# Supplier Evasion of a Buyer's Audit: Implications for Motivating Supplier Social and Environmental Responsibility

Erica L. Plambeck and Terry A. Taylor

Graduate School of Business, Stanford University

Haas School of Business, University of California, Berkeley

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Abstract: Prominent buyers' brands have been damaged because their suppliers caused major harm to workers or the environment, e.g., through a deadly factory fire or release of toxic chemicals. How can buyers motivate suppliers to exert greater care to prevent such harm? This paper characterizes a "backfiring condition" under which actions taken by prominent buyers (increasing auditing, publicizing negative audit reports, providing loans to suppliers) motivate a supplier to exert greater effort to pass the buyer's audit by hiding information, and *less* care to prevent harm. Intuitively-appealing actions for a buyer (penalizing a supplier for harming workers or the environment, or for trying to deceive an auditor) may be similarly counterproductive. Contrary to conventional wisdom, squeezing a supplier's margin (by reducing the price paid to the supplier or increasing wages for workers) motivates the supplier to exert greater care to prevent harm–under the backfiring condition. Whereas the necessary and sufficient condition depends on the relative convexity of the supplier's hiding cost function, a simple sufficient condition is that supplier is likely to successfully hide information from the auditor, in equilibrium. Anecdotal evidence suggests that the backfiring condition is prevalent or increasingly so. Similar insights apply to mitigation of unauthorized subcontracting.

## 1. Introduction

*"When the heat is turned up too fast and hard, it drives the factories to move in the other direction. They end up hiding information from us."* - Kevin O'Donnell, Director of Environmental Engineering, Nike, November 2, 2009

Apple, Disney, Marks & Spencer, Zara and other prominent firms have recently been exposed as sourcing from suppliers that have caused major harm to workers or the environment (Chamberlain 2011, Duggan 2012, Duhigg and Barboza 2012, IPE 2012). When a firm's supplier is revealed as abusing workers (e.g., through hazardous working conditions leading to workplace injuries and deaths) or damaging the environment (e.g., through a major, illegal release of toxic chemicals) the ensuing scandal damages the brand of the buying firm. A supplier's risk of causing a major harm to workers or the environment depends on the extent of the supplier's effort to employ responsible safety and environmental practices. Currently, buyers' auditing of suppliers' practices is the primary motivation for suppliers to exert that responsibility effort, because regulatory institutions and law enforcement are weak in developing and emerging economies in which suppliers are concentrated (Economy 2007, Locke et al. 2007).

The aforementioned buying firms have responded to the scandals by increased auditing (Disney 2011, Duhigg and Windfield 2012, Genasci 2012, Inditex 2012). Other buying firms have recently increased auditing in order to avert such scandals (Carbone 2012, Biraj 2013). However, based on data from Nike's audits of its suppliers, Locke et al. (2007) find that auditing alone is ineffective in improving factory conditions. This paper provides an explanation for how increased auditing can reduce suppliers' efforts to prevent harm to workers and the environment.

Buying firms are under increasing pressure from nongovernmental organizations (NGOs) and other actors that expose and publicize suppliers' harms to workers and the environment. NGOs pressure buyers because the buyers are concerned about reputation and brand, whereas their suppliers are largely indifferent (Lee et al. 2009, 2012b). Newly founded Chinese NGOs generated the recent scandals for the aforementioned buying firms (Chamberlain 2011, Duggan 2012, Duhigg and Barboza 2012, IPE 2012). Only recently has China's government started to permit some, "orderly" activism by NGOs and established the public's right to know about environmental pollution (Economy 2007, Lee et al. 2012b). Journalists and activists are identifying branded firms that sourced, directly or through unauthorized subcontracting, from facilities in which workers died in recent fires and collapsed buildings in Bangladesh (Strauss et al. 2013, Motlagh 2014). In addition, NGOs are pressuring buyers to pay higher prices to their suppliers, thinking that this will motivate suppliers to improve safety (Dudley 2012a). This paper provides an explanation for how all these heightened pressures on buyers could backfire by reducing suppliers' efforts to be responsible.

To do so, this paper models the widespread phenomenon that suppliers attempt to hide information about potentially unsafe practices or conditions from buyers. A prominent multinational buyer that observes a "red flag" that a factory is unsafe typically will withdraw its business from the supplier, rather than risk brand damage (Lee et al. 2012a, Dudley 2012b). Facing that loss of business and the high cost of responsible practices, many suppliers instead attempt to hide information from their buyers' auditors (Foster and Harney 2005, Gould 2005).

An audit typically consists of touring the factory, reviewing documents, and interviewing factory employees; suppliers act to deceive auditors in each of these elements (Wong 2007). Some suppliers build walls or block entrances to hide portions of facilities with possible safety problems (Roberts and Engardio 2006). Falsifying documents is a widespread practice (Foster and Harney 2005, Harney 2008). Suppliers commonly maintain a false set of work and training logs to show to auditors, in order to hide any evidence of abusive or unsafe working conditions (Roberts and Engardio 2006). Some create false records of inspection and maintenance of buildings and equipment for safety and pollution prevention, and create false records of safety training that did not actually occur (Pruett 2005, Walsh and Greenhouse 2012, Patel 2014). Training workers and managers to mislead auditors also is a widespread practice (Foster and Harney 2005, Roberts and Engardio 2006). Employees are motivated to deceive auditors by the threat of financial or physical punishment for whistleblowing, and because their jobs would be at risk if their employer failed the audit and lost the buyer as a customer (Esbenshade 2004, Egels-Zandén 2007).

Not only do many suppliers attempt to deceive an auditor, they commonly succeed in passing an audit through deception or bribery. Suppliers deceive auditors in regions around the world "from China to Cambodia to Turkey to Guatemala [to] India...and Bangladesh" (Goodman 2013). Suppliers have become increasingly sophisticated in their abilities to deceive auditors, due in part to the emergence of software for producing false documents and consulting organizations that help suppliers deceive auditors (Gould 2005, Roberts and Engardio 2006). Suppliers also pass audits through bribery (China Labor Watch 2009, Motlagh 2014). Suppliers have strong financial incentives to pass audits (Clifford and Greenhouse 2013) whereas auditors have little incentive to reject bribes because their wages tend to be low and their turnover high (Harney 2008, Plambeck et al. 2012). The recent news is marked by violations by suppliers that passed audits through deception or bribery (Walsh and Greenhouse 2012, Clifford and Greenhouse 2013).

In summary, the anecdotal evidence above suggests that at least some suppliers are "hiding"–exerting effort to pass a buyer's audit through deception or bribery–and are likely to be successful in doing so. This paper shows that that is a sufficient condition for various actions aimed at improving supplier responsibility (e.g., increased auditing) to backfire and have the opposite effect. §3 identifies the necessary and sufficient "backfiring condition" under which increased auditing effort reduces a supplier's responsibility effort. Increased pressure on buyers, from NGOs that expose and publicize their suppliers' harm to workers or the environment, also does so.

Whereas buyers historically have relied on auditing, §4 examines alternative ways in which a buyer might motivate a supplier to exert more responsibility effort to avoid harm to workers and the environment, including: penalizing the supplier for harm or hiding effort; providing a loan to the supplier; paying a higher price; publicizing negative audit reports; and making hiding more difficult. These actions may be harmful or helpful, depending on whether or not the backfiring condition holds.

Motivated by recent events in Bangladesh, §5 shows how our model and results extend to the setting where the buyer invests in making the supplier's facility safe, but the supplier subcontracts to unauthorized, unsafe factories.

**Related Literature**

In the law enforcement literature, (Kambhu 1989, Malik 1990 and Innes 2001) model an offender's hiding effort and show how that changes the socially optimal penalty and monitoring effort to catch offenders. In the financial auditing literature, (Baiman et al. 1991, Kornish and Levine 2004, Khalil et al. 2010 and papers surveyed therein) model a manager's bribery of an auditor to obtain a favorable report, and show how that changes shareholders' optimal policy for compensating managers and auditors. Similarly, in the supply chain management literature, this paper is the first to model a supplier's effort to hide safety or environmental problems from a buyer, and shows how that changes a buyer's optimal policy. For example, the papers surveyed in the next paragraph associate supplier responsibility with a higher price, reduced production cost, or other strong financial incentive for the supplier; in the spirit of (Kerr 1975), this paper identifies conditions under which such policies promote hiding instead of responsibility.

In the literature on responsible supply chain management, Guo et al. (2014) examines a buyer's choice to pay a high price to a "responsible" supplier or pay a low price and risk a scandal. In (Chen and Lee 2014), a buyer screens for an ethical supplier by offering a menu of contracts in which a high price is coupled with withholding payment in the event of a responsibility violation. In (Aral et al. 2014), a buyer audits prospective suppliers, and then runs an auction in which suppliers with favorable audit reports receive higher prices. In (Izhutov and Lee 2013), a supplier makes sequential investments that increase the probability that it qualifies as responsible; increasing the supplier's margin motivates greater investment. In (Lewis et al. 2013) a buyer makes sequential investments that reduce a supplier's cost to produce in a more responsible manner. In (Xu et al. 2015), a buyer may audit or pay a premium to motivate supplier responsibility; a government mandate to disclose auditing effort enables pre-commitment, which can reduce auditing and supplier responsibility. Corbett and DeCroix (2001) and Caro et al. (2013) and this paper model noncontractible efforts by multiple firms in a supply chain that jointly determine the supply chain environmental impact.

In closely-related quality literature, a supplier's effort determines the probability that a product is not defective, and a buyer's inspection effort determines the probability of detecting a defective product. Assuming that the firms' efforts are noncontractible, Baiman et al. (2000) show that the first best efforts are induced by contracting for the supplier to pay a penalty if the product fails either the buyer's inspection or in use. Acknowledging the difficulties of implementing such a penalty contract, (Baiman et al. 2000) propose a returns contract and characterize the resulting second best efforts. Several papers extend the model in (Baiman et al. 2000) and address the problem that a buyer cannot force its supplier to pay a penalty for defects (Babich and Tang 2012, Bondareva and Pinker 2013) or can extract at most limited, "fair" compensation (Balachandran and Radhakrishnan 2005). In (Bondareva and Pinker 2013), a supplier willingly pays a limited penalty for defects to avoid losing future business. In (Babich and Tang 2012), a buyer delays payment to the supplier in order to withhold payment in the event that the product fails in use. In each of these mechanisms, the magnitude of the penalty is limited. Similarly, §4.5 of this paper evaluates an option for a buyer to impose a limited penalty on a supplier for causing a major harm to workers or the environment. Hwang et al. (2006) identify conditions under which, rather than inspect the supplier's product, a buyer should conduct a quality audit of the supplier's facility and source from the supplier only if the facility passes the audit. Our model can be interpreted as addressing the latter situation, while incorporating a supplier's effort to pass the quality audit through deception.

Kim (2015) surveys the literature on optimal monitoring in law enforcement. In contrast to that literature and our paper, (Kim 2015) models dynamic variation over time in factory pollution and inspection by a regulator.

## 2. Model Formulation

As depicted in Figure 1, a supplier chooses a level of responsibility effort $e_r$ to avoid causing a major harm to workers or the environment, and chooses a level of hiding effort $e_h$ to evade the buyer's audit. The efforts are chosen on the scale of $e_r$, $e_h \in [0, 1]$ because they correspond to probabilities. With probability $1 - e_r$ the supplier's facility is "unsafe," meaning that operating the facility may cause a major harm to workers or the environment (e.g., a deadly fire or major release of toxic chemicals). With probability $e_h$, the supplier is able to successfully hide any evidence that the factory is unsafe. The supplier incurs costs $K_r(e_r)$ and $K_h(e_h)$ that increase with its levels of responsibility and hiding effort.

