody>
<tr>
<td>$p &gt; 0$</td>
<td>Retail price</td>
</tr>
<tr>
<td>$w &gt; 0$</td>
<td>Component wholesale price from a supplier</td>
</tr>
<tr>
<td>$w' &gt; 0$</td>
<td>Endogenous component wholesale price through horizontal sourcing</td>
</tr>
<tr>
<td>$c_r &gt; w$</td>
<td>Unit cost of responsibly sourced components</td>
</tr>
<tr>
<td>$f &gt; 0$</td>
<td>Fixed cost of vertical integration</td>
</tr>
<tr>
<td>$Q &gt; 0$</td>
<td>Current market size of each firm</td>
</tr>
<tr>
<td>$\alpha \in (-1, 0)$</td>
<td>Direct impact of an exposed violation</td>
</tr>
<tr>
<td>$\beta \in (\alpha, -\alpha)$</td>
<td>Indirect impact (externalities) of an exposed violation</td>
</tr>
<tr>
<td>$\sigma \in (0, 1)$</td>
<td>Probability of a violation exposure</td>
</tr>
</tbody>
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integrated firm $A$ sets wholesale price $w'$ for buyer $B$, who decides whether to source from firm $A$ or supplier $B$. The random violation exposures are then realized. Before integration, each supplier has independent probability $\sigma$ to be exposed of a violation. (The case with correlated violation exposure risks is investigated in Section 6.1.) Finally, the firms purchase components and make products to satisfy the demands. Table 1 summarizes all parameters and decision variables.

4. Analysis without horizontal sourcing

We first analyze the model assuming horizontal sourcing is infeasible (i.e., an integrated firm $A$ cannot supply buyer $B$). In practice, horizontal sourcing is not ubiquitous for a number of potential reasons. First, if the component in consideration is highly customized to one firm’s specific requirements, it will be difficult for another firm to use the same component. Second, firms in industries where competition is intensive may have psychological resistance to 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. This section’s analysis also serves as a basis of comparison in Section 5 where we analyze the model with horizontal sourcing, and highlight the different insights between the two cases.

Our goal is to understand whether the buyer $A$ would integrate with supplier $A$ (and hence ensure CSER) or stay disintegrated (and hence maintain conventional practices). We use $I$ and $D$ to respectively denote buyer $A$’s decision to integrate with supplier $A$ or stay disintegrated. Therefore, buyer $A$ has two possible strategies, $D$ and $I$. Let $\pi_X^i$ denote buyer $i$’s expected profit when buyer $A$ follows strategy $X$. Below are the expressions of the expected profits (recall that $\sigma$ is a supplier’s violation exposure probability):

$$\pi_I^A = (p - c_r)Q[\sigma(1 + \beta) + (1 - \sigma)] - f,$$
We assume a sufficiently small fixed cost $f$ and a sufficiently small cost of responsibly sourced component ($c_r < -[\alpha(p - 2w) + 2(1 - \sqrt{\alpha + 1})(p - w)]/\alpha$, recall that $-1 < \alpha < 0$) such that $D$ does not dominate $I$. (The specific threshold for $f$ can be found in the Online Supplement.) These assumptions rule out uninteresting cases; we also know that these assumptions may be satisfied in practice from the documented examples of vertical integration for CSER such as Taylor Guitars and Tiffany (see Section I). The following proposition characterizes the structure of the optimal strategy, and Figure 2 visualizes the optimal strategy. (Parameters used in generating this figure are $p = 2$, $w = 1/8$, $c_r = 1/4$, $Q = 4$, $\alpha = -3/8$.)

**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. When $\beta < \max(\alpha, \beta_2(f))$: the optimal strategy is $D$.
2. When $\max(\alpha, \beta_2(f)) < \beta < \beta_1(f)$: If $\sigma \in (\sigma^R, \sigma^R)$, buyer A’s optimal strategy is $I$. If $\sigma \in (0, \sigma^R] \cup [\sigma^R, 1)$, its optimal strategy is $D$.
3. When $\beta_1(f) \leq \beta$: If $\sigma \in (\sigma^R, 1)$, buyer A’s optimal strategy is $I$. If $\sigma \in (0, \sigma^R]$ its optimal strategy is $D$.

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

**Figure 2**  
Buyer A’s optimal strategy without horizontal sourcing. Dashed boundaries are for $f = 0.10$, the solid ones for $f = 0.15$, and dotted for $f = 0.35$. 

\[ \begin{align*} 
\pi_A^D &= \pi_D^B = (p - w)Q[\sigma^2(1 + \alpha) + \sigma(1 - \sigma)(1 + \alpha) + (1 - \sigma)\sigma(1 + \beta) + (1 - \sigma)^2], \\
\pi_I^B &= (p - w)Q[\sigma(1 + \alpha) + (1 - \sigma)]. 
\end{align*} \]
Let us understand buyer A’s optimal strategy. One can see that if the violation exposure probability is sufficiently low, firm A stays disintegrated and maintains conventional practices, which is intuitive. This observation reflects the basic trade-off between avoiding one’s own violation exposures, and reducing sourcing costs. What is less intuitive is that, with strongly negative exposure externalities, high probabilities of violation exposure can also drive firm A to stay disintegrated and maintain conventional practices rather than to become vertically integrated and ensure CSER. The cause of this behavior is the negative externalities. While an integrated firm A can eliminate its own violation risks through vertical integration, it is still vulnerable to negative 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 the other firm anyway. As a result, firm A chooses to remain disintegrated instead.

The above observations have managerial implications for NGOs focusing on CSER. They can influence the violation exposure probabilities to some extent by adjusting the resources dedicated to scrutinizing firms, and it is easy to assume that more intensive scrutiny is more likely to “scare” firms into ensuring CSER in sourcing [Baron et al. 2011, Greenhouse 2013]. Nevertheless, our analysis suggests that in scenarios where externalities are strongly negative, such NGOs’ scrutiny efforts may backfire and drive firms away from CSER.

On the other hand, note that the 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 probabilities of exposure σ where buyer A’s optimal strategy is I grows as externality β increases.

Recall our discussion in Section 1 that NGOs can influence exposure externalities by choosing how they report violations: a report can broadly indict an industry or a region and foster negative externalities, or be more specific about firms directly involved in a violation while exonerating uninvolved firms and foster positive externalities. Proposition 2 suggests that, without horizontal sourcing, higher externalities may be more in line with inducing CSER. (Interestingly, if horizontal sourcing is feasible, this is no longer the case; see Section 5.)

So far we have discussed the CSER behaviors. Next we investigate the firms’ profits. One might intuitively think that for buyer B, who 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 \( D \), then increasing \( \sigma \) by \( \tau \in (\tau^c, \tau^r) \) shifts the optimal strategy to \( I \) and increases buyer B’s profit. The characterizations of \( \Delta_1 \), \( \tau^c \) and \( \tau^r \) are found in the proof of the proposition.

With negative exposure externalities, buyer B may actually benefit from an increased probability of a violation exposure, because when it pushes firm A into vertical integration, buyer B will be free of any negative externalities due to firm A’s violations.

To summarize, without horizontal sourcing, our analysis of the model suggests that the externalities of exposed CSER violations significantly influence firms’ behaviors. In general, a firm is more likely to ensure CSER through vertical integration with higher externalities, but when externalities are strongly negative, overly intensive scrutiny may backfire and drive a firm away from CSER. These findings provide instructive implications for NGOs to strategically influence the externalities and violation exposure probabilities to induce CSER in sourcing.

5. Analysis with horizontal sourcing

In this section, we analyze the model with horizontal sourcing. We continue to use the notations from Section 4, where \( D \) and \( I \) respectively represent buyer A’s strategy of staying disintegrated and maintaining conventional practices, and integrating with supplier A and ensuring CSER. Additionally, we use subscripts \( S \) and \( N \) on \( I \) to respectively denote whether or not buyer B sources from the integrated firm A through horizontal sourcing. We denote by \( w' \) the horizontal sourcing wholesale price set by an integrated firm A. Using backward induction, we solve the three-stage (integration, pricing, procurement) sequential game (as shown in Figure 1). The following proposition characterizes the equilibrium.

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

1. When \( \beta \leq \beta_3(f) \): If \( \sigma \in (0, \sigma_1] \), the equilibrium is \( D \). If \( \sigma \in (\sigma_1, 1) \), it is \( I_S \).
2. When \( \beta_3(f) < \beta < \frac{w-c_r-\alpha(p-w)}{p-c_r} \): If \( \sigma \in (0, \sigma_R] \), the equilibrium is \( D \). If \( \sigma \in (\sigma_R, \sigma_2] \), it is \( I_N \). If \( \sigma \in (\sigma_2, 1) \), it is \( I_S \).
3. When \( \frac{w-c_r-\alpha(p-w)}{p-c_r} \leq \beta \): If \( \sigma \in (0, \sigma_R] \), the equilibrium is \( D \). If \( \sigma \in (\sigma_R, 1) \), it is \( I_N \).

The equilibrium horizontal sourcing wholesale price is \( w' = w + \alpha \sigma (w - p) \). The threshold \( \beta_3(f) \) is a continuous increasing function of \( f \) characterized in the proof of the proposition. The characterization of \( \sigma_R \) is found Proposition 1, and those of \( \sigma_1 \) and \( \sigma_2 \) are found in the proof of the proposition.
Figure 3  Firms’ equilibrium strategy with horizontal sourcing. Dashed boundaries are for \( f = 0.10 \), the solid ones for \( f = 0.15 \), and dotted for \( f = 0.35 \).

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 into vertical integration and CSER. This is in stark contrast to Proposition 1 and Figure 2 (the case without horizontal sourcing), where higher exposure probabilities may drive firm A away from CSER. As we explained in Section 4, when horizontal sourcing is infeasible, scrutiny may discourage firm A’s CSER efforts because the negative externalities of buyer B’s violation exposures may make the efforts futile. When horizontal sourcing is feasible, however, firm A can eliminate negative externalities by sharing responsible supply with buyer B, thus scrutiny always drives CSER. Furthermore, when firm A is integrated and ensures CSER (in the \( I \) regions), higher exposure probabilities drive firm A to share responsible supply with buyer B (equilibrium shifting from \( I_N \) to \( I_S \)), expanding CSER to the entire industry. This is because under more intensive scrutiny, buyer B is willing to pay more premium for responsible supply, strengthening the incentive for firm A to share it.

We then investigate the impact of externalities. Interestingly, higher externalities cause the \( D \) and \( I_N \) regions to grow against the \( I_S \) region; this can be observed in Figure 3 and we provide an analytical characterization as well:

**Proposition 5.** Assume that horizontal sourcing is feasible, then the range of violation exposure probabilities \( \sigma \) where \( I_S \) is the equilibrium shrinks as externality \( \beta \) increases.

In addition, once again in stark contrast to Proposition 2 and Figure 2, strongly positive externalities actually impair industry-wide CSER in sourcing: Proposition 5 and Figure 3 show that
within the $\mathcal{I}$ regions where firm $A$ is integrated and ensures CSER, when externalities are strongly positive, firm $A$ stops sharing responsible supply with buyer $B$ (equilibrium shifting form $\mathcal{I}_S$ to $\mathcal{I}_N$). The explanation is that, positive externalities mean that firm $A$ benefits from buyer $B$’s violation exposures, which is a disincentive for the former to share responsible supply with the latter. Note that this issue is nonexistent without horizontal sourcing. Therefore, interestingly, while 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 should consciously consider whether horizontal sourcing is feasible in the relevant industries when choosing their scrutiny and reporting policies, so as to avoid unintended consequences.

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

**Proposition 6.** Assume $\beta < 0$ and $\sigma_1 - \Delta_2 < \sigma \leq \sigma_1$ so that the equilibrium is $\mathcal{D}$, then increasing $\sigma$ by $\tau \in [\tau^r, \tau^r]$ shifts the equilibrium to $\mathcal{I}_S$ and increases both firm $A$ and buyer $B$’s profits. The characterizations of $\Delta_2$, $\tau^r$ and $\tau^r$ 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 infeasible (Section 4) with those when horizontal sourcing is feasible (Section 5), to appraise the CSER value of horizontal sourcing. Because horizontal sourcing is an additional lever that benefits the social responsibility outcome, the possibility of horizontal sourcing strictly improves CSER:

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

Moreover, when one compares Figures 2 and 3, it is apparent that horizontal sourcing brings CSER to the entire industry in a significant parameter region. Thus, horizontal sourcing greatly improves industry-wide CSER.

To summarize, when horizontal sourcing is feasible, intensive scrutiny drives CSER, 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 when horizontal sourcing is infeasible, where higher externalities provide the right incentives, but overly intensive scrutiny may backfire. In general, the possibility of horizontal sourcing greatly improves CSER.
6. Extensions

Thus far we have adopted a base model which allowed us to derive structural properties and reveal insights. It is important to verify that the key insights are not driven by specific assumptions in the base model. In this section we investigate various extensions of the base model and show that the key insights remain unchanged, and in some cases also make new observations pertaining to the extensions.

6.1. Correlated violation exposure risks

In the base 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. A case of a positive correlation may be that an exposed violation at one supplier triggers more intensive scrutiny of other similar suppliers. On the other hand, observing an exposed violation at one supplier, other suppliers may take proactive measures to rectify and/or conceal malpractices, leading to negatively correlated violation exposure risks. In this section, we investigate our model with correlated violation exposure probabilities. We carry out the investigation by means of a numerical study as outlined below.

Recall that in the main model, we assume that each supplier faces an independent violation exposure probability \( \sigma \). To introduce correlations without changing the marginal probabilities (namely each supplier still has probability \( \sigma \) to be exposed of a violation), we adopt the correlated bi-variant Bernoulli model in Hu and Kostamis (2015) as described below. We denote the joint probabilities of four possible exposure scenarios by \( q_{00}, q_{01}, q_{10}, q_{11} \), where 1 represents a violation exposure and 0 represents no exposure, at suppliers \( A \) and \( B \). 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 correlation, we define \((q_{00}, q_{01}, q_{10}, q_{11}) = (r \sigma (1 - \sigma) + (1 - \sigma)^2, (1 - r) \sigma (1 - \sigma), (1 - r) \sigma (1 - \sigma), (1 - \sigma) \sigma (1 - \sigma) + \sigma^2)\) 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 \( (q_{01} = q_{10} = 0) \).