The buyer chooses an auditing effort $e_a \in [0, 1]$ and incurs cost $K_a(e_a)$ that increases with $e_a$. If the supplier's facility is unsafe then, by exerting more auditing effort, the buyer becomes more

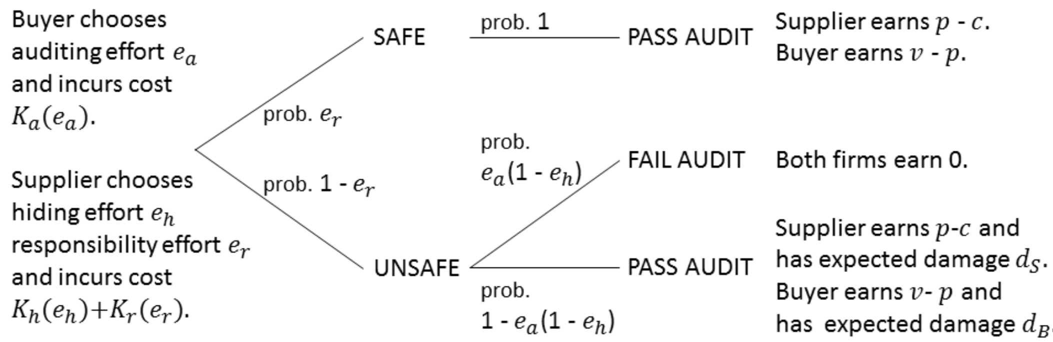


Figure 1: Model of Auditing, Hiding and Responsibility Effort.

likely to observe the problematic practices or conditions that make the facility unsafe (unless these are successfully hidden by the supplier). Hence with probability $e_a(1-e_h)$ an unsafe facility fails the audit. Otherwise, the facility passes the audit. The likelihood that the facility passes the audit is $1-e_a(1-e_h)(1-e_r)$. If the buyer sources from the supplier, she sources a fixed quantity, which we scale to 1, pays the supplier $p$ and has contribution margin of $v-p>0$, while the supplier has contribution margin $p-c>0$; $v$ denotes the buyer's value of sourcing from the supplier, and $c$ denotes the supplier's production cost. If the supplier's facility is unsafe and the buyer sources from the supplier, then the buyer incurs an additional expected cost of $d_B$; this parameter combines the probability that a major harm to workers or the environment will actually occur, the probability that it will be publicized, and the expected resulting costs for the buyer. We assume that the buyer does not want to source from an unsafe facility

$$d_B > v-p,$$

which implies that if the supplier fails the audit, then the buyer does not source from the supplier.

We rule out uninteresting equilibria in which the buyer exerts zero auditing effort or the supplier exerts zero responsibility effort, because then there is no meaningful interaction between the firms. Instead, $v$ and $p$ are sufficiently large that in equilibrium, both firms exert effort, the buyer sources from the supplier in the event that the supplier passes the audit, and both firms earn strictly positive expected profit. The buyer chooses auditing effort $e_a$ to maximize expected profit

$$\pi_b = [1-e_a(1-e_h)(1-e_r)](v-p) - (1-e_r)[1-e_a(1-e_h)]d_B - K_a(e_a), \tag{1}$$

the supplier chooses responsibility effort $e_r$ and hiding effort $e_h$ to maximize expected profit

$$\pi_s = [1-e_a(1-e_h)(1-e_r)](p-c) - (1-e_r)[1-e_a(1-e_h)]d_S - K_r(e_r) - K_h(e_h), \tag{2}$$

where $d_B$ is the buyer's expected damage from sourcing from an unsafe supplier and $d_S$ is the supplier's expected damage from operating an unsafe facility. The latter represents all the supplier's expected costs associated with harm to workers or the environment.

We assume that the cost functions $K_i(e_i)$ for $i \in \{a, h, r\}$ are strictly increasing, twice differentiable, convex and satisfy $K_i(0) = 0$. Convexity is natural in that one would expect each firm to prioritize the most cost effective activities. For example, to increase the likelihood of detecting an unsafe facility, the buyer could: increase the amount of time that an auditor spends inspecting the facility, interviewing employees or reviewing paperwork; hire a more expensive, more capable auditor; or expend resources on training the auditor. Assuming that the buyer prioritizes the most cost-effective of those activities, achieving an increasingly high level of $e_a$ will incur an increasing marginal cost $K'_a(e_a)$.

We assume that the supplier's best response hiding and responsibility efforts $(\tilde{e}_h(e_a), \tilde{e}_r(e_a))$ are interior (i.e., $\tilde{e}_i(e_a) \in (0, 1)$ for $i \in \{h, r\}$ for $e_a \in (0, 1]$) and the unique solution to the first order conditions

$$(\partial/\partial e_r)\pi_s = d_S + e_a(1 - e_h)(p - c - d_S) - K'_r(e_r) = 0 \quad (3)$$

$$(\partial/\partial e_h)\pi_s = e_a(1 - e_r)(p - c - d_S) - K'_h(e_h) = 0; \quad (4)$$

further, $\tilde{e}_i(e_a)$ is continuous in $e_a$ for $i \in \{h, r\}$. The buyer knows the supplier's objective function (2) but cannot observe the supplier's actual responsibility and hiding efforts, which leads us to focus on a simultaneous-move Nash equilibrium. Hence we assume existence of a unique equilibrium $(e^*_a, e^*_r, e^*_h)$ that is the unique solution to (3), (4) and

$$(\partial/\partial e_a)\pi_b = (1 - e_h)(1 - e_r)(d_B - v + p) - K'_a(e_a) = 0. \quad (5)$$

Conditions that assure the existence of a unique equilibrium, which is interior, are in the appendix. Our focus on the interior solution rules out a scenario in which a supplier intentionally causes a major harm to workers or the environment, e.g., by dumping chemicals. However, it does allow for the major harm to be occurring at the time of the buyer's audit, as with a leakage of chemicals or worker exposure to toxic chemicals arising from insufficient inspection and maintenance of equipment or insufficient safety precautions. At the time that the supplier chooses how much effort to exert in hiding information from the buyer, e.g., by falsifying its record of inspection, maintenance and safety training, the supplier does not yet know whether its factory will turn out to be safe or cause major harm.

The price $p$ is a constant, except in §4.3, rather than optimized jointly with auditing effort $e_a$. That reflects the reality of most buying firms, in which a procurement organization seeks quality, rapid delivery, etc. at a low price (high $v$ and low $p$) and a *separate* organization seeks to prevent sourcing from a supplier that harms workers or the environment. Those two organizations are often at odds, have poor communication, and fail to work closely together (Harney 2008).

The online supplement establishes that our results hold in a more complex model, in which the supplier's facility may be in a variety of different unsafe states $j \in \{1, .., N\}$, each corresponding to a different level of expected damage for the buyer $d_B^j$. In that model, the supplier's responsibility effort $e_r$ decreases the buyer's expected damage in the event that the supplier is unsafe and the buyer sources from the supplier.

## 3. Results: Buyer's Auditing Effort

A buyer might reasonably expect that increased auditing will lead to increased responsibility effort. That is true if the supplier cannot hide. However, Proposition 1 shows that increased auditing can "backfire" by reducing the supplier's responsibility effort. All proofs are in the online supplement.

**Proposition 1** ($a.$) *The supplier's best response responsibility effort* $\tilde{e}_r$ *decreases in the buyers's auditing effort* $e_a$ *if and only if*

$$K_h'(\tilde{e}_h)/K_h''(\tilde{e}_h) > 1 - \tilde{e}_h. \tag{6}$$

($b.$) *A sufficient condition for* (6) *to hold is that*

$$\tilde{e}_h > \underline{e}_h, \tag{7}$$

*where the threshold* $\underline{e}_h < 1$ *if* $K_h''(e_h) \leq K$ *for some* $K < \infty$.

The rationale is that increased auditing motivates the supplier to exert more hiding effort, which is a substitute for responsibility effort. When the backfiring condition (6) holds, pushing the supplier harder has the effect of encouraging the supplier to "give up" on exerting responsibility effort and instead to focus on hiding any evidence of potentially unsafe conditions or practices.

Some evidence suggests that the backfiring condition is prevalent or becoming more so. Because

$$K_h'(\tilde{e}_h) = e_a(1 - \tilde{e}_r)(p - c - d_S), \tag{8}$$

(6) tends to hold when the buyer's auditing effort $e_a$ is large, the supplier's expected damage from operating an unsafe facility $d_S$ is small relative to the supplier's margin $p - c$, the supplier's responsibility effort $\tilde{e}_r$ is small, and the supplier's hiding effort $\tilde{e}_h$ is large. Commonly in practice, as documented in §1, buyers are increasing their auditing efforts $e_a$ and suppliers are likely to pass audits by hiding information, i.e., $\tilde{e}_h$ is large. Suppliers' safety and environmental responsibility efforts are inadequate because responsibility is costly and government enforcement is weak, i.e., $\tilde{e}_r$ and $d_S$ are low (Foster and Harney 2005, Egels-Zandén 2007, Harney 2008). A supplier's financial incentive to pass an audit, represented by $p - c$ in our model, is large (Foster and Harney 2005). Jacobs and Singhal (2014) provide evidence that margins $p - c$ are large for publicly-traded Bangladeshi garment suppliers. Yet buyers are under pressure to pay increasingly high prices $p$ (Dudley 2012a,

Jacobs and Singhal 2014). Finally, as documented in §1, a supplier's harm to workers or the environment is increasingly likely to be publicized and linked to a buyer, which increases a buyer's expected damage from sourcing from an unsafe supplier $d_B$ and thus, as shown in Proposition 2 below, increases auditing effort $e_a$.

To understand why backfiring occurs under the specified conditions, focus first on the sufficient condition in Proposition 1b. Backfiring occurs when the supplier is likely to pass the buyer's audit by hiding information, i.e., $\tilde{e}_h$ is sufficiently large. To the extent that $\tilde{e}_h$ is large, the supplier's marginal value of responsibility effort

$$d_S + e_a(1 - \tilde{e}_h)(p - c - d_S) \tag{9}$$

is small and has a small partial derivative with respect to $e_a$, meaning that increased auditing has little direct effect on responsibility effort. The small marginal value of responsibility effort implies that $\tilde{e}_r$ is small. Consequently, the supplier's marginal value of hiding effort, the right hand side of (8), has a large partial derivative with respect to $e_a$. Hence increased auditing stimulates a large increase in hiding effort $\tilde{e}_h$, which decreases the marginal value of responsibility effort (9) and causes the supplier to reduce her responsibility effort.

Figure 2 illustrates that backfiring occurs when the supplier's damage from operating an unsafe facility $d_S$ is small, responsibility is costly, and either the supplier's margin $p - c$ or the buyer's auditing effort $e_a$ is sufficiently large. In Figure 2's shaded region, increasing the buyer's auditing effort $e_a$ backfires by reducing the supplier's best response responsibility effort $\tilde{e}_r$; with power cost functions for hiding and responsibility $K_h(e_h) = \alpha_h(e_h)^{\beta_h}$ and $K_r(e_r) = \alpha_r(e_r)^{\beta_r}$, parameters are $\alpha_h = 1$, $\beta_h = 3/2$, $\alpha_r = 2$, $\beta_r = 2$ and $d_S = 0$. Increasing the supplier's cost of responsibility $\alpha_r$ or decreasing the supplier's expected damage from operating an unsafe facility $d_S$ shifts the backfiring region boundary in the direction of the arrows.

Intuitively, the supplier's incentive to exert hiding effort–and consequently $\tilde{e}_h$–is large when supplier faces little penalty for operating an unsafe facility, has a high cost for responsibility effort, has a strong financial reward for passing the audit, and faces sufficient scrutiny from the buyer. Mathematically, those conditions correspond to high marginal value of hiding effort in the right hand side of (8) and high $\tilde{e}_h$, so (6) holds.

Finally, backfiring tends to occur when the supplier's hiding cost function exhibits little relative convexity. To the extent that $K_h''(\tilde{e}_h)$ is small, after an increase in the buyer's auditing effort $e_a$ increases the marginal value of hiding (right hand side of (8)), the supplier makes a relatively large increase in her hiding effort $\tilde{e}_h$ in order to equate the marginal cost with the marginal value

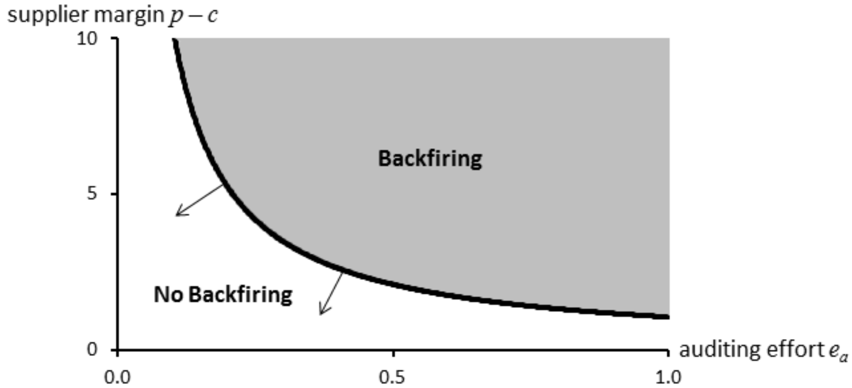


Figure 2: Backfiring as a Function of Buyer's Auditing Effort and Supplier's Margin.

of hiding, which prompts the supplier to reduce her responsibility effort. When the hiding cost function exhibits little relative convexity, i.e., $K_h''(\tilde{e}_h)$ is small relative to $K_h'(\tilde{e}_h)$ so the left hand side of (6) is large, then backfiring occurs even if the conditions that favor backfiring described above (large $e_a$ or $p-c-d_S$ and costly responsibility, which induce small $\tilde{e}_r$, large $\tilde{e}_h$, and large marginal value and cost of hiding in (8)) do *not* hold. In the sufficient condition for backfiring (7), the threshold $\underline{e}_h$ is less than $1-\min_{e_h\in[0,1]}\{K_h'(e_h)/K_h''(e_h)\}$, which implies that $\underline{e}_h$ is small when the hiding cost function exhibits little relative convexity.

Why should a buyer increase its auditing effort when that would backfire by causing the supplier to exert more hiding effort and less responsibility effort? Proposition 2 shows that that can be an optimal response to the increasing pressure from NGOs and other actors that expose and shame buying firms for the social and environmental harms caused by their suppliers. In equilibrium, as $d_B$ increases so that the buyer is more motivated to eliminate an unsafe supplier, the buyer's optimal auditing level increases–even when that increase in auditing backfires.

Let $(6')$ and $(7')$ denote (6) and (7) evaluated at the equilibrium levels of responsibility, hiding and auditing effort.

**Proposition 2** *The buyer's equilibrium auditing effort $e_a^*$ increases with the buyer's expected damage from sourcing from an unsafe supplier $d_B$. The supplier's equilibrium responsibility effort $e_r^*$ decreases with $d_B$ if and only if* $(6')$.

A rich literature shows how a buyer can reduce the expected cost associated with the risk of disruption of a supplier's production process, notably by developing a back-up alternative source (Tomlin 2006, Gurnani et al. 2012). That would be captured in our model by adding $+e_a(1-e_h)(1-e_r)m$ to the buyer's expected profit (1), where $m$ represents the contribution the buyer receives by sourcing from the back-up supplier in the event that the primary supplier fails the audit. As is evident from the first order conditions (3)-(5), increasing $m$ has directionally the same effect as increasing $d_B$ on the equilibrium auditing, hiding and responsibility efforts. Hence under the backfiring condition (6′), having a back-up alternative source might make the buyer worse off, by causing the buyer to spend more on auditing and the primary supplier to become less responsible.

## 4. Results: Other Ways a Buyer Might Improve Supplier Responsibility

Historically, buyers have sought to improve supplier responsibility through increased auditing but, as shown in §3, that may be counterproductive. Therefore this section evaluates other actions a buyer might take to improve supplier responsibility.

### 4.1. Providing a Loan to the Supplier

Walmart, Gap and other buyers are offering loans to Bangladeshi garment suppliers with the aim of enabling those suppliers to make their facilities safe (Wohl 2013). This motivates an extension to our model formulation in which the supplier has a budget constraint

$$K_r(e_r) + K_h(e_h) \leq B. \tag{10}$$

By providing a loan to the supplier, the buyer increases the supplier's budget $B$. If the budget constraint (10) is not binding in equilibrium, then a loan to the supplier has no effect on the supplier's equilibrium levels of responsibility and hiding effort. In this subsection, therefore, we focus on the interesting case where (10) is binding in equilibrium.

If the supplier's expected damage from operating an unsafe facility $d_S$ is large, then the supplier has substantial incentive to exert responsibility effort. Consequently, increasing the supplier's budget naturally leads the supplier to increase her responsibility effort $e_r^*$. Proposition 3 shows that if the supplier's expected damage $d_S$ is small, the opposite can occur.

In reality, many suppliers have negligible expected damage $d_S$ from operating an unsafe facility. Regulatory institutions are weak in the developing and emerging economies in which suppliers are concentrated (Economy 2007, Locke et al. 2007). For example, in Bangladesh, garment factory owners have paid little or no compensation to families of workers that died in the collapsed buildings and factory fires of 2012-2013 (Motlagh 2014). China has stringent environmental laws, but expected fines for violations are negligible because regulators lack resources, prioritize economic growth and are corruptible (Economy 2007, Lee et al. 2009). NGOs target multinational buyers rather than their suppliers because the buyers are concerned about brand damage, whereas "few [suppliers] pay any attention to this sort of public pressure," according to the director of a prominent NGO (Lee et al. 2009).

**Proposition 3** *Suppose the supplier's expected damage from operating an unsafe facility* $d_S = 0$. *Increasing the supplier's budget* $B$ *decreases the supplier's equilibrium responsibility effort* $e_r^*$ *if and only if* (6′).

The intuition is that when the backfiring condition (6′) holds, the supplier is highly motivated to increase hiding effort to pass the audit. She uses the expanded budget do so, which decreases her incentive for responsibility effort.

### 4.2. Pre-Committing to Auditing Effort

Auditing effort is noncontractible in our base model because, in reality, auditing is complex. To increase the likelihood of detecting an unsafe facility, a buyer could, for example, increase the skill, sophistication and motivation of the auditor, or increase the level of scrutiny that the auditor applies in review of documents, interviews of workers and managers or facility inspection. To contractually-specify all relevant aspects of auditing effort and enforce the contract could be prohibitively difficult if not impossible.

Nevertheless, suppose that the buyer finds a way to commit to her auditing effort level in advance. She chooses auditing effort $e_a$ to maximize expected profit (1) with the supplier's best response $\tilde{e}_i$ replacing $e_i$ for $i \in \{r, h\}$. Let $(\hat{e}_a, \hat{e}_r, \hat{e}_h)$ denote the resulting equilibrium in auditing, responsibility and hiding effort, and (6″) denote inequality (6), where $\hat{e}_h$ replaces $\tilde{e}_h$. If the supplier were unable to hide, the ability to precommit would cause the buyer to do more auditing. Proposition 4 shows the opposite result.

**Proposition 4** *If the buyer can commit to her auditing effort in advance and* (6″) *holds, then the buyer chooses a lower auditing effort*

$$\hat{e}_a < e_a^*. \tag{11}$$

The intuition is that when (6″) holds, the supplier's hiding effort is sensitive to auditing, so auditing intensely backfires by increasing hiding and reducing responsibility. Consequently, by committing to a lower level of auditing, the buyer reduces hiding, which increases her expected profit. Note that (6″) may hold, meaning that auditing backfires by reducing the supplier's responsibility effort even at the equilibrium optimal pre-commitment auditing effort, because auditing enables the buyer to detect and avoid sourcing from an unsafe facility.

### 4.3 Squeezing the Supplier's Margin

A common view is that "squeezing" a supplier's margin causes the supplier neglect safety and environmental responsibilities (Dudley 2012a, Goodman 2013). Therefore, as discussed above, NGOs are pressuring buyers to pay higher prices to suppliers. Further, some academic literature suggests that buyers can improve supplier responsibility by helping suppliers to improve their production efficiencies (Locke et al. 2007, Locke and Romis 2010), which translates to reducing the supplier's production cost $c$ in our model.

However, Proposition 5 shows that under the backfiring condition (6′), a buyer should reduce the price $p$ and increase the supplier's production cost $c$. To increase a supplier's production cost in practice, the buyer could require the supplier to raise wages to achieve Fair Trade certification or could pressure government to raise the minimum wage, as prominent apparel buyers have done in Bangladesh (Al-Mahmood 2013, Cheng 2013).

**Proposition 5** *If* (6′) *holds, then the supplier's equilibrium responsibility effort* $e_r^*$ *and the buyer's expected profit* $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)}$ *increase with the supplier's production cost* $c$ *and decrease with the price* $p$.

The intuition for Proposition 5 parallels that for Proposition 1 because increasing the supplier's margin $p - c$ has the same effect on the supplier's incentives for responsibility and hiding effort as does increasing the buyer's auditing effort $e_a$, as is evident in (3) and (4).

Proposition 5 (and the propositions in §§4.4-4.6 and 4.8) implicitly assume that the supplier will not shut down in response to a marginal reduction in its expected profit. Jacobs and Singhal (2014) provide empirical evidence of the validity of that assumption, by documenting that a large sample of Bangladeshi garment suppliers are highly profitable, more so than their buyers.

In most buying firms, as documented in §2, decisions regarding price and auditing are made separately. Harney (2008) quotes an executive at a branded apparel firm saying, "The sourcing group and the compliance group could almost be on different planets." The next result suggest that by coordinating the price and auditing decisions–namely by accounting for how price affects the costs of auditing and sourcing from a potentially unsafe facility–a buying firm might resolve the problem that auditing backfires by reducing responsibility. The Corollary follows from Proposition 5's result that if the backfiring condition (6′) holds, then the buyer increases her expected profit by reducing the price $p$.

**Corollary** *If the price* $p$ *maximizes the buyer's expected profit* $\pi_b|_{(e_a,e_r,e_h)=(e_a^*(p),e_r^*(p),e_h^*(p))}$*, then* (6′) *does not hold.*

A caveat is that a supplier may command a higher price than would maximize the buyer's expected profit. Another caveat is that the buyer may pay the supplier a high price $p$ to motivate investments in quality, capacity or relationship-specific assets that are not represented in the profit function $\pi_b$ defined in (1).

### 4.4. Engaging Governments or Other Buyers to Penalize the Supplier for Harm

To increase a supplier's expected damage from operating an unsafe facility $d_S$, buyers could pressure governments to increase the penalty for a supplier that harms workers or the environment. For example, Disney ceased to source garments from Bangladesh due to safety concerns, then reinstated Bangladesh after successful negotiations with the government. In 2014, for the first time in the history of Bangladesh, a garment factory owner will undergo trial for criminal negligence leading to the death of workers (Motlagh 2014). Alternatively, buyers might negotiate an industry accord to ensure that no buyer sources from a supplier following a major harm to workers or the environment. Proposition 6 confirms that increasing $d_S$ makes the supplier more responsible.

**Proposition 6** *The supplier's equilibrium responsibility effort* $e_r^*$ *and buyer's expected profit* $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)}$ *increase with the supplier's expected damage from operating an unsafe facility* $d_S$*.*

### 4.5. Contracting to Penalize the Supplier for Harm to Workers or the Environment

The literature surveyed in §1 proposes mechanisms by which a buyer can extract a limited payment from a supplier that delivers a defective product. Suppose the buyer adapts one of those mechanisms to penalize a supplier for harm to workers or the environment. Let $y$ denote the expected value of that penalty for a supplier operating an unsafe facility. In the buyer's expected profit (1), $(d_B - y)$ replaces $d_B$; in the supplier's expected profit (2), $(d_S + y)$ replaces $d_S$. For example, the buyer might delay payment for a contractually-specified period of time after the supplier produces, and withhold payment upon obtaining evidence of a major harm to workers or the environment. In that scenario, $y$ reflects the probability that a supplier operating an unsafe facility will cause major harm to workers or the environment, the probability that the buyer will obtain evidence of that harm within the specified time period, and the magnitude of the withheld payment. The expected penalty $y$ that the buyer can practically impose will be small in that the magnitude of the payment the buyer can withhold is small relative to the damage the buyer incurs from its supplier's major harm to workers or the environment.

In contrast to Proposition 6–although the contractual penalty $y$ has the same effect on the supplier's expected profit (2) as increasing $d_S$, and the additional benefit of directly increasing the buyer's expected profit–instituting the contractual penalty $y$ can *decrease* the supplier's responsibility effort and the buyer's expected profit.

**Proposition 7** *As the expected penalty the supplier pays the buyer when operating an unsafe facility $y$ increases, the supplier's equilibrium responsibility effort $e_r^*$ decreases if and only if*

$$K_a''(e_a^*)K_h''(e_h^*) - [(1-e_h^*)K_h''(e_h^*) - K_h'(e_h^*)][e_a^*K_a''(e_a^*) + K_a'(e_a^*) \times (p-c-d_S-y)/(d_B-v+p)] + (1-e_r^*)^2(p-c-d_S-y)(d_B-v+p) < 0. \quad (12)$$

*For some parameters, instituting a penalty $y > 0$ decreases the buyer's equilibrium expected profit $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ y>0} < \pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ y=0}$ and increases the supplier's equilibrium expected profit $\pi_s|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ y>0} > \pi_s|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ y=0}$.*

To develop intuition for (12), consider a no-hiding scenario in which $(\grave{e}_a, \grave{e}_r)$ denotes the equilibrium in auditing and responsibility effort, the solution to (3) and (5) with $e_h = 0$, $(d_S + y)$ replacing $d_S$, and $(d_B - y)$ replacing $d_B$. In that scenario, condition (12) simplifies to

$$K_a'(\grave{e}_a)/K_a''(\grave{e}_a) > (1-\grave{e}_a)(d_B - v + p)/(p - c - d_S - y). \quad (13)$$

As $y$ increases, the buyer's equilibrium auditing effort $\grave{e}_a$ decreases, because the buyer has greater expected profit when sourcing from an unsafe supplier. The decrease in auditing effort is large when (13) holds, which causes the supplier to exert less responsibility effort $\grave{e}_r$, despite the increase in the expected penalty from operating an unsafe facility. Condition (13) resembles (6′). Auditing effort is sensitive to a change in $y$ when the marginal cost of auditing effort is high, the cost of auditing effort is not too convex, and the auditing effort is low, for qualitatively the same reasons, presented after Proposition 1, that the supplier's hiding effort is sensitive to a parameter change when (6′) holds. In general, with hiding, (12) holds–meaning that increasing $y$ reduces the supplier's equilibrium responsibility effort $e_r^*$–when the buyer's auditing effort is sensitive and the supplier's hiding effort is insensitive to a parameter change. If the backfiring condition (6′) holds, then condition (12) is violated, because the supplier responds to the reduced auditing that accompanies an increase in $y$ by reducing hiding and increasing responsibility effort.