Figures 4 and 5 depict buyer \( A \)'s optimal strategies when horizontal sourcing is infeasible and feasible, respectively, 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 all previous figures. Case (a)'s of Figures 4 and 5 have positive correlations, and are structurally similar to Figure 2 and Figure 3, thus confirming that the main insights in Section 4 and 5 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) does not share
similar structures as the $D$ 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 exposure probabilities cannot be negatively correlated. For example, if each of suppliers $A$ and $B$ has marginal probability 0.9 of a violation exposure, then they will almost always be exposed of violations simultaneously, thus must be strongly positively correlated. Therefore, (b) of Figure 4 and 5 is not completely comparable to Figure 2 and Figure 3 and where comparable ($\sigma \lesssim 0.53$), they are structurally similar.

Figure 4 Buyer $A$’s optimal strategy with correlated violation exposure probabilities, no horizontal sourcing.

The solid (dotted) boundaries are for $r = 0.2$ and $r = -0.4$ ($r = 0.4$ and $r = -0.2$)

An interesting question that would have important managerial implications is how CSER outcomes change with the correlation between violation exposure risks. We find that with positive externalities, the integration regions where buyer $A$ integrates with supplier $A$ ($I/I_S/I_N$) grow when the correlation increases (algebraically, rather than in absolute magnitude); and with negative externalities, the integration regions shrink when the correlation increases. 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 in choosing their scrutiny
policies. NGOs may influence violation exposure correlations to some extent. For example, when a violation is exposed, NGOs can focus resources on the involved supplier, reducing correlations, or allocate more resources to other similar suppliers, increasing correlations. Our results suggest that NGOs should consider the nature of externalities in the relevant 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 base model to allow buyers to choose one of two available suppliers, and thus, they may end up sourcing from a shared supplier. In particular, for both no horizontal and horizontal sourcing cases, we assume that if buyer $A$ decides to stay disintegrated, then the buyers simultaneously choose the supplier to source from (either supplier $A$ or $B$). 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. demands drop to $(1+\alpha)Q$). We denote the equilibrium of both buyers sharing a supplier with $D_C$, and that of the buyers sourcing from different suppliers with $D_U$. We first present the case without horizontal sourcing in Proposition 8 and Figure 6. The figure is generated using the same parameters as in Figure 2 and $f = 0.1$.

**Proposition 8.** Assume no horizontal sourcing.

1. When $\beta \leq \beta_1(f)$: The optimal strategy is $D$. 

Figure 5  
Firms’ equilibrium strategies with correlated violation exposure probabilities, with horizontal sourcing. 

The solid (dotted) boundaries are for $r = 0.2$ and $r = -0.4$ ($r = 0.4$ and $r = -0.2$).
2. When $\beta_1(f) < \beta < 0$: If $\sigma \in (0, \sigma_3]$, the equilibrium is $D_C$. Otherwise, if $\sigma \in (\sigma_3, 1)$, it is $I$.

3. When $0 \leq \beta$: If $\sigma \in (0, \sigma_R]$, the equilibrium is $D_U$. If $\sigma \in (\sigma_R, 1)$, it is $I$.

The threshold $\sigma_3$ is a continuous decreasing function of $\beta$ and its characterization is found in the proof of the proposition. The characterizations of $\sigma_R$ and $\beta_1(f)$ are found in Proposition 7.

![Figure 6 Equilibria with non-exclusive suppliers without horizontal sourcing.](image)

Note that when externality is nonnegative, all the equilibria are the same as in the base model since the buyers source from different suppliers. However, with negative externalities, the buyers’ sourcing behaviors change compared to the base model because they source from a shared supplier. Consequently, the region where buyer $A$ stays disintegrated for high probabilities of exposure in Proposition 1 (the $D$ 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 the externality than from integrating with its supplier and facing strong negative externalities. Thus, when we allow non-exclusive suppliers, higher probabilities of exposure always drive CSER. As for the impact of externality on the equilibrium structure, Proposition 8 implies that higher externalities always drive CSER. This trend is unchanged from the base model (Proposition 2).

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

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

1. When $\beta \leq 0$: If $\sigma \in (0, \sigma_4]$, the equilibrium is $D_C$. If $\sigma \in (\sigma_4, 1)$, it is $I_S$. 


2. When $0 < \beta \leq \beta_2(f)$: If $\sigma \in (0, \sigma_1]$, the equilibrium is $D_U$. If $\sigma \in (\sigma_1, 1)$, it is $I_S$.

3. When $\beta_2(f) < \beta < \frac{w - cr - \alpha(p - w)}{p - cr}$: If $\sigma \in (0, \sigma^R]$, the equilibrium is $D_U$. If $\sigma \in (\sigma^R, \sigma_2]$, it is $I_N$. If $\sigma \in (\sigma_2, 1)$, it is $I_S$.

4. When $\frac{w - cr - \alpha(p - w)}{p - cr} \leq \beta$: If $\sigma \in (0, \sigma^R]$, the equilibrium is $D_U$. If $\sigma \in (\sigma^R, 1)$, it is $I_N$.

The equilibrium horizontal sourcing wholesale price is $w' = w + \alpha \sigma (w - p)$. The characterizations of $\beta_2(f)$, $\sigma_1$ and $\sigma_2$ are found in Proposition 4, that of $\sigma^R$ is found in Proposition 1, and that of $\sigma_4$ is found in the proof of the proposition.

![Figure 7 Equilibria with non-exclusive suppliers and horizontal sourcing. The solid (dashed) boundaries are for $f = 0.15$ ($f = 0.1$)](image)

Similar to without horizontal sourcing, in Proposition 8, when externalities are negative, both buyers share a supplier if they stay disintegrated in an equilibrium. Overall, we observe consistent trends as in the base model: higher probabilities of exposure always drive CSER, whereas strongly positive externalities may hurt CSER due to discouraging buyer $A$ from sharing its responsible supply with buyer $B$.

6.3. Endogenous retail prices

In this section, we extend the base model’s exogenous retail price to endogenous retail prices. In particular, we assume the following demand function $Q_i = \theta_i - \gamma p_i + \epsilon p_j$, where $p_i$ and $p_j$ are the retail prices, and $\theta_i$ can take one of three values $1$, $1 + \alpha$ and $1 + \beta$, respectively for when no violation is exposed, a violation is exposed at a buyer’s own supplier, and a violation is exposed at the competing buyer’s supplier. Therefore, the parameters $\alpha$ and $\beta$ carry similar meanings as
in the base model. The parameters $\gamma$ and $\epsilon$ 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 the non-trivial cases where both buyers’ outputs are positive, and consistently observe that the model behaves qualitatively similar to our base model. This is evident in the representative examples (for both no horizontal sourcing and with horizontal sourcing) we provide in Figure 8, which are generated with parameters $\alpha = -3/8$, $w = 1/8$, $c_r = 1/4$, $\gamma = 0.6$, $f = 0.1$, and $\epsilon = 0.1$.

![Figure 8](image_url)

(a) No horizontal sourcing
(b) With horizontal sourcing

**Figure 8** Equilibria with endogenous retail prices. The solid (dashed) boundaries are for $f = 0.015$ ($f = 0.01$)

### 6.4. Capacitated horizontal sourcing

In this section, we consider a scenario in which the integrated firm $A$ has enough capacity $C$ for itself, but not enough to also provide all the needed supply for buyer $B$ through horizontal sourcing, namely $Q < C < 2Q$. In this case, we assume that in equilibrium $I_S$, buyer $B$ purchases $C - Q$ units of (responsible) supply from firm $A$ and the rest $2Q - C$ units from (conventional) supplier $B$ to fulfill demand $Q$. In other words, buyer $B$ dual-sources from responsible and conventional sources in equilibrium $I_S$. Recall that a violation may be exposed at the conventional supplier $B$ with probability $\sigma$, which still supplies buyer $B$ (even though only partially), thus buyer $B$ faces the same violation exposure probability $\sigma$ in equilibrium $I_S$. However, the demand impacts of such a violation exposure may be lower because only a portion of buyer $B$’s products are involved. To model this effect, we define direct and indirect proportional demand impact parameters respectively
as $\alpha_s = (2Q - C)\alpha/Q$, $\beta_s = (2Q - C)\beta/Q$. We also define $k = C - Q$ as firm A’s capacity in excess of its own demand that can be sold to buyer B. Proposition 10 characterizes the equilibria of this model extension.

**Proposition 10.** Assume horizontal sourcing is feasible and $f < f_2$. There exist thresholds $\beta_4(f)$ and $k_1(f, \beta)$ satisfying $\overline{\beta}(f) < \beta_4(f) < \overline{\beta}(f) < 0$ and $k(\beta, f) < k_1(f, \beta) < k(\beta, f)$, such that
1. When $\beta < \beta_4(f)$ and $k < k_1(f, \beta)$: If $\sigma \in (0, \sigma_5] \cup [\sigma_6, 1)$, the equilibrium is $D$. If $\sigma \in (\sigma_5, \sigma_6)$, it is $I_S$.
2. When $\beta_4(f) \leq \beta < \beta_3(f)$, or $\beta < \beta_4(f)$ and $k \geq k_1(f, \beta)$: If $\sigma \in (0, \sigma_5]$, the equilibrium is $D$. If $\sigma \in (\sigma_5, \sigma_6)$, it is $I_S$.
3. When $\beta_3(f) < \beta < \frac{w - c_r - \alpha(p - w)}{p - c_r}$: If $\sigma \in (0, \sigma_R]$, the equilibrium is $D$. If $\sigma \in (\sigma_R, \sigma_2]$, it is $I_N$. If $\sigma \in (\sigma_2, 1)$, it is $I_S$.
4. When $\frac{w - c_r - \alpha(p - w)}{p - c_r} \leq \beta$: If $\sigma \in (0, \sigma_R]$, the equilibrium is $D$. If $\sigma \in (\sigma_R, 1)$, it is $I_N$.

The equilibrium horizontal sourcing wholesale price is $w' = w + \alpha \sigma(w - p)$. The characterizations of $\beta_2(f)$ and $\sigma_2$ are found in Proposition 4, that of $\sigma_R$ is found in Proposition 1, and those of $\sigma_5$, $\sigma_6$, $\overline{\beta}$, $\overline{k}$ and $k$ are found in the proof of the proposition.

![Equilibrium when firm A’s capacity is less than the total demand, i.e., $C < 2Q$](image)
risks. As a result, the equilibrium structure of Figure 9(a) resembles that of Figure 2 in Section 4 without horizontal sourcing. On the other hand, when an integrated firm A’s capacity is high enough to meaningfully reduce buyer B’s violation exposure risks through horizontal sourcing, the equilibrium structure of Figure 9(b) resembles that of Figure 3 in Section 5 with horizontal sourcing. This trend is expected, and confirms that our insights are useful in understanding the impact of horizontal sourcing even with limited capacities.

6.5. Both buyers can vertically integrate

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

**Proposition 11.** Assume both firms can vertically integrate and no horizontal sourcing.

1. When \(\beta \leq \max(\alpha, \beta_2(f))\): the optimal strategy is \(D\).
2. When \(\max(\alpha, \beta_2(f)) \beta < \beta_1(f)\): If \(\sigma \in (\sigma^R, \bar{\sigma}^R)\), \((I, I)\) is an equilibrium. If \(\sigma \in (0, \sigma^R] \cup [\bar{\sigma}^R, 1)\), \((D, D)\) is an equilibrium.
3. When \(\beta_1(f) \leq \beta \leq 0\): If \(\sigma \in (\sigma^R, 1)\), \((I, I)\) is an equilibrium. If \(\sigma \in (0, \sigma^R]\), \((D, D)\) is an equilibrium.
4. When \(0 < \beta\): If \(\sigma \in (\sigma_7, 1)\), \((I, I)\) is an equilibrium. If \(\sigma \in (\sigma^R, \sigma_7]\), either \((I, D)\) or \((D, I)\) is an equilibrium. If \(\sigma \in (0, \sigma^R]\), \((D, D)\) is an equilibrium.

Furthermore, \(\beta_2(f) > \alpha\) if and only if \(f > f_1\). The characterizations of \(\sigma^R\), \(\bar{\sigma}^R\), \(\beta_1\) and \(\beta_2\) are found in Proposition 7 and that of \(\sigma_7\) is found in the proof of the proposition.

One can see that Proposition 11 where both buyers can vertically integrate is very similar to Proposition 11 where only buyer \(A\) can vertically integrate. In addition, the base model’s property that higher externalities drive vertical integration and thus CSER (Proposition 2) also carries over:

**Proposition 12.** In the equilibrium described in Proposition 11, the range of \(\sigma\) where at least one firm plays the strategy \(I\) grows as \(\beta\) increases.

In summary, all main results in Section 4 where only buyer \(A\) can vertically integrate carry over to this extension where both buyers can vertically integrate.
7. Conclusion

In an increasingly socially- and environmentally-conscious world, when a supplier’s CSER violation is exposed, its client often suffers market consequences. In addition, competing firms may benefit from the exposure due to substitution, or suffer from it due to consumer suspicion about general practices in the industry. The 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 the resources allocated to scrutinizing suppliers, as well as the way violations are publicized. The former choice affects the likelihood of a violation being exposed, whereas the latter choice influences whether an exposed violation benefits or hurts other 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 when conventional approaches such as auditing are ineffective, and the impact of horizontal sourcing on the strategy. We modeled two competing firms, one of which may vertically integrate with its supplier which ensures CSER. An exposed violation impacts the demand of the involved firm, but may also positively or negatively impact that of the competing firm. We first investigated the model assuming horizontal sourcing is infeasible, then allow horizontal sourcing through which a vertically integrated firm can supply the other buyer, and compare the results.

Our findings indicate that firms’ optimal/equilibrium integration and CSER decisions are non-trivial, and differ with and without horizontal sourcing. We first show that vertical integration can be a viable strategy for CSER in sourcing, hence identifying a new driver of vertical integration—corporate social and environmental responsibility considerations. We then analyze whether horizontal sourcing can be an effective strategy to mitigate CSER externalities from a competing supply chain. Our analysis shows that firms’ behaviors differ based on whether horizontal sourcing is feasible. When horizontal sourcing is infeasible, higher violation exposure externalities improve CSER, but overly intensive violation scrutiny alongside strongly negative externalities may backfire and discourage CSER. When horizontal sourcing is feasible, however, these trends are inverted: intensive violation scrutiny improves CSER, but strongly positive externalities may discourage an integrated firm from sharing responsible supply with competitors, impairing industry-wide CSER. In general, horizontal sourcing can greatly improve CSER in an industry. These findings have
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<td>No Horizontal Sourcing</td>
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Table 2  Summary of insights

instructive implications for firms interested in ensuring CSER in their supply chains, as well as for NGOs’ violation scrutiny and reporting policies and they are summarized in Table 2.