Contracting for the supplier to pay a penalty to the buyer in the event that the supplier causes a major harm to workers or the environment can reduce the buyer's expected profit and increase the supplier's expected profit in equilibrium, by reducing the buyer's auditing effort and the supplier's responsibility effort. The proof of Proposition 7 provides a numerical example.

### 4.6. Penalizing the Supplier for Hiding

Buyers are beginning to partner with NGOs that oversee the buyers' audits (Ma 2012). NGO oversight might enable the buyer to make a credible commitment to terminate the supplier in the event that the buyer obtains evidence of hiding effort by the supplier. One might conjecture that the buyer should make that commitment and take complementary actions to increase the probability of detecting hiding effort by the supplier. To the contrary, Proposition 8 shows that doing so can decrease the supplier's responsibility effort and the buyer's expected profit.

**Proposition 8** *Suppose that with probability $\theta e_h$, where $\theta \in [0,1]$, the buyer detects hiding effort and does not source from the supplier. As $\theta$ increases, the supplier's equilibrium responsibility effort $e_r^*$ decreases if and only if*

$$\begin{aligned}&[e_a^* K_a''(e_a^*) + K_a'(e_a^*)](p-c)(p-c-d_S)\\&- d_S\{K_a''(e_a^*)[e_h^* K_h''(e_h^*) + K_h'(e_h^*)] + (1-e_r^*)^2(d_B - v + p)(p-c-d_S)\} < 0. \qquad (14)\end{aligned}$$

*For some parameters, instituting the penalty of termination for detected hiding $\theta > 0$ decreases the buyer's equilibrium expected profit $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ \theta>0} < \pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ \theta=0}$.*

Increasing the supplier's expected damage from operating an unsafe facility $d_S$, as recommended in §4.4, tends to cause (14) to hold. The supplier is motivated to exert responsibility effort to avoid those damages in the event that she wins the buyer's business. Increasing $\theta$ and hence the likelihood that the buyer will detect hiding effort and terminate the supplier reduces that motivation for responsibility effort. Conversely, if $d_S = 0$ then (14) is violated.

Commitment to terminate the supplier for detected hiding effort can reduce the buyer's expected profit through two mechanisms: reduced supplier responsibility effort and failure to source from a supplier that is safe. The proof of Proposition 8 provides a numerical example.

In contrast to Propositions 7 and 8, Proposition 9 shows that instituting a financial penalty for detected hiding effort increases the supplier's responsibility effort and the buyer's expected profit.

**Proposition 9** *Suppose that with probability $\theta e_h$, where $\theta \in [0,1]$, the buyer detects hiding and the supplier pays a penalty $z \geq 0$ to the buyer. Increasing $\theta$ or $z$ increases the supplier's equilibrium responsibility effort $e_r^*$ and the buyer's expected profit $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)}$.*

Intuitively, instituting a financial penalty for detected hiding effort discourages hiding, which increases the marginal value of responsibility effort. The buyer benefits from the supplier's reduced hiding effort and increased responsibility effort, as well as from the direct financial payment.

Implementing a penalty for detected hiding will be challenging, and will require that $\theta$ and $z$ be sufficiently small. The evidence of hiding must be verifiable, which will tend to make $\theta$ small. In the event that the buyer detects hiding and the supplier passes the audit, the buyer could deduct the penalty (pay the supplier $p - z$ instead of $p$), but forcing the supplier to pay $z$ in the event of a failed audit could be impossible, for the reasons explained in (Babich and Tang 2012). Imposing the financial penalty for detected hiding only in the event that the supplier passes the audit can reduce the supplier's responsibility effort and the buyer's profit, similar to Proposition 8. Conceivably, the buyer could require the supplier to pay $z$ in advance (in the hope of future business) and could commit to refund $z$ unless hiding is detected. That commitment could be enforced by the buyer's reputational concerns, if $z$ is sufficiently small. Suppliers are often cash-constrained, which would limit the magnitude of $z$ in the up-front payment.

### 4.7. Publicizing Negative Audit Reports

Suppose that, in the event of a failed audit, the supplier sells to an alternative buyer at expected price $\underline{p} \in [c + d_S, p]$; the supplier operates–and incurs expected damage $d_S$ if the facility is unsafe–regardless of whether she passes the audit. Hence, the supplier's expected profit becomes

$$\pi_s = [1 - e_a(1-e_r)(1-e_h)](p-c) - e_a(1-e_r)(1-e_h)(\underline{p}-c) - (1-e_r)d_S - K_r(e_r) - K_h(e_h). \quad (15)$$

The buyer can reduce $\underline{p}$ by publishing, in the event of the failed audit, the evidence that the supplier is unsafe. In reality, NGOs are pressuring buyers to publish their negative audit reports (Walsh and Greenhouse 2012); Apple, Walmart, and signatories to the Accord on Fire and Building Safety in Bangladesh have committed to do so (Duhigg and Wingfield 2012, Accord 2013, Wohl 2013). However, Proposition 10 suggests that this might reduce the buyer's expected profit.

**Proposition 10** *Suppose that the supplier sells to an alternative buyer following a failed audit. If* (6′) *holds, then the supplier's equilibrium responsibility effort* $e_r^*$ *and the buyer's expected profit* $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)}$ *increase in the expected price paid by the alternative buyer* $\underline{p}$.

The intuition is that under the backfiring condition (6′), increasing the penalty for a failed audit (reducing $\underline{p}$) leads to greater hiding and hence lower responsibility effort.

Similarly, reporting safety and environmental violations to government authorities following a failed audit reduces the supplier's responsibility effort and the buyer's expected profit, if the backfiring condition (6′) holds and the supplier faces a government-imposed penalty for such violations.

### 4.8. Making Hiding More Difficult

A buyer could engage an NGO to monitor the audit; a supplier has greater difficulty deceiving or bribing an auditor while an NGO monitor is present (Ma 2012). A buyer could commit to find a new job or pay severance for any worker in a supplier's facility that loses a job because of a failed audit, as do signatories to the Accord on Fire and Building Safety in Bangladesh (Accord 2013). That would eliminate the strong incentive for workers to hide problematic practices during the audit (Esbenshade 2004, Egels-Zandén 2007), and thus make it more difficult for the supplier to train workers to do so.

However, Proposition 11 shows that making hiding more difficult can reduce the supplier's responsibility effort. Empirical literature on the relationship between time-in-training and job performance (see (Liu and Batt 2007) and references therein) suggests that the cost to train employees to deceive an auditor is well represented by a convex power function $\alpha {e_h}^{-\gamma}$ with $\gamma < -1$, $\alpha > 0$, and $e_h$ the success probability. One may interpret $\gamma$ as the difficulty of hiding because $\alpha {e_h}^{-\gamma}$ increases with $\gamma$.

**Proposition 11** *Suppose the supplier's hiding cost function is of the form $K_h(e_h) = \alpha {e_h}^{-\gamma}$. The supplier's equilibrium responsibility effort $e_r^*$ and the buyer's expected profit $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)}$ decrease in the supplier's difficulty of hiding $\gamma$ if and only if*

$$e_h^* > \exp(1/\gamma). \tag{16}$$

The rationale is that increasing $\gamma$ simultaneously increases the hiding cost $K_h(e_h)$ for all $e_h \in (0, 1)$ and reduces the marginal cost $K_h'(e_h)$ for $e_h > \exp(1/\gamma)$, which causes the supplier to exert more hiding effort and less responsibility effort when (16) holds. Therefore, buyers should proceed cautiously with actions aimed at making hiding more difficult and costly for suppliers, and focus on increasing the effective marginal cost of hiding.

Whereas this §4 evaluates various actions for the buyer individually, a buyer might, in practice, implement several of those actions simultaneously. However, most of the actions that increase the supplier's responsibility effort also decrease the supplier's expected profit. To avoid causing the supplier to shut down, a buyer may be constrained to adopt only a subset of those actions or only to limited extent (e.g., imposing only small penalties for detected hiding and for causing harm).

## 5. Unauthorized Subcontracting

In Bangladesh, apparel buyers H&M, Carrefour and Next invested to make their suppliers' factories safe, and subsequently suffered brand damage from publicity of deadly fires in unauthorized subcontractors' facilities (Strauss et al. 2013). This motivates the following alternative interpretation of our model.

Suppose that the supplier has a safe facility. Let $e_r$ denote the fraction of the buyer's order that the supplier plans to produce in-house, and $1 - e_r$ the fraction for which it subcontracts, paying $K_s(1 - e_r)$ to the unauthorized subcontractors. Correspondingly, the supplier plans to use its own, limited capacity to produce $1 - e_r$ for other buyers, during the time period in which the supplier is supposed to dedicate its capacity to production for the buyer. During that time period, the buyer audits the supplier for unauthorized subcontracting at random times with a frequency proportional to $e_a$. At each time that the auditor arrives, the likelihood that the supplier is cheating by producing for a different buyer is $1-e_r$. The auditor can detect unauthorized subcontracting by seeing that the supplier is cheating by producing for a different buyer. However, the supplier attempts to hide that from the auditor: $e_h$ is the likelihood of successfully doing do. Therefore the probability that the buyer's auditing detects unauthorized subcontracting is $e_a(1-e_h)(1-e_r)$. We assume that the buyer takes delivery and pays the supplier if and only if it does not detect unauthorized subcontracting. In the event that the buyer detects unauthorized subcontracting and so refuses to take delivery from the supplier, the supplier sells the units that it subcontracted or produced for the buyer at some lower price $\underline{p} < p$. Moreover, after failing an audit, the supplier uses any residual capacity that it had allocated for the buyer to produce units that sell at that same, lower price $\underline{p}$. In contrast, through advance commitments, the supplier earns expected profit of $R(1-e_r)-(1-e_r)c$ on the quantity $1-e_r$ that it plans to produce for other buyers, where $R(\cdot)$ is increasing and satisfies $R(1-e_r) \geq (1-e_r)\underline{p}$. Hence the supplier's objective function is

$$\begin{aligned}\pi_s &= [1-e_a(1-e_h)(1-e_r)]p + e_a(1-e_h)(1-e_r)\underline{p} - e_r c - K_s(1-e_r) \\ &\quad + R(1-e_r) - (1-e_r)c - K_h(e_h) \\ &= p - c - e_a(1-e_h)(1-e_r)(p-\underline{p}) - K_r(e_r) - K_h(e_h), \qquad (17)\end{aligned}$$

where $K_r(e_r) \equiv K_s(1-e_r) - R(1-e_r)$ is increasing in $e_r$.

To understand the buyer's objective, observe that the expected quantity that the buyer purchases (indirectly) from unauthorized suppliers is $(1-e_r)[1-e_a(1-e_h)(1-e_r)]$. We assume that the buyer's expected damage increases, linearly, with the quantity that it purchases (indirectly) from unauthorized subcontractors, for two reasons. The first is that if a buyer purchases a larger quantity from an unauthorized supplier, it is more likely to be discovered to be linked to that supplier in the event of a major publicized violation by that supplier, e.g., because an item labeled for the buyer is on site at the time of a fire or building collapse, remains intact, and is found by activists afterwards (Motlagh 2014). The second reason is that unauthorized subcontractors tend to be very small, with much less capacity than the direct supplier, so that as the aggregate quantity from unauthorized subcontractors increases, the direct supplier engages a larger number of unauthorized subcontractors on behalf of the buyer (Lahiri and Passariello 2013), which increases the expected number that will have a major, publicized harm to workers or the environment linked to the buyer. Therefore the buyer's objective function is

$$\pi_b = [1-e_a(1-e_h)(1-e_r)](v-p) - (1-e_r)[1-e_a(1-e_h)(1-e_r)]d_B - K_a(e_a); \qquad (18)$$

this is the same as (1), except for the substitution of $[1-e_a(1-e_h)(1-e_r)]$ for $[1-e_a(1-e_h)]$ in

(1).