Our results 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 a priori unclear whether promoting vertical integration is a viable strategy by which NGOs may stimulate economic growth in developing nations. Our study shows that despite the costs, vertical integration for CSER can be economically viable for OEMs, which suggests that NGOs may indeed pursue this strategy to improve the livelihood of people in developing nations.

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

Supplier’s responsibility choice

We assume that suppliers simultaneously decide whether to become responsible or not after buyer A’s integration decision. If a supplier becomes responsible, the unit production cost of the component increases to \( c_s \). We assume \( c_s < w \); otherwise, becoming responsible would never be profitable for the supplier and the equilibrium is exactly the same as the base model. Consistent with the spirit of our examples, we assume that buyer cannot verify supplier’s responsibility choice. Therefore, buyer A’s integration decision remains unchanged compared to the base model.

We use subscript \((i,j)\), where \( i,j \in \{Re,Co\} \), on \( D \) to denote suppliers’ responsibility choice in the equilibrium (\( Re \) for responsible \( Co \) for conventional supplier). For instance, \( D_{ReCo} \) means in the equilibrium supplier A becomes responsible and supplier B stays conventional. Next proposition presents our results.

**Proposition A1.** Suppose that supplier can decide to become responsible or not, and firm A stays disintegrated. Then,

1. \( D_{ReRe} \) is an equilibrium if and only if \( \sigma \geq -\frac{c_s}{w\alpha} \).
2. \( D_{ReCo} \) and \( D_{CoRe} \) are equilibria if and only if \( \sigma < -\frac{c_s}{w\alpha} \), \( \nu(\sigma,\beta,c_s,w,\alpha) > 0 \) and \( \beta > 0 \).
3. \( D_{CoCo} \) is an equilibrium if and only if \( \nu(\sigma,\beta,c_s,w,\alpha) \leq 0 \).

Furthermore, \( \nu \) is given in the proof of the proposition.

Note that proposition holds regardless of whether horizontal sourcing is feasible or not. Figure A1 and A2 illustrate the proposition for parameters \( p = 2, w = 1/8, c_r = 1/4, Q = 4, \alpha = -3/8 \) and \( f = 0.15 \), as before, and different \( c_s \) values when horizontal sourcing is not feasible. In the figures, we eliminate the multiple equilibria by choosing the pareto efficient equilibrium.

The figure shows that when \( c_s \) is large (i.e., \( c_s = 1/15 \)) the equilibrium is exactly the same as the base model; and thus, the insights derived from this new model. Not surprisingly, as \( c_s \) decreases \( D_{ReRe} \) region invades \( D_{CoCo} \) region and consequently, the amount of responsibly sourced supply increases. Note that this only happens when suppliers have a much smaller unit production cost than that of the buyer after becoming responsible. One can argue that in practice this does not happen very often. And, hence, even if the suppliers are allowed to choose their responsibility, the equilibrium will be similar to our base model.
Proofs

Proof of Proposition 1: To prove the proposition, we first define a difference function of profits under different scenarios. Then, we investigate the behavior of this difference function. Define \( \Delta^I_D = \pi_A^I - \pi_A^D \). \( \frac{d\Delta^I_D}{d\sigma} = -Q (\beta c_r + p(\alpha - 2\beta\sigma) - w(\alpha - 2\beta\sigma + \beta)) \) so \( \Delta^I_D \) is an increasing function if and only if \( \beta > \frac{\alpha(w-p)}{c_r-2p+w} \). In addition, \( \Delta^I_D(\sigma = 0) < 0 \) always holds. When \( f = 0 \), \( \Delta^I_D(\sigma = 1) < 0 \) if and only if \( \beta < \frac{c_r + \alpha(w-p)}{p-c_r} < \frac{\alpha(w-p)}{c_r-2p+w} \). Thus, under our assumption \( f < Q \left( \frac{\alpha(p-w)^2}{c_r-2p+w} - cr + w \right) = \Delta^I_N(\sigma = \)
1, \beta = \frac{\alpha(p-w)}{-c_\tau+2p-w}) and also the fact that \d \Delta_\nu^T / \d \beta > 0, there exists a \beta_1(f) \in (\frac{c_r+o_\nu-(\alpha+1)w}{p-c_\tau}, \frac{\alpha(w-p)}{c_r-2p+w}) such that when \beta > \beta_1 a unique probability of exposure \sigma^R satisfies \Delta_\nu^T(\sigma^R) = 0 , and \mathcal{I} is the optimal strategy if and only \sigma \in (\sigma^R, 1). \beta_1 is defined by \Delta_\nu^T(\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_\nu^T intersects \sigma axis either twice or never depending on the value of f. It can be shown that when f < f_1 = \max_, \Delta_\nu^T(\beta = \alpha), \Delta_\nu^T intersects \sigma axis at two \sigma values \sigma^R and \sigma_R satisfying \sigma^R < \sigma_R. This happens for any \beta < \beta_1. However, when f > f_1, there exists a \beta_2 < \beta_1 satisfying \max_, \Delta_\nu^T(\beta_2, \sigma) = 0 such that when \beta < \beta_2, \Delta_\nu^T < 0 always hold (thus, D is optimal regardless of \sigma). From the definition of f_1, \beta_2 exists if and only if f > f_1.

Assuming \beta < \beta_1, when \Delta_\nu^T intersects \sigma axis at \sigma_R and \sigma_R, the optimal strategy is \mathcal{D} if \sigma \in (0, \sigma^R] \cup [\sigma_R, 1), and \mathcal{I} if \sigma \in (\sigma^R, \sigma_R) because \Delta_\nu^T is a concave function for \beta < \beta_1. □

Proof of Proposition 2. To prove the proposition, we need to show that as \beta increases, the cutoff \sigma values (\sigma's as defined in the proof of Proposition 1) that define the \mathcal{I} region increase or decrease in a way that expands \mathcal{I} region. In other words, the followings must hold: 1) \d \sigma^R / \d \beta < 0; 2) \d \sigma^R / \d \beta > 0 whenever \sigma_R \in (0, 1).

From the implicit function theorem, \d \sigma^R / \d \beta = -\frac{\partial \Delta_\nu^T / \partial \beta}{\partial \Delta_\nu^T / \partial \sigma}|_{\sigma = \sigma_R}. From the proof of Proposition 1 we know that when \beta < \beta_1, \Delta_\nu^T is a concave function of \sigma with two roots satisfying \sigma_R < \sigma_R. Additionally, \Delta_\nu^T(\sigma = 0) < 0, \Delta_\nu^T(\sigma = 1) < 0. Therefore, \partial \Delta_\nu^T / \partial \sigma|_{\sigma = \sigma_R} < 0. As a result, \d \sigma_R / \d \beta and \partial \Delta_\nu^T / \partial \beta|_{\sigma = \sigma_R} = Q \sigma (-c_\tau + p\sigma - \sigma w + w) have the same sign. It is easy to see that \sigma_R > \frac{c_\tau-w}{p-w}, hence \d \sigma_R / \d \beta > 0.