Proposition 12 shows that both of the propositions in §3 and most of the relevant propositions in §4 hold in this setting with unauthorized subcontracting. Propositions 6 and 7 are not relevant in this setting because the supplier's facility is safe. The proofs of Propositions 5, 10 and 11 employ the plausible assumption that at the equilibrium effort levels, the buyer's expected profit is increasing in the supplier's responsibility effort.

**Proposition 12** *Propositions* 1*,* 2*,* 3 *and* 9 *hold as stated. Propositions* 5*,* 10 *and* 11 *hold under the assumption that the buyer's equilibrium expected profit increases in the supplier's responsibility effort,* $(\partial/\partial e_r)\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} > 0$.

Some anecdotal evidence from the Bangladesh apparel industry suggests that the backfiring condition (6′) is prevalent or increasingly so. Because

$$K_h'(e_h^*) = e_a^*(1-e_r^*)(p-\underline{p}),$$

(6′) tends to hold when auditing effort $e_a^*$ is large, the volume of unauthorized subcontracting $1-e_r^*$ is large, and the price $p$ paid by the buyer is large relative to the supplier's salvage value $\underline{p}$. In response to publicized deadly fires in unauthorized subcontractors' facilities, buyers are increasing their auditing efforts $e_a^*$ (Biraj 2013). Unauthorized subcontracting is "pervasive" (Lahiri and Passariello 2013); in a "typical example" a supplier accepts orders for 10 times the volume it can produce, and subcontracts the rest (Labowitz and Baumann-Pauly 2014). This suggests that $1-e_r^*$ is large for many suppliers. The Bangladeshi government and banks give financial rewards for increased export sales to suppliers that directly export goods to multinational buyers (Labowitz and Baumann-Pauly 2014). In effect, that increases both $p$ and $R'(1-e_r)$. Moreover, a buyer's investment to make a supplier's facility safe makes the supplier more desirable to other "free-riding" buyers (Greenhouse 2013), which further increases $R'(1-e_r)$. Increasing $R'(1-e_r)$ increases the volume of unauthorized subcontracting $1-e_r^*$. Hiding unauthorized subcontracting is straightforward, in that a supplier can pay subcontractors in cash based on verbal agreements, falsify records of production and shipments, display inventory made by the subcontractor as its own production, and train employees to appear to be producing for one buyer while cheating by serving another (Clifford and Greenhouse 2013, Lahiri 2013, Labowitz and Baumann-Pauly 2014), which suggests that $e_h^*$ is large, the sufficient condition for backfiring (7′).

Under the backfiring condition (6′), Proposition 12 shows that to mitigate unauthorized subcontracting, a buyer should squeeze the supplier's margin $p-c$ and impose a financial penalty for evidence of effort to hide subcontracting. The buyer should *not*: increase auditing effort to detect

| Increase Responsibility Effort | | Decrease Responsibility Effort | |
|---|---|---|---|
| Under Backfiring Condition | Always | Sometimes | Under Backfiring Condition |
| • decrease auditing<br>• increase supplier's wages for workers (by pressuring government)<br>• decrease price | • penalize supplier for harm: government fine<br>• penalize supplier for hiding effort: payment to buyer | • penalize supplier for harm: payment to buyer<br>• penalize supplier for hiding effort: terminate sourcing<br>• make hiding more difficult for supplier | • increase auditing<br>• reduce supplier's production cost (by providing technical assistance to supplier)<br>• increase price<br>• lend to supplier<br>• publicize failed audit |

Figure 3: Buyer Actions That Increase or Decrease Supplier Responsibility Effort.

unauthorized subcontracting, publicize failed audits for unauthorized subcontracting, or provide loans to suppliers.

## 6. Concluding Remarks

This paper is the first in the supply chain management literature to model a supplier's effort to hide information during a buyer's audit. Nike executives inspired the research by expressing concern that increased auditing and financial incentives for responsibility caused suppliers to hide information rather than become more responsible.

The paper shows that, consistent with the Nike executives' concern, a variety of well-intentioned buyer actions (listed in the right half of Table 1) can decrease the supplier's responsibility effort. The actions in the rightmost column of Table 1 decrease the supplier's responsibility effort under the "backfiring condition." Under that condition, the actions that a buyer should take to increase the supplier's responsibility effort (listed in the leftmost column of Table 1) are contrary to the usual prescription. The buyer should commit to do less auditing, or should squeeze the supplier's margin–either by paying a lower price or by pressuring the government to increase wages for workers in the supplier's facility.

Plausible penalties for hiding or harm can be counterproductive; see the center-right column of Table 1. In contrast, the penalties in the center-left column of Table 1 are more difficult for a buyer to implement (requiring influence over the government or a mechanism to extract money from a supplier even after a failed audit and termination of sourcing) but reliably increase supplier responsibility effort.

Our analysis also provides guidance for NGOs wanting to encourage suppliers' efforts to prevent harm to workers and the environment. Under the backfiring condition, increasing NGO pressures on buyers (to pay higher prices, to publish negative audit reports, shaming buyers for harm caused by suppliers and subcontractors) reduce suppliers' efforts to prevent harm. NGOs should directly penalize the owners and managers of factories that harm workers or the environment, e.g., by publishing their names in local newspapers and online, to shame them in their communities.

The paper has provided anecdotal evidence that the backfiring condition is prevalent or increasingly so, but empirical tests are needed. One approach would take advantage of any external event that motivates a buyer to increase auditing effort across all suppliers. A contemporaneous increase in the frequency of audit-failure and incidence of harm to workers or the environment, following an increase in supplier auditing, would indicate that the backfiring condition holds for some suppliers; proof is provided in the online supplement. A second empirical approach would be to survey factory managers about the efficacy of hiding unsafe conditions. As explained in (Jayaraman and De Vericourt 2013), one cannot ask a respondent to self-incriminate, but must instead enable respondents to implicate others. For example, one might ask: How likely are your competitors to pass audits through deceptive or corrupt practices? A high incidence of "very likely" responses would suggest that the backfiring condition holds.

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# Appendix

**Conditions for existence of a unique equilibrium.** The following conditions ensure existence of a unique equilibrium and that the equilibrium efforts are interior $e_i^* \in (0,1)$ for $i \in \{a,r,h\}$ :

$$(v-c)^2[1+d_B/K_a''(e_a)]<K_r''(e_r)K_h''(e_h), \tag{19}$$

$K_i'(0) = 0$ for $i \in \{a, r, h\}$, $K_j'(1) \geq v - c$ for $j \in \{r, h\}$, $K_a'(1) \geq d_B$, $d_S < p - c$, $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} \geq 0$ and $\pi_s|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} \geq 0$. Inequality (19) holds if the total supply chain margin is sufficiently small, or if the costs of auditing, hiding and responsibility effort are sufficiently convex.

# Online Supplement
# Appendix A

This appendix provides the proofs of Propositions 1 to 11. Lemma 1 will be used in the proofs of Lemma 3 and Propositions 2 and 4.

**Lemma 1** *If* (6) *holds, then*

$$(1-\tilde{e}_r)K_r''(\tilde{e}_r) - K_r'(\tilde{e}_r) + d_S > 0 \tag{20}$$

*and supplier's hiding effort* $\tilde{e}_h$ *increases in the buyers's auditing effort* $e_a$.

**Proof of Lemma 1 and Proposition 1:** Differentiating (3) and (4) with respect to $e_a$, we obtain

$$[1 - e_h - e_a(\partial e_h/\partial e_a)](p - c - d_S) - (\partial e_r/\partial e_a)K_r''(e_r) = 0 \tag{21}$$

$$[1 - e_r - e_a(\partial e_r/\partial e_a)](p - c - d_S) - (\partial e_h/\partial e_a)K_h''(e_h) = 0. \tag{22}$$

Using (21)-(22) and the fact that $(\tilde{e}_r, \tilde{e}_h)$ satisfy (3)-(4), we obtain

$$\partial\tilde{e}_r/\partial e_a = [(1-\tilde{e}_h)K_h''(\tilde{e}_h) - K_h'(\tilde{e}_h)](p-c-d_S)/[K_r''(\tilde{e}_r)K_h''(\tilde{e}_h) - e_a^2(p-c-d_S)^2] \tag{23}$$

$$\partial\tilde{e}_h/\partial e_a = [(1-\tilde{e}_r)K_r''(\tilde{e}_r) - K_r'(\tilde{e}_r) + d_S](p-c-d_S)/[K_r''(\tilde{e}_r)K_h''(\tilde{e}_h) - e_a^2(p-c-d_S)^2]. \tag{24}$$

Because $(\tilde{e}_r, \tilde{e}_h)$ is a best response for the supplier, the Hessian of $\pi_s$ evaluated at $(e_r, e_h) = (\tilde{e}_r, \tilde{e}_h)$ is negative definite, which implies that the denominator in (23) is strictly positive. This establishes Proposition 1a: $\partial\tilde{e}_r/\partial e_a < 0$ if and only if (6). Next we establish Lemma 1. If (6) holds, then $\partial\tilde{e}_r/\partial e_a < 0$. From (21), this implies $\partial\tilde{e}_h/\partial e_a = [(1-e_h)(p-c-d_S) - (\partial\tilde{e}_r/\partial e_a)K_r''(\tilde{e}_r)]/[e_a(p-c-d_S)] > 0$. Therefore, (24) implies (20). It remains to establish Proposition 1b. Because the supplier's best response responsibility and hiding effort is interior and satisfies (4), $K_h'(\tilde{e}_h) > 0$; further, as noted above, $K_h''(\tilde{e}_h) > 0$. It follows that (7) implies (6).■

Lemma 2 will be used in the proofs of Lemma 3 and Propositions 2, 6 and 11. Let

$$\begin{aligned}\Gamma &= K_a''(e_a^*)\left[K_r''(e_r^*)K_h''(e_h^*) - (e_a^*)^2(p-c-d_S)^2\right] + (d_B - v + p)(p-c-d_S) \times \\ &\quad \{(1-e_r^*)[(1-e_r^*)K_r''(e_r^*) - K_r'(e_r^*) + d_S] + (1-e_h^*)[(1-e_h^*)K_h''(e_h^*) - K_h'(e_h^*)]\}.\end{aligned} \tag{25}$$

**Lemma 2** *If the supplier's responsibility effort* $\tilde{e}_r$ *and hiding effort* $\tilde{e}_h$ *and the marginal cost of auditing effort* $K_a'(e_a)$ *are continuous in the buyer's auditing effort* $e_a$, *then* $\Gamma > 0$.

**Proof of Lemma 2:** The buyer's best response auditing effort $\tilde{e}_a(e_r, e_h)$ is the unique solution to $\Upsilon(e_a, e_r, e_h) = 0$, where $\Upsilon(e_a, e_r, e_h) = (1-e_h)(1-e_r)(d_B - v + p) - K_a'(e_a)$. We will show that

$$(\partial/\partial e_a)\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))|_{(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a)) = (e_a^*, e_r^*, e_h^*)} < 0. \tag{26}$$

To do so, we first establish that

$$\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))|_{e_a=0} > 0 > \Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))|_{e_a=1}. \tag{27}$$

Because $K_a(\cdot)$ is convex, $\pi_b(\cdot)$ is concave. Therefore, if $\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))|_{e_a=0} \leq 0$, then $(e_a, e_r, e_h) = (0, \tilde{e}_r(0), \tilde{e}_h(0))$ is an equilibrium, which contradicts that the unique equilibrium in interior. Similarly, if $\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))|_{e_a=1} \geq 0$, then $(e_a, e_r, e_h) = (1, \tilde{e}_r(1), \tilde{e}_h(1))$ is an equilibrium, which contradicts that the unique equilibrium in interior. This establishes (27). The proof that (26) holds is by contradiction. Suppose that (26) is violated in that the inequality is reversed. Because $\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))$ is continuous in $e_a$, the first inequality in (27) implies there exists $\ddot{e}_a \in (0, e_a^*)$ such that $\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))|_{e_a=\ddot{e}_a} = 0$. Therefore, $(e_a, e_r, e_h) = (\ddot{e}_a, \tilde{e}_r(\ddot{e}_a), \tilde{e}_h(\ddot{e}_a))$ is an equilibrium, which contradicts that $(e_a^*, e_r^*, e_h^*)$ is the unique equilibrium. Suppose that (26) is violated in that the inequality is replaced with an equality. Because $\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))$ is continuous in $e_a$, the first inequality in (27) implies that the second inequality in (27) is violated. We conclude that (26) holds. Observe that

$$(\partial/\partial e_a)\Upsilon(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))|_{(e_a, \tilde{e}_r(e_a), \tilde{e}_h(e_a))=(e_a^*, e_r^*, e_h^*)} = -\Gamma / \left[K_r''(e_r^*)K_h''(e_h^*) - (e_a^*)^2(p-c-d_S)^2\right]. \tag{28}$$

Because $(\tilde{e}_r, \tilde{e}_h)$ is a best response for the supplier, the Hessian of $\pi_s$ evaluated at $(e_r, e_h) = (\tilde{e}_r, \tilde{e}_h)$ is negative definite, which implies that the denominator in (28) is strictly positive. Therefore, (26) implies that $\Gamma > 0$.■

Lemma 3 will be used in the proof of Proposition 5.