The proof of \d \sigma^R / \d \beta < 0 can be shown similarly and is omitted. □

Proof of Proposition 3. We first look how firm B’s profit behave as a function of \sigma and construct the conditions that ensure that firm B’s profit may increase with increasing \sigma. \d \pi^B / \d \sigma = Q\alpha(p-w) < 0, \d \pi^B / \d \sigma = Q(p-w)(\alpha - 2\beta \sigma + \beta) < 0, and also \pi^B - \pi^B = \beta Q(\sigma - 1)\sigma(p-w) > 0 when \beta < 0. Thus, \pi^B jumps upwards when buyer A switches from strategy \mathcal{D} to \mathcal{I} and \beta < 0 at \sigma^R. \sigma^R is defined in Proposition 1. Define \Delta_1 > 0 as \pi^B(\sigma^R - \Delta_1) = \pi^B(\sigma^R). Also define \tau^c > 0, and \tau^c > 0 in the following ways: \tau^c = \sigma^R - \sigma and \tau^c = \sigma^R + \tau^c. To see the existence of \Delta_1 and \tau^c, note that \lim_{\sigma \to 0} \pi^B = \lim_{\sigma \to 0} \pi^B and \lim_{\sigma \to -1} \pi^B = \lim_{\sigma \to -1} \pi^B. Since at \sigma^R the profit jump upwards, firm B’s profit would increase with increasing \sigma so long as \tau \in (\tau^c, \tau^c). □

Proof of Proposition 4. To find the subgame perfect nash equilibrium, we first investigate buyer B’s decision to purchase or not purchase from its competitor. It is easy to see that buyer B
purchases from firm A if and only if \( \pi^B_D = \pi^B_{I_S} \). Thus, firm A offers a price that makes buyer B indifferent to source from firm A or from supplier B. Thus,

\[
\pi^B_D = \pi^B_{I_S} \iff Q(p - w) = Q((\alpha + 1)\sigma - \sigma + 1)(p - w) \iff w' = \alpha \sigma(w - p) + w.
\]

Then \( \pi^A_{I_S} = Q(-c_r - \alpha \sigma(p - w) + w) + Q(p - c_r) - f \). Next, define

\[
\Delta^I_D = Q\left(-2c_r + \sigma(2\alpha + \beta)(w - p) + \beta \sigma^2(p - w) + 2w\right) - f,
\]

\[
\Delta^I_S = (\beta \sigma - 1)c_r - p\sigma(\alpha + \beta) + \alpha \sigma w + w,
\]

\[
\Delta^I_N = (\beta \sigma - 1)c_r - p\sigma(\alpha + \beta) + \alpha \sigma w + w.
\]

where \( \Delta^i_j = \pi^A_i - \pi^A_j \).

Note that \( \Delta^I_D \) is same as \( \Delta^I_D \) defined in the proof of Proposition \( \square \) Since we investigated the behavior of this function in the proof of Proposition \( \square \) we only need to investigate the functions \( \Delta^I_S \) and \( \Delta^I_D \). Note that \( \Delta^I_S \) is a linear function of \( \sigma \) and its value at \( \sigma = 0 \) is \( w - cr < 0 \). 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

\[
\beta < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p}.
\]

Thus, when \( \beta \geq \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \), \( I_S \) cannot be an equilibrium, and consequently equilibrium structure is same as Proposition \( \square \) When \( \beta < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \), \( \Delta^I_S \) has a single root

\[
\sigma_2 = \frac{c_r}{\beta c_r - p(\alpha + \beta) + \alpha w}.
\]

\[
d^2 \Delta^I_S / d^2 \sigma = 2\beta(p - w),
\]

and thus, \( \Delta^I_S \) is convex (concave) for \( \beta > 0 \) (\( \beta < 0 \)) and linear for \( \beta = 0 \). Furthermore, it is easy to show that \( \Delta^I_S(\sigma = 0) < 0 \) and \( \Delta^I_S(\sigma = 1) > 0 \). Thus, there exist a single root of \( \Delta^I_S \). Denote this root with \( \sigma_1 \). The next lemma is needed for the remainder of the proof and it can proven easily using the implicit function theorem. Hence, its proof is omitted.

**LEMMA A1.** The followings hold: \( d\sigma^R / d\beta < 0, d\sigma_1 / d\beta > 0, d\sigma_2 / d\beta > 0 ; \) and when \( \beta = 0 \) and \( f = 0 \), \( \sigma^R = \sigma_1 = \sigma_2 \).

We need to look at 2 different cases: \( 0 \leq \beta < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \) and \( \beta < 0 \).

**Case 1.** \( 0 \leq \beta < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \): Figure \( \square \) illustrates this case for the same parameters as in Figure \( \square \). Suppose that \( f = 0 \). We first show that \( \sigma^R < \sigma_1 < \sigma_2 \). This would prove that for low (high) \( \sigma \)'s \( D \) (\( I_S \)) and for medium \( \sigma \)'s \( I_N \) is the equilibrium. By some algebra it can be shown that \( \Delta^I_D(\sigma_2) > 0 \) if and only if \( \beta > 0 \). This proves the ordering when \( f = 0 \).

Now suppose that \( f > 0 \). Note that \( d\sigma_1 / df > 0, d\sigma^R / df > 0 \) and \( d\sigma_2 / df = 0 \). These facts, Lemma \( \square \) and the upper bound on \( f \) defined in the proof of Proposition \( \square \) imply that there exists a \( \beta_3 \in (0, \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p}) \) satisfying \( \sigma_1(\beta_3) = \sigma_2(\beta_3) = \sigma^R(\beta_3) \). It is easy to see that \( \beta_3 \) is a continuous increasing function \( f \).
Case 2. \( \beta < 0 \) : When \( \beta < 0 \), from Lemma A1 \( \sigma_2 < \sigma_1 < \sigma^R \). Thus, \( \mathcal{I}_N \) cannot be an equilibrium. Consequently, the equilibrium is determined by \( \Delta^{IS}_D \), which know that positive if and only if \( \sigma > \sigma_1 \). Hence, it is proved.

Finally, Case 1, 2 and \( \beta \geq \frac{cr + \alpha p - (\alpha + 1)w}{cr - p} \) can be combined to obtain the proposition. \( \square \)

Proof of Proposition 6. We need to show the followings:
1. \( \frac{d\sigma_1}{d\beta} > 0 \), whenever \( \mathcal{D} \) and \( \mathcal{I}_S \) have a shared boundary.
2. \( \frac{d\sigma_2}{d\beta} > 0 \), whenever \( \mathcal{I}_N \) and \( \mathcal{I}_S \) have a shared boundary.

From Lemma A1 these hold. \( \square \)

Proof of Proposition 5. When \( \beta < 0 \), \( \frac{d\pi_A}{d\sigma} < 0 \), \( \frac{d\pi_A}{d\sigma} > 0 \), \( \frac{d\pi_B}{d\sigma} > 0 \) and \( \frac{d\pi_B}{d\sigma} < 0 \). Furthermore, \( \pi_B^{IS} - \pi_D = \beta Q(\sigma - 1)\sigma(p - w) > 0 \) and \( \pi_A^{IS}(\sigma_1) = \pi_A^{IS}(\sigma_1) \). Thus, buyer B’s profit jumps up at \( \sigma_1 \) when the equilibrium changes from \( \mathcal{D} \) to \( \mathcal{I}_S \) and buyer A’s profit is continuous at \( \sigma_1 \). Figure A4 illustrates these.