**Lemma 3** *The supplier's equilibrium responsibility effort $e_r^*$ decreases in the price $p$ and increases in the supplier's production cost $c$ if and only if $(6')$. If $(6')$ holds, then the supplier's equilibrium hiding effort $e_h^*$ increases in the $p$ and decreases in $c$.*

**Proof of Lemma 3 and Proposition 2:** Differentiating (3), (4) and (5) with respect to $d_B$, we obtain

$$[(1-e_h)(\partial e_a/\partial d_B) - e_a(\partial e_h/\partial d_B)](p-c-d_S) - (\partial e_r/\partial d_B)K_r''(e_r) = 0 \tag{29}$$

$$[(1-e_r)(\partial e_a/\partial d_B) - e_a(\partial e_r/\partial d_B)](p-c-d_S) - (\partial e_h/\partial d_B)K_h''(e_h) = 0 \tag{30}$$

$$(1-e_r)(1-e_h) - [(1-e_h)(\partial e_r/\partial d_B) + (1-e_r)(\partial e_h/\partial d_B)](d_B - v + p) - (\partial e_a/\partial d_B)K_a''(e_a) = 0. \tag{31}$$

Using (29)-(31) and the fact that $(e_a^*, e_r^*, e_h^*)$ satisfy (3)-(5), we obtain

$$\partial e_a^*/\partial d_B = (1-e_h^*)(1-e_r^*)\left[K_r''(e_r^*)K_h''(e_h^*) - (e_a^*)^2(p-c-d_S)^2\right]/\Gamma \quad (32)$$

$$\partial e_r^*/\partial d_B = [(1-e_h^*)K_h''(e_h^*) - K_h'(e_h^*)](1-e_h^*)(1-e_r^*)(p-c-d_S)/\Gamma \quad (33)$$

$$\partial e_h^*/\partial d_B = [(1-e_r^*)K_r''(e_r^*) - K_r'(e_r^*) + d_S](1-e_h^*)(1-e_r^*)(p-c-d_S)/\Gamma \quad (34)$$

Similar parallel arguments establish that

$$\partial e_r^*/\partial p = [(1-e_h^*)K_h''(e_h^*) - K_h'(e_h^*)][e_a^* K_a''(e_a^*) + (1-e_h^*)(1-e_r^*)(p-c-d_S)]/\Gamma$$

$$\partial e_h^*/\partial p = [(1-e_r^*)K_r''(e_r^*) - K_r'(e_r^*) + d_S][e_a^* K_a''(e_a^*) + (1-e_h^*)(1-e_r^*)(p-c-d_S)]/\Gamma$$

$$\partial e_r^*/\partial c = -[(1-e_h^*)K_h''(e_h^*) - K_h'(e_h^*)]e_a^* K_a''(e_a^*)/\Gamma$$

$$\partial e_h^*/\partial c = -[(1-e_r^*)K_r''(e_r^*) - K_r'(e_r^*) + d_S]e_a^* K_a''(e_a^*)/\Gamma.$$

From Lemma 2, $\Gamma > 0$. Therefore, $\partial e_r^*/\partial d_B < 0$, $\partial e_r^*/\partial p < 0$ and $\partial e_r^*/\partial c > 0$ if and only if (6′). Let (20′) denote inequality (20), where $e_r^*$ replaces $\tilde{e}_r$. Suppose (6′) holds. This implies that (20′) holds (by Lemma 1). Therefore, $\partial e_h^*/\partial p > 0$ and $\partial e_h^*/\partial c < 0$.■

**Proof of Proposition 3:** When the supplier's budget constraint is binding, the supplier's problem is to choose $e_r$ and $e_h$ to maximize (2) subject to (10), where the inequality binds. When $d_S = 0$, the supplier's problem can be rewritten with a change of variables as

$$\max_{\varepsilon_r \in [0,B]} \{[1 - e_a \rho_r(\varepsilon_r)\rho_h(B-\varepsilon_r)](p-c)\}, \quad (35)$$

where $\varepsilon_i = K_i(e_i)$ and $\rho_i(\varepsilon_i) = 1 - e_i$ for $i \in \{r, h\}$; $\varepsilon_r$ denotes the supplier's expenditure on responsibility effort and $\rho_r(\varepsilon_r)$ denotes the probability that the supplier's facility is unsafe; $\varepsilon_h$ and $\rho_h(\varepsilon_h)$ are interpreted similarly. In (35), observe that the supplier's problem is to allocate a fixed budget across the two types of effort to maximize the probability of passing the audit, and her optimal allocation is invariant to the buyer's auditing effort $e_a$ and the supplier's margin $p - c$. Therefore, problem (35) can be rewritten as $\min_{\varepsilon_r \in [0,B]} \psi(\varepsilon_r)$, where $\psi(\varepsilon_r) = \rho_r(\varepsilon_r)\rho_h(B-\varepsilon_r)$. Because the supplier's equilibrium responsibility and hiding efforts are strictly positive and because $K_i(0) = 0$ for $i \in \{r, h\}$, the supplier's equilibrium expenditure on responsibility effort is interior $\varepsilon_r \in (0, B)$. The supplier's equilibrium responsibility expenditure $\varepsilon_r$ is the solution to the first order condition

$$(\partial/\partial\varepsilon_r)\psi(\varepsilon_r) = \rho_r'(\varepsilon_r)\rho_h(B-\varepsilon_r) - \rho_r(\varepsilon_r)\rho_h'(B-\varepsilon_r) = 0. \quad (36)$$

Because the supplier's equilibrium responsibility expenditure $\varepsilon_r^*$ is unique, and because

$(\partial^2/\partial\varepsilon_r^2)\psi(\varepsilon_r^*) > 0$, by the implicit function theorem,

$$\begin{aligned}\partial\varepsilon_r^*/\partial B < 0 \quad &\iff \quad \rho_r'(\varepsilon_r^*)\rho_h'(B-\varepsilon_r^*) - \rho_r(\varepsilon_r^*)\rho_h''(B-\varepsilon_r^*) > 0 \\ &\iff \quad \rho_h'(\varepsilon_h^*)^2 - \rho_h(\varepsilon_h^*)\rho_h''(\varepsilon_h^*) > 0 \qquad (37) \\ &\iff \quad K_h'(e_h^*)/K_h''(e_h^*) > 1 - e_h^*; \qquad (38)\end{aligned}$$

where (37) follows from $\varepsilon_r^*$ satisfying (36) and $\varepsilon_h^* = B - \varepsilon_r^*$; and (38) follows from $\rho_h(\varepsilon_h) = 1 - K_h^{-1}(\varepsilon_h)$ and $e_h = K_h^{-1}(\varepsilon_h)$.■

**Proof of Proposition 4:** Let $\hat{\pi}_b$ denote the right hand side of (18), where $\tilde{e}_i$ replaces $e_i$ for $i \in \{r, h\}$. Then $\hat{\pi}_b$ denotes buyer's expected profit when the buyer commits to the auditing level prior to the supplier's choosing her responsibility and hiding effort. Therefore, when the buyer commits to her auditing effort in advance, the buyer's equilibrium auditing effort $\hat{e}_a$ satisfies the first order condition

$$\begin{aligned}(\partial/\partial e_a)\hat{\pi}_b = [1-\tilde{e}_h(e_a)][1-\tilde{e}_r(e_a)](d_B - v + p) - K_a'(e_a) + \{v - p + (1 - e_a[1-\tilde{e}_h(e_a)]) \\ \times (d_B - v + p)\}(\partial\tilde{e}_r/\partial e_a) - e_a[1-\tilde{e}_r(e_a)](d_B - v + p)(\partial\tilde{e}_h/\partial e_a) = 0.\end{aligned}$$

Therefore,

$$\begin{aligned}(\partial/\partial e_a)\pi_b|_{e_a=\hat{e}_a} &= [1-\tilde{e}_h(\hat{e}_a)][1-\tilde{e}_r(\hat{e}_a)](d_B - v + p) - K_a'(\hat{e}_a) \\ &= -\{v - p + (1 - \hat{e}_a[1-\tilde{e}_h(\hat{e}_a)])(d_B - v + p)\}(\partial\tilde{e}_r/\partial e_a) \\ &\quad + \hat{e}_a[1-\tilde{e}_r(\hat{e}_a)](d_B - v + p)(\partial\tilde{e}_h/\partial e_a). \qquad (39)\end{aligned}$$

Because $K_a(e_a)$ is convex in $e_a$, $\pi_b(e_a)$ is concave in $e_a$. Therefore, (11) holds if and only if $(\partial/\partial e_a)\pi_b|_{e_a=\hat{e}_a} > 0$. From Lemma 1 and Proposition 1, (6$''$) implies $\partial\tilde{e}_r/\partial e_a < 0$ and $\partial\tilde{e}_h/\partial e_a > 0$; from (39), this implies $(\partial/\partial e_a)\pi_b|_{e_a=\hat{e}_a} > 0$.■

**Proof of Proposition 5:** If (6$'$) holds, then $\partial e_r^*/\partial c > 0$ and $\partial e_h^*/\partial c < 0$ (by Lemma 3). Further,

$$\begin{aligned}(\partial/\partial c)\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = \quad &(\partial e_r^*/\partial c)\{e_a^*(1-e_h^*)(v-p) + [1 - e_a^*(1-e_h^*)]d_B\} \\ &- (\partial e_h^*/\partial c)(1-e_r^*)(d_B - v + p) > 0,\end{aligned}$$

where the equality follows from the envelope theorem and the inequality follows from $\partial e_r^*/\partial c > 0$ and $\partial e_h^*/\partial c < 0$. If (6$'$) holds, then $\partial e_r^*/\partial p < 0$ and $\partial e_h^*/\partial p > 0$ (by Lemma 3). Further,

$$\begin{aligned}(\partial/\partial p)\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = (\partial e_r^*/\partial p)\{v - p + [1 - e_a^*(1-e_h^*)](d_B - v + p)\} - (\partial e_h^*/\partial p) \\ \times e_a^*(1-e_r^*)(d_B - v + p) - [1 - e_a^*(1-e_h^*)(1-e_r^*)] < 0,\end{aligned}$$

where the equality follows from the envelope theorem and the inequality follows from $\partial e_r^*/\partial p < 0$

and $\partial e_h^*/\partial p > 0$.■

**Proof of Proposition 6:** Differentiating (3), (4) and (5) with respect to $d_S$, we obtain

$$1 - e_a(1-e_h) + [(1-e_h)(\partial e_a/\partial d_S) - e_a(\partial e_h/\partial d_S)]\,(p-c-d_S) - (\partial e_r/\partial d_B)K_r''(e_r) = 0 \quad (40)$$

$$-e_a(1-e_r) + [(1-e_r)(\partial e_a/\partial d_S) - e_a(\partial e_r/\partial d_S)]\,(p-c-d_S) - (\partial e_h/\partial d_B)K_h''(e_h) = 0 \quad (41)$$

$$-\,[(1-e_h)(\partial e_r/\partial d_S) + (1-e_r)(\partial e_h/\partial d_S)]\,(d_B - v + p) - (\partial e_a/\partial d_S)K_a''(e_a) = 0. \quad (42)$$

Using (40)-(42) and the fact that $(e_a^*, e_r^*, e_h^*)$ satisfy (3)-(5), we obtain

$$\begin{aligned}\partial e_r^*/\partial d_S = \;& [(1-e_r^*)^2(p-c-d_S)(d_B-v+p) \\ & + K_a''(e_a^*)\{K_h''(e_h^*)[1-e_a^*(1-e_h^*)] + (e_a^*)^2(1-e_r^*)(p-c-d_S)\}]/\Gamma > 0 \\ \partial e_h^*/\partial d_S = \;& -[(1-e_h^*)(1-e_r^*)(p-c-d_S)(d_B-v+p) \\ & + e_a^* K_a''(e_a^*)\{(1-e_r^*)K_r''(e_r^*) + [1-e_a^*(1-e_h^*)](p-c-d_S)\}]/\Gamma < 0,\end{aligned}$$

where the inequality follows because $\Gamma > 0$ (by Lemma 2). Further,

$$\begin{aligned}(\partial/\partial d_S)\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = \;& (\partial e_r^*/\partial d_S)[d_B - e_a^*(1-e_h^*)(d_B-v+p)] - (\partial e_h^*/d_S)e_a^*(1-e_r^*) \\ & \times (d_B-v+p) - [1-e_a^*(1-e_h^*)(1-e_r^*)] > 0,\end{aligned}$$

where the equality follows from the envelope theorem and the inequality follows from $\partial e_r^*/\partial d_S > 0$ and $\partial e_h^*/\partial d_S < 0$.■