Define \( \sigma_c \) as follows:
1. \( \sigma_c > \sigma_1 \),
2. \( \pi^A_{I_S}(\sigma_c) = \pi^B_{I_S}(\sigma_c) \).

\( \sigma_c \) exists because \( \pi^A_{D}(\sigma_1) < \pi^B_{D}(\sigma_1) \) and \( \pi^A_{D}(1) > \pi^B_{D}(1) \), and also profits are linear functions of \( \sigma \) when \( \sigma > \sigma_1 \).

Define \( \sigma_x \) in the following way:

1. if there exists a \( \sigma \in (0, \sigma_1) \) such that \( \pi^A_{D}(\sigma) = \pi^B_{I_S}(\sigma_c) \), then \( \sigma_x = \sigma \),
2. otherwise, \( \sigma_x = 0 \).

For a given \( \sigma \in (\sigma_x, \sigma_1) \), define \( \sigma^*_A \) as \( \pi^A_{D}(\sigma) = \pi^B_{I_S}(\sigma^*_A) \) and \( \sigma^*_A > \sigma_1 \). It easy to see that \( \sigma^*_A \) exists in \( (\sigma_1, 1) \). Also define \( \sigma^*_B \) in the following way:

1. if there exists a \( \sigma' \in (\sigma_1, 1) \) such that \( \pi^B_{D}(\sigma) = \pi^B_{I_S}(\sigma') \), then \( \sigma^*_B = \sigma' \),
2. otherwise, \( \sigma^*_B = 1 \).

Then, \( \sigma_1 - \sigma_x = \Delta_2, \tau' = \sigma^*_B - \sigma \) and \( \tau_c = \sigma^*_A - \sigma \). \( \square \)

**Proof of Proposition 7.** To see this, note that when \( I_S \) is the equilibrium \( \pi^A_{I_S} > \pi^A_{I_N} \). Thus, \( I \) region in no horizontal sourcing case is always included in the \( I_S \cup I_N \) region in horizontal sourcing case. \( \square \)

**Proof of Proposition 8.** We first compare the profits when the buyers share and not share suppliers, i.e., \( \pi^1_D \) and \( \pi^2_D \). Note that \( \pi^1_D = \pi^D \) where \( \pi^D \) is defined in Section 3 and used in Sections 4 and 5. When the buyers share suppliers, their profits are as given as

\[
\pi^i_D = Q(\alpha \sigma + 1)(p - w).
\]

Furthermore, \( \pi^i_D - \pi^i_D_C = \beta(-Q)(\sigma - 1)(\sigma(p - w)) > 0 \iff \beta > 0 \). Thus, when \( \beta > 0 \), the equilibrium is same as 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 \( \pi^A_{D_C} \) and \( \pi^A_{I_S} \). This can be done easily since \( \pi^A_{D_C} - \pi^A_{I_S} \) is a quadratic function with at most one root for \( \sigma \in (0, 1) \).

Hence, omitted. \( \square \)

**Proof of Proposition 9.** As per the proof of Proposition 8, \( D_U \) (\( D_C \)) can be the equilibrium if and only if \( \beta \leq 0 \) (\( \beta > 0 \)). Using this fact and comparing the profit functions under strategies \( I_N \), \( I_S \), \( D_U \) and \( D_C \), we can obtain the equilibrium. The calculations are similar to the proof of Proposition 4. Hence omitted. \( \square \)

**Proof of Proposition 10.** Note that the capacity constraint may change the profit functions of buyer A and B only under \( I_S \) equilibrium. The wholesale price set by buyer A is given by \( \pi^B_{I_S} = (p - w)(\alpha \sigma(Q - k) + Q) + k(w - w') = (\alpha + 1)Q \sigma(p - w) + Q(1 - \sigma)(p - w) = \pi^B_{D'}. \) Thus, \( w' = \alpha \sigma(w - p) + w \). This leads to \( \pi^A_{I_S} = \beta \sigma(k - Q)(c_r - p) - k c_r - Q c_r + k(\alpha \sigma(w - p) + w) + p Q - f. \) Define \( f_2 = \lim_{\beta \to 0} \max_{\hat{\sigma}} \Delta_{D^N}^{I_S}(\sigma) \). In addition, define the difference function \( \Delta_{I_S}^{I_N} = \pi^A_{I_S} - \pi^A_{I_N} = \)
Notice that the capacity constraint does not change the roots of this function. Thus, the comparison of buyer A’s profits for \( I_N \) and \( I_S \) is same as the base model. Furthermore, the comparison of buyer A’s profits for \( I_N \) and \( D \) is same as the base model as well. Thus, the boundaries of \( I_N \) and \( I_S \), and \( I_N \) and \( D \) are same as the base model.

However, the boundary of \( I_S \) and \( D \) may be different than the base model. Therefore, we only need to investigate \( \beta < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \). We do so in two case: \( 0 < \beta < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \) and \( \beta \leq 0 \). First, define

\[
\Delta_{I_D} = \sigma (\beta (c_r + Q) - kp + Qw) - \alpha (k + Q)(p - w) - (k + Q)(c_r - w) - f + \beta Q\sigma^2 (p - w).
\]

**Case 1.** \( 0 < \beta < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \): Suppose that \( f = 0 \). In this case, \( \Delta_{I_D} (0) < 0 \), \( \Delta_{I_D} (1) > 0 \) and \( d\Delta_{I_D} / d\sigma > 0 \). Thus, \( \Delta_{I_D} \) has a single root. Denote this root with \( \sigma_3 \). By some algebra, it can be verified that \( \Delta_{I_D} (\sigma_2) > 0 \), which implies that

\[
\sigma^R < \sigma_3 < \sigma_2.
\]

Also note that,

\[
\lim_{\beta \to 0} \sigma^R = \lim_{\beta \to 0} \sigma_3 = \lim_{\beta \to 0} \sigma_2.
\]

We next show the following:

\[
d\Delta_{I_N} (\sigma_2 (\beta), \beta) / d\beta > 0.
\]

Note that \( \frac{d\Delta_{I_N} (\sigma_2 (\beta), \beta)}{d\beta} = \frac{\partial \Delta_{I_N} (\sigma, \beta)}{\partial \sigma} + \frac{\partial \Delta_{I_N} (\sigma, \beta)}{\partial \beta} \). From the proof Proposition 1, \( \partial \Delta_{I_N} / \partial \sigma > 0 \), and from Lemma A1 \( \partial \sigma_2 / \partial \beta > 0 \). In addition, \( \frac{\partial \Delta_{I_N} (\sigma, \beta)}{\partial \sigma} = Q \sigma (-c_r + p \sigma - \sigma w + w)|_{\sigma_2} > 0 \). Thus, inequality \( A3 \) is proved. Finally, \( A1 \), \( A2 \), \( A3 \) and the fact that \( \Delta_{I_N} \) and \( \Delta_{I_D} \) decrease with \( f \) imply that for any \( f > 0 \) there exist a unique \( \beta' < 0 < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \) such that \( \Delta_{I_N} (\sigma_2, \beta') = 0 \), and thus, \( \beta' = \beta_3 \), and the followings hold: when \( \beta < \beta' < \frac{c_r + \alpha p - (\alpha + 1)w}{c_r - p} \), if \( \sigma \in (0, \sigma^R) \), the equilibrium is \( D \). If \( \sigma \in \sigma^R, \sigma_2 \), it is \( I_N \). If \( \sigma \in (\sigma_2, 1) \), it is \( I_S \). On the other hand, when \( \beta \geq 0 \), if \( \sigma \in (0, \sigma_3] \), the equilibrium is \( D \). If \( \sigma \in (\sigma_3, 1) \), it is \( I_S \).