**Proof of Proposition 7:** Under expected penalty $y$, the equilibrium conditions are (3)-(5), where $(d_S + y)$ replaces $d_S$ and $(d_B - y)$ replaces $d_B$. Differentiating (3)-(5) with respect to $y$, we obtain

$$1 - e_a(1-e_h) + [(\partial e_a/\partial y)(1-e_h) - (\partial e_h/\partial y)e_a](p-c-d_S-y) - (\partial e_r/\partial y)K_r''(e_r) = 0 \quad (43)$$

$$-e_a(1-e_r) + [(\partial e_a/\partial y)(1-e_r) - (\partial e_r/\partial y)e_a](p-c-d_S-y) - (\partial e_h/\partial y)K_h''(e_h) = 0 \quad (44)$$

$$-(1-e_r)(1-e_h) - [(\partial e_r/\partial y)(1-e_h) + (\partial e_h/\partial y)(1-e_r)](d_B - y - v + p) - (\partial e_a/\partial y)K_a''(e_a) = 0. \quad (45)$$

Using (43)-(45) and the fact that $(e_a^*, e_r^*, e_h^*)$ satisfies (4) and (5), we obtain

$$\begin{aligned}\partial e_r^*/\partial y \;=\; & \{K_a''(e_a^*)K_h''(e_h^*) - [(1-e_h^*)K_h''(e_h^*) - K_h'(e_h^*)][e_a^* K_a''(e_a^*) + K_a'(e_a^*) \\ & \times(p-c-d_S-y)/(d_B-v+p)] + (1-e_r^*)^2(p-c-d_S-y)(d_B-v+p)\}/\Gamma \end{aligned} \quad (46)$$

where $\Gamma$ is as defined in (25), wherein $(d_S+y)$ replaces $d_S$ and $(d_B-y)$ replaces $d_B$. By straightforward extension of Lemma 2, $\Gamma > 0$. Therefore, $\partial e_r^*/\partial y < 0$ if and only if inequality (12) holds. Next we provide parameters under which instituting a penalty $y > 0$ decreases the buyer's profit and increases the supplier's profit. Suppose $K_a(e_a) = 0.5(e_a)^2$, $K_r(e_r) = 0.25(e_r)^2$, $K_h(e_h) = 20(e_h)^2$, $d_B = 3$, $d_S = 0$, $v = 19$, $p = 17$, and $c = 14$. Without a penalty (i.e., $y = 0$), the equilibrium auditing effort $e_a^* = 0.62$, responsibility effort $e_r^* = 0.36$, hiding effort $e_h^* = 0.03$, buyer's expected profit $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 0.28$ and supplier's expected profit $\pi_s|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 1.50$. Under penalty $y = 0.46$, the equilibrium efforts and profits are $e_a^* = 0.38$, $e_r^* = 0.28$, $e_h^* = 0.02$, $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 0.25$ and $\pi_s|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 1.78$.■

**Proof of Proposition 8:** The likelihood that the facility passes the audit is $1 - e_a(1 - e_h)(1 - e_r) - \theta e_h$, and the likelihood that an unsafe facility passes the audit is $(1 - e_r)[1 - e_a(1 - e_h) - \theta e_h]$. The buyer's expected profit $\pi_b$ is given by the right hand side of (1) and supplier's expected profit $\pi_s$ is given by the right hand side of (2), with the addition of $-\theta e_h$ within each of the square brackets in both expressions. Denote (3) with the addition of $-\theta e_h d_S$ in the center expression as (3″), and denote (4) with the addition of $-\theta[p - c - (1 - e_r)d_S]$ in the center expression as (4″). The first order conditions for the supplier's responsibility and hiding effort decisions are (3″) and (4″). Differentiating (3″), (4″) and (5) with respect to $\theta$, we obtain

$$-e_h d_S + (\partial e_a/\partial\theta)(1 - e_h)(p - c - d_S) - (\partial e_h/\partial\theta)[e_a(p - c - d_S) + \theta d_S] - (\partial e_r/\partial\theta)K_r''(e_r) = 0 \quad (47)$$

$$(\partial e_a/\partial\theta)(1 - e_r)(p - c - d_S) - (\partial e_r/\partial\theta)[e_a(p - c - d_S) + \theta d_S] - [p - c - (1 - e_r)d_S] - (\partial e_h/\partial\theta)K_h''(e_h) = 0 \quad (48)$$

$$-[(\partial e_h/\partial\theta)(1 - e_r) + (\partial e_r/\partial\theta)(1 - e_h)](d_B - v + p) - (\partial e_a/\partial\theta)K_a''(e_a) = 0. \quad (49)$$

Using (47)-(49) and the fact that $(e_a^*, e_r^*, e_h^*)$ satisfy (3″), (4″) and (5), we obtain

$$\partial e_r^*/\partial\theta = ([e_a^* K_a''(e_a^*) + K_a'(e_a^*)](p - c)(p - c - d_S) - d_S\{K_a''(e_a^*)[e_h^* K_h''(e_h^*) + K_h'(e_h^*)] + (1 - e_r^*)^2(d_B - v + p)(p - c - d_S)\})/\Gamma,$$

where $\Gamma$ is as defined in (25), wherein $-(e_a^*)^2(p - c - d_S)^2$ is replaced by $-[e_a^*(p - c - d_S) + \theta d_S]^2$, $+d_S$ is replaced by $+(1 - \theta)d_S$ and $-K_h'(e_h^*)$ is replaced by $-K_h'(e_h^*) - \theta(p - c)$. By straightforward extension of Lemma 2, $\Gamma > 0$. Therefore, $\partial e_r^*/\partial y < 0$ if and only if inequality (14) holds. Next we provide parameters under which instituting the penalty of termination for detected hiding $\theta > 0$ decreases the buyer's equilibrium expected profit. Suppose $K_a(e_a) = 0.4(e_a)^2$, $K_r(e_r) = 10(e_r)^2$, $K_h(e_h) = 0.02(e_h)^2$, $d_B = 10.0$, $d_S = 2.0$, $v = 13.50$, $p = 4.0$, and $c = 1.0$. If the buyer does not institute a penalty for detected hiding (i.e., $\theta = 0$), then the equilibrium auditing effort $e_a^* = 0.041$, responsibility effort $e_r^* = 0.100$, hiding effort $e_h^* = 0.927$, buyer's expected profit $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 0.502$ and supplier's expected profit $\pi_s|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 1.080$. If the buyer institutes the penalty of termination for detected hiding, then under ease of detecting hiding $\theta = 0.1$, the equilibrium efforts and profits are $e_a^* = 0.163, e_r^* = 0.095, e_h^* = 0.712$, $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 0.431$ and $\pi_s|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = 0.962$. ■

**Proof of Proposition 9:** The buyer's expected profit $\pi_b$ is given by the right hand side of (1), with the addition of $+\theta e_h z$; the supplier's expected profit $\pi_s$ is given by the right hand side of (2), with the addition of $-\theta e_h z$. First, we will show that $\partial e_r^*/\partial z > 0$ and $\partial e_h^*/\partial z < 0$. Denote (4) with the addition of $-\theta z$ in the center expression as ($4'''$). The first order conditions for the supplier's responsibility and hiding effort decisions are (3) and ($4'''$). Differentiating (3), ($4'''$) and (5) with respect to $z$, we obtain

$$[(\partial e_a/\partial z)(1-e_h) - (\partial e_h/\partial z)e_a](p-c-d_S) - (\partial e_r/\partial z)K_r''(e_r) = 0 \tag{50}$$

$$[(\partial e_a/\partial z)(1-e_r) - (\partial e_r/\partial z)e_a](p-c-d_S) - \theta - (\partial e_h/\partial z)K_h''(e_h) = 0 \tag{51}$$

$$-[(\partial e_h/\partial z)(1-e_r) + (\partial e_r/\partial z)(1-e_h)](d_B - v + p) - (\partial e_a/\partial z)K_a''(e_a) = 0. \tag{52}$$

Using (50)-(52) and the fact that $(e_a^*, e_r^*, e_h^*)$ satisfy (3), ($4'''$) and (5), we obtain

$$\begin{aligned}\partial e_r^*/\partial z &= [e_a^* K_a''(e_a^*) + (1-e_h^*)(1-e_r^*)(d_B - v + p)](p-c-d_S)\theta/\Gamma \\ \partial e_h^*/\partial z &= -[K_a''(e_a^*)K_r''(e_r^*) + (1-e_h^*)^2(d_B - v + p)(p-c-d_S)]\theta/\Gamma,\end{aligned}$$

where $\Gamma$ is as defined in (25), wherein $-K_h'(e_h^*)$ is replaced by $-K_h'(e_h^*) - \theta z$. By straightforward extension of Lemma 2, $\Gamma > 0$. Therefore, $\partial e_r^*/\partial z > 0$ and $\partial e_h^*/\partial z < 0$. Consider $\overline{z} > \underline{z}$. Then $\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ z=\overline{z}} = \max_{e_a\in[0,1]} \pi_b|_{(e_r,e_h)=(e_r^*,e_h^*),\ z=\overline{z}} > \max_{e_a\in[0,1]} \pi_b|_{(e_r,e_h)=(e_r^*,e_h^*),\ z=\underline{z}}$ $= \pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*),\ z=\underline{z}}$, where the inequality follows because $e_r^*|_{z=\overline{z}} > e_r^*|_{z=\underline{z}}$, $e_h^*|_{z=\overline{z}} < e_h^*|_{z=\underline{z}}$, and $\pi_b$ is decreasing in $e_h$ and increasing in $e_r$ and $z$. The comparative statics for $\theta$ follow by a parallel argument.■

**Proof of Proposition 10:** The first order conditions that characterize the equilibrium in auditing, hiding and responsibility $(e_a^*, e_r^*, e_h^*)$ are given by (3), (4) and (5), where $c$ is replaced by $\underline{p}$. The result follows by argument parallel to that in the proof of Lemma 3 and Proposition 2.■

**Proof of Proposition 11:** By the envelope theorem,

$$\begin{aligned}(\partial/\partial\gamma)\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} = \quad & (\partial e_r^*/\partial\gamma)\{e_a^*(1-e_h^*)(v-p) + [1-e_a^*(1-e_h^*)]d_B\} \\ & - (\partial e_h^*/\partial\gamma)e_a^*(1-e_r^*)(d_B - v + p).\end{aligned} \tag{53}$$

We will show that $\partial e_r^*/\partial\gamma < 0$ if and only if (16), and $\partial e_h^*/\partial\gamma > 0$ if and only if (16). Differentiating

(3), (4) and (5) with respect to $\gamma$, we obtain

$$[(1-e_h)(\partial e_a/\partial\gamma) - e_a(\partial e_h/\partial\gamma)](p-c-d_S) - (\partial e_r/\partial\gamma)K_r''(e_r) = 0 \quad (54)$$

$$[(1-e_r)(\partial e_a/\partial\gamma) - e_a(\partial e_r/\partial\gamma)](p-c-d_S) - \alpha_h[\gamma\ln(e_h)-1](e_h)^{-\gamma-1}$$
$$-\alpha_h\gamma(1+\gamma)(e_h)^{-\gamma-2}(\partial e_h/\partial\gamma) = 0 \quad (55)$$

$$-[(1-e_h)(\partial e_r/\partial\gamma) + (1-e_r)(\partial e_h/\partial\gamma)](d_B - v + p) - (\partial e_a/\partial\gamma)K_a''(e_a) = 0. \quad (56)$$

Using (54)-(56) and the fact that $(e_a^*, e_r^*, e_h^*)$ satisfy (3)-(5), we obtain

$$\begin{aligned} \partial e_r^*/\partial\gamma &= (e_h^*)^{-\gamma-1}[e_a^* K_a''(e_a^*) + (1-e_r^*)(1-e_h^*)(d_B - v + p)](p-c-d_S)\alpha_h[\gamma\ln(e_h)-1]/\Gamma \\ \partial e_h^*/\partial\gamma &= -(e_h^*)^{-\gamma-1}[K_a''(e_a^*)K_r''(e_r^*) + (1-e_h^*)^2(d_B - v + p)(p-c-d_S)]\alpha_h[\gamma\ln(e_h)-1]/\Gamma. \end{aligned}$$

Recall from Lemma 2 that $\Gamma > 0$. Therefore, $\partial e_r^*/\partial\gamma < 0$ if and only if (16), and $\partial e_h^*/\partial\gamma > 0$ if and only if (16). The result follows from this observation and (53).■

# Appendix B

This appendix provides the proof of **Proposition 12**. In all proofs, the supplier's production cost $c$ is replaced by the price $\underline{p}$, and $d_S = 0$ because the supplier's facility is safe. The first order condition for the buyer's auditing effort (5) becomes $(\partial/\partial e_a)\pi_b = (1-e_h)(1-e_r)[(1-e_r)d_B - v + p] - K_a'(e_a) = 0$. Because the buyer's equilibrium auditing effort $e_a^* > 0$, $(1-e_r^*)d_B - v + p > 0$. Further, if $(\partial/\partial e_r)\pi_b|_{(e_a,e_r,e_h)=(e_a^*,e_r^*,e_h^*)} > 0$, then $e_a^*(1-e_h^*)(v-p) + [1 - 2e_a^*(1-e_h^*)(1-e_r^*)]d_B > 0$.

**Lemma 1 and Proposition 1.** The proof is unchanged.

We adapt the definition of $\Gamma$, which is used in Lemma 2 and the proofs of subsequent results.

$$\begin{aligned} \Gamma = {} & K_a''(e_a^*)\left[K_r''(e_r^*)K_h''(e_h^*) - (e_a^*)^2(p-\underline{p})^2\right] + (p-\underline{p}) \times \{[(1-e_r^*)d_B - v + p](1-e_r^*) \times \\ & [(1-e_r^*)K_r''(e_r^*) - K_r'(e_r^*)] + [2(1-e_r^*)d_B - v + p](1-e_h^*)[(1-e_h^*)K_h''(e_h^*) - K_h'(e_h^*)]\}. \end{aligned}$$

**Lemma 2.** The proof holds when $d_B$ is replaced by $(1-e_r)d_B$ in the definition of $\Upsilon(e_a, e_r, e_h)$.

**Lemma 3 and Proposition 2.** The proof holds with the following changes: The left hand side of (31) is replaced with $\{(1-e_r)^2(1-e_h) - [2(1-e_r)d_B - v + p](1-e_h)(\partial e_r/\partial d_B) - [(1-e_r)d_B - v + p](1-e_r)(\partial e_h/\partial d_B)\} - (\partial e_a/\partial d_B)K_a''(e_a)$. In (32)-(34), $(1-e_h^*)(1-e_r^*)$ is replaced by $(1-e_h^*)(1-e_r^*)^2$.

**Proposition 3.** The proof is unchanged.

**Proof of Proposition 5.** The proof holds when $[1 - e_a^*(1-e_h^*)]d_B$ is replaced by $[1 - 2e_a^*(1-e_h^*)(1-e_r^*)]d_B$, $(d_B - v + p)$ is replaced by $[(1-e_r^*)d_B - v + p]$, and $\{v - p + [1 - e_a^*(1-e_h^*)](d_B - v + p)\}$ is replaced by $e_a^*(1-e_h^*)(v-p) + [1 - 2e_a^*(1-e_h^*)(1-e_r^*)]d_B$.

**Proof of Proposition 9.** The proof holds when $(d_B - v + p)$ is replaced by $[(1 - e_r^*)d_B - v + p] - (\partial e_r^*/\partial z)(1 - e_h)(1 - e_r)d_B$ in (52), is replaced by $[(1 - e_r^*)d_B - v + p]$ in the expression for $\partial e_r^*/\partial z$, and is replaced by $[2(1 - e_r^*)d_B - v + p]$ in the expression for $\partial e_h^*/\partial z$.

**Proof of Proposition 10.** The proof is unchanged.

**Proof of Proposition 11.** The proof holds when $(d_B - v + p)$ is replaced by $[(1 - e_r^*)d_B - v + p] - (\partial e_r^*/\partial \gamma)(1 - e_h)(1 - e_r)d_B$ in (56), is replaced by $[(1 - e_r^*)d_B - v + p]$ in the expression for $\partial e_r^*/\partial \gamma$, and is replaced by $[2(1 - e_r^*)d_B - v + p]$ in the expression for $\partial e_h^*/\partial \gamma$.

# Appendix C

This appendix establishes that the results extend to the setting with multiple unsafe supplier states. Consider a generalization of our model formulation in which with probability $\Sigma_{j=1}^N P^j(e_r)$ the facility is unsafe; $P^j(e_r) \in [0, 1]$ is the probability that the facility is in unsafe state $j \in \{1, .., N\}$; if the buyer sources from a supplier in unsafe state $j$, the buyer incurs additional expected cost $d_B^j$. We assume that the buyer does not want to source from an unsafe facility

$$d_B^j > v - p,$$

which implies that if the supplier fails the audit, then the buyer does not source from the supplier. The buyer's expected profit is given by (1) where $d_B$ is replaced by $\Sigma_{j=1}^N P^j(e_r)d_B^j$, the buyer's expected cost of sourcing from an unsafe facility, which we assume is weakly decreasing in the supplier's responsibility effort $e_r$. For ease of exposition, let $d_B(e_r) = \Sigma_{j=1}^N P^j(e_r)d_B^j$. The supplier incurs additional expected cost $d_S$ from operating an unsafe facility The implicit assumption that $d_S$ does not vary with the state $j \in \{1, .., N\}$ may reflect the status quo for the many suppliers that face negligible costs $d_S = 0$ for operating an unsafe facility. Alternatively, $d_S$ could represent a maximal penalty for the supplier, such as supplier being forced to go out of business permanently after causing a major harm to workers or the environment.

In all proofs, $d_B(e_r)$ replaces $d_B$, except as noted otherwise below. The first order conditions are unchanged except that in (5), $d_B(e_r)$ replaces $d_B$.

**Proof of Lemma 1 and Proposition 1.** The proof is unchanged.

We adapt the definition of $\Gamma$, which is used in Lemma 2 and the proofs of subsequent results, by replacing $d_B$ with $d_B(e_r^*)$ and adding the term $-(1 - e_r^*)(1 - e_h^*)(p - c - d_S)[(1 - e_h^*)K_h''(e_h^*) - K_h'(e_h^*)]d_B'(e_r^*)$.

**Proof of Lemma 2.** The proof is unchanged.

For Proposition 2, let $d_B^j = \underline{d}_B + \Delta^j$ for $j \in \{1,..,N\}$. The Proposition holds when $d_B$ is replaced by $\underline{d}_B$.

**Proof of Lemma 3 and Proposition 2.** The proof holds when $(\partial e_i^*/\partial \underline{d}_B)$ replaces $(\partial e_i^*/\partial d_B)$ for $i \in \{a, r, h\}$ throughout, and $(1-e_r)(1-e_h)[1+(\partial e_r/\partial \underline{d}_B)d_B'(e_r)]$ replaces $(1-e_r)(1-e_h)$ in (31).

**Proof of Proposition 3.** The proof is unchanged.

**Proof of Proposition 4.** The proof holds with the following changes: On the right hand side of the first displayed equation, $d_B(\tilde{e}_r(e_a))$ replaces $d_B$ and $-[1-\tilde{e}_r(e_a)](1-e_a[1-\tilde{e}_h(e_a)])d_B'(\tilde{e}_r(e_a))(\partial \tilde{e}_r/\partial e_a)$ is added. In the remaining displayed equations, $d_B(\tilde{e}_r(\hat{e}_a))$ replaces $d_B$. On the right hand side of (39), $+[1-\tilde{e}_r(\hat{e}_a)](1-\hat{e}_a[1-\tilde{e}_h(\hat{e}_a)])d_B'(\tilde{e}_r(\hat{e}_a))(\partial \tilde{e}_r/\partial e_a)$ is added.

**Proof of Proposition 5.** The proof holds with the following changes: In the center expression of the first displayed equation, $d_B(e_r^*)$ replaces $d_B$ and $-(1-e_r^*)[1-e_a^*(1-e_h^*)]d_B'(e_r^*)(\partial e_r^*/\partial c)$ is added. In the center expression of the second displayed equation, $d_B(e_r^*)$ replaces $d_B$ and $-(1-e_r^*)[1-e_a^*(1-e_h^*)]d_B'(e_r^*)(\partial e_r^*/\partial p)$ is added.

**Proof of Proposition 6.** The proof holds with the following changes: In all expressions following equation (42), $d_B(e_r^*)$ replaces $d_B$. In the center expression for the displayed equation for $\partial e_h^*/\partial c$, within the square brackets $-(1-e_r^*)^2(1-e_h^*)(p-c-d_S)d_B'(e_r^*)$ is added. In the center expression of the last displayed equation, $-(1-e_r^*)[1-e_a^*(1-e_h^*)]d_B'(e_r^*)(\partial e_r^*/\partial d_S)$ is added.

**Proof of Proposition 7.** The proof holds with the following changes: On the left hand side of equation (45), $-(1-e_r)(1-e_h)[1+(\partial e_r/\partial \underline{d}_B)d_B'(e_r)]$ replaces $-(1-e_r)(1-e_h)$. In equation (46), $d_B(e_r^*)$ replaces $d_B$. In the numerical example, $N=1$ and $d_B^1 = 3$ replaces $d_B = 3$.

**Proof of Proposition 8.** The proof holds with the following changes: In the center expression for the displayed equation for $\partial e_r^*/\partial \theta$, $d_B(e_r^*)$ replaces $d_B$. In the numerical example, $N=1$ and $d_B^1 = 10.0$ replaces $d_B = 10.0$.

**Proof of Proposition 9.** The proof holds with the following changes: On the left hand side of (52), $+(1-e_r)(1-e_h)d_B'(e_r)(\partial e_r/\partial z)$ is added. In the last two displayed equations, $d_B(e_r^*)$ replaces $d_B$. On the right hand side of the last displayed equation, within the square brackets $-(1-e_r^*)(1-e_h^*)^2(p-c-d_S)d_B'(e_r^*)$ is added.

**Proof of Proposition 10.** The proof is unchanged.

**Proof of Proposition 11.** The proof holds with the following changes: In equation (53) and in the last two displayed equations, $d_B(e_r^*)$ replaces $d_B$. On the right hand side of equation (53), $-(1-e_r^*)[1-e_a^*(1-e_h^*)]d_B'(e_r^*)(\partial e_r^*/\partial\gamma)$ is added. On the left hand side of equation (56), $+(1-e_r)(1-e_h)d_B'(e_r)(\partial e_r/\partial\gamma)$ is added. On the right hand side of the last displayed equation, within the first set of square brackets $-(1-e_r^*)(1-e_h^*)^2(p-c-d_S)d_B'(e_r^*)$ is added.

# Appendix D

This appendix provides the proof of the claim in §6 that: If an increase in auditing effort $e_a$ is accompanied by a decrease in the probability of passing the audit and an increase in the probability of a major harm to workers of the environment, then the increase in $e_a$ must be accompanied by a decrease in responsibility effort.

**Proof:** An increase in $e_a$ is accompanied by a decrease in the probability of passing the audit

$$1-\overline{e}_a[1-\tilde{e}_r(\overline{e}_a)][1-\tilde{e}_h(\overline{e}_a)] < 1-\underline{e}_a[1-\tilde{e}_r(\underline{e}_a)][1-\tilde{e}_h(\underline{e}_a)], \tag{57}$$

where $\overline{e}_a > \underline{e}_a$ and $(\tilde{e}_h(e_a),\tilde{e}_r(e_a))$ denotes the supplier's best response hiding and responsibility efforts under auditing effort $e_a$. An increase in $e_a$ is accompanied by an increase in the probability of a major harm to workers of the environment

$$[1-\tilde{e}_r(\overline{e}_a)](1-\overline{e}_a[1-\tilde{e}_h(\overline{e}_a)]) > [1-\tilde{e}_r(\underline{e}_a)](1-\underline{e}_a[1-\tilde{e}_h(\underline{e}_a)]). \tag{58}$$

Therefore,

$$0 > \underline{e}_a[1-\tilde{e}_r(\underline{e}_a)][1-\tilde{e}_h(\underline{e}_a)] - \overline{e}_a[1-\tilde{e}_r(\overline{e}_a)][1-\tilde{e}_h(\overline{e}_a)] > \tilde{e}_r(\overline{e}_a) - \tilde{e}_r(\underline{e}_a),$$

where the first inequality follows from (58) and the second from (57).■