**Case 2.** \( \beta \leq 0 \): Suppose that \( f = 0 \). In this case, since \( d\Delta_{I_D} / dk > 0 \) and also from Proposition 1, \( I_N \) cannot be an equilibrium. Thus, we only need to compare buyer A’s profit in \( I_S \) and \( D \), i.e. if \( \Delta_{I_S} > (\leq) 0 \), then \( I_S(D) \) is the equilibrium. One can see that

\[
\lim_{\sigma \to 1} \frac{d\Delta_{I_D}}{d\sigma} < 0 \iff \beta < \frac{\alpha (p - w)}{-c_r + 2p - w} = \beta \text{ and } k < \frac{Q (\beta (c_r + w) + p (\alpha - 2 \beta) + \alpha (-w))}{\beta c_r - p (\alpha + \beta) + \alpha w} = \kappa.
\]

\[
(A4)
\]
\[
\lim_{\sigma \to 1} \Delta_D^{T_S} < 0 \Leftrightarrow \beta < -\frac{c_r - \alpha p + \alpha w + w}{c_r - p} = \beta \quad \text{and} \quad k < \frac{Q(\beta c_r + c_r + \alpha p - \beta p - (\alpha + 1)w)}{(\beta - 1)c_r - p(\alpha + \beta) + (\alpha + 1)w} = \delta. \tag{A5}
\]

In addition, it can be shown easily that when \(\lim_{\sigma \to 1} \Delta_D^{T_S} \geq 0\), \(\Delta_D^{T_S}\) has a single root \(\sigma_5\), where \(\Delta_D^{T_S}\) is positive if and only if \(\sigma > \sigma_5\). Otherwise, it has two roots \(\sigma_5\) and \(\sigma_6\), where \(\Delta_D^{T_S}\) is positive if and only if \(\sigma \in (\sigma_5, \sigma_6)\). Furthermore, \(\lim_{\sigma \to 1} d\Delta_D^{T_S} / d\beta > 0\) and \(\lim_{\sigma \to 1} d\Delta_D^{T_S} / dk > 0\). Thus, combined with inequalities (A4), (A5), these prove the proposition, where \(\beta_4\) and \(k_1\) are defined by \(\lim_{\sigma \to 0, \sigma \to 1} \Delta_D^{T_S}(\beta_4, k, f) = 0\) and \(\lim_{\sigma \to 1} \Delta_D^{T_S}(\beta, k_1(\beta), f) = 0\), when \(f > 0\). \(\square\)

**Proof of Proposition 14.** In this model, there may be four different equilibria, \((I; I), (I; D), (D; I)\) and \((D; D)\). Define the profit functions in these equilibria as \(\pi_{(I; I)}^{I} = (p - c_r)Q - f, \quad \pi_{(D; D)}^{I} = \pi_{(D; D)}^{D} = \pi_{(D; D)}^{B} = (p - c_r)(\beta \sigma + 1)Q - f\), and \(\pi_{(I; I)}^{D} = \pi_{(I; I)}^{A} = \pi_{(I; I)}^{B} = Q(-c_r + \alpha \sigma (w - p) + w) - f\) and \(\Delta_\pi = \pi_{(I; I)}^{A} - \pi_{(I; I)}^{B} = \pi_{(I; I)}^{B} - \pi_{(I; I)}^{D} = \pi_{(I; I)}^{D} - \pi_{(I; I)}^{A} = \Delta_D^{T_S}\), where \(\Delta_D^{T_S}\) is as defined in the proof of Proposition 1. Thus, we know that \(\Delta_\pi\) has two roots \(0 < \sigma^R < \sigma^R < 1\) when \(\beta < \beta_1\), and \(\Delta_\pi > 0\) if and only if \(\sigma\) is in between these two roots. Otherwise when \(\beta \geq \beta_1\), \(0 < \sigma^R \leq 1\) and \(\Delta_\pi > 0\) if and only if \(\sigma > \sigma^R\). \(\Delta_\pi\) has a single root at \(\sigma = -\frac{Qc_r + f - Qw}{\alpha Q(p - w)} = \sigma_1\) and \(\Delta_\pi > 0\) if and only if \(\sigma > \sigma_7\). Furthermore, \(\sigma_7 < \sigma^R\) if and only if \(\beta < 0\).

Next we find the equilibrium for \(\beta > 0\), the other cases can be found similarly, and hence, omitted. Note that in this case \(\sigma^R < \sigma_7\). Suppose that \(\sigma > \sigma_7\) and the equilibrium is \((D; D)\). Note that firm \(A\) benefits from deviating to \((I; D)\) since \(\Delta_\pi > 0\) in this case. Thus, \((D; D)\) cannot be an equilibrium. Similarly in \((I; D)\) ((\(D; I)\)), firm \(B\) \((A)\) has an incentive to deviate to \((I; I)\) since \(\Delta_\pi > 0\) in this case. In \((I; I)\), neither firms has an incentive to deviate. Thus, \((I; I)\) is the equilibrium when \(\sigma > \sigma_7\). If \(\sigma^R < \sigma \leq \sigma_7\), in \((I; I)\), each firm has an incentive to unilaterally deviate to staying conventional because \(\Delta_\pi < 0\). In \((D; D)\), each firm has an incentive to unilaterally deviate to \(I\) because \(\Delta_\pi > 0\). However, in \((I; D)\) and \((D; I)\), neither firm has an incentive to deviate. If \(\sigma \leq \sigma^R\), we can see that except in \((D; D)\) in \((I; I)\), \((D; I)\) and \((I; D)\), at least one firm has an incentive to unilaterally deviate. Thus the equilibrium is \((D; D)\). \(\square\)

**Proof of Proposition 14.** Note that the thresholds \(\sigma^R\) and \(\sigma^R\) are same as in Proposition 1. And, in Proposition 2 we show that as \(\beta\) increases, these thresholds behave in a way that expands the \(\mathcal{I}\) region (i.e., \(d\sigma^R / d\beta < 0, d\sigma^R / d\beta > 0\) whenever \(\sigma^R \in (0, 1)\)). This combined with the fact that \(c_r / (\alpha p)\) does not change with \(\beta\) prove the proposition. \(\square\)

**Proof of Proposition 14.** Denote supplier’s profits with \(\pi_{m,n}^{S}\), where \(i \in \{A, B\}\), and \(m, n \in \{Re, Co\}\). Also define \(\eta = \pi_{ReRe}^{SA} - \pi_{CoRe}^{SA} = \pi_{ReRe}^{SB} - \pi_{ReCo}^{SB}\) and \(\nu = \pi_{ReCo}^{SA} - \pi_{CoCo}^{SA} = \pi_{CoRe}^{SB} - \pi_{CoCo}^{SB}\). Finding the root of \(\eta\) as \(-c_s / \alpha w\), the proposition can be shown easily. \(\square\)