Sourcing from emerging economies may yield direct cost savings, but companies often face greater risk of supplier responsibility problems due to many factors, with lax regulatory enforcement in these regions being one of them. Intuitively, to mitigate such risks, companies can design incentive schemes in sourcing contracts and invest in screening mechanisms for supplier sourcing. However, the relative effectiveness of these actions is often not known. To address this problem, we first develop a model that captures the supplier’s rational decision making. Under this model, the supplier responsibility risk is endogenized and can be influenced by various factors, including the supplier’s intrinsic ethical level. We then propose to use a delayed payment contract to mitigate supplier responsibility risk. When the supplier’s intrinsic ethical level is unobservable to the buyer, we study the optimal screening mechanism based on the delayed payment contract. Surprisingly, we find that, when the buyer anticipates a high cost impact as a result of supplier responsibility problems, the optimal screening mechanism collapses to a random selection. To remedy this problem, we further consider screening mechanisms involving voluntary or mandatory supplier certification. We show that both certification mechanisms can help mitigate supplier responsibility risk in certain cases. Specifically, a properly designed mandatory certification can help the buyer to achieve the first-best performance when the cost impact from supplier responsibility problems is high.

Key words: Ethical Sourcing, Supplier Responsibility, Delayed Payment, Screening Mechanism, Supplier Certification, Information Asymmetry.

History: Revised on May 23, 2014.
1. Introduction

As supply chains become more and more global, supply sources for many companies have reached more and more emerging economies. Sourcing from emerging economies has the advantage of lower operating and labor costs. In the past, sourcing executives would tradeoff such savings with other factors such as lead times, customs, disruptions, and inventory. However, in recent years, risks of supplier noncompliance with environmental and labor standards have been heightened to new levels. According to a recent SCM World survey of chief supply chain officers and executives (Lee et al. 2012), while supply shortages, logistics disruptions, and supplier financial failures remained high on the list of supply chain risks, more than half of the respondents were now concerned with risks of supplier responsibility problems. Recent fatal incidents of factory fire and building collapse in Bangladesh have prompted global companies to call for even greater efforts to manage risks associated with unethical practices on the part of their suppliers. In short, ethical and responsible supply sourcing has become increasingly important for supply chain executives.

Supplier responsibility problems can be viewed as a quality problem, but it differs from traditional quality problems. Violations of environmental or labor standards during the production process will cause damage to the buyer’s brand and reputation, but may not affect the physical quality of the product. Thus, traditional quality-based cost sharing mechanisms, such as price rebates or warranties (e.g., Reyniers and Tapiero 1995), are not applicable here. In some cases, even with a cost sharing mechanism in place, it may be difficult to enforce the penalty clause in the contract with small suppliers in emerging economies (see §4 for a detailed discussion).

To mitigate supplier responsibility risk, companies typically adopt two types of actions: 1) invest in better sourcing strategies that would use tighter screening and scrutiny of potential suppliers, so as to source from suppliers that are deemed to be less risky, coupled with contracts that align incentives of the suppliers to reduce the risk of noncompliance; and 2) on an ongoing basis, adopt direct control and monitoring. Supplier screening would require thorough evaluation of suppliers, and often may involve having a third party to certify suppliers to be in good standing in terms of compliance to social and environmental standards. The buyers would then source from the certified suppliers. Incentive alignment aims to induce suppliers to act more responsibly. For example, to encourage responsible behavior, companies can provide suppliers with rewards such as premier supplier status and investments in supplier development. Conversely, to discourage unethical behavior, companies can forfeit payments or reduce business volume (see Lee et al. 2012). Direct control and monitoring requires companies to have visibility of conditions of the supply chain.
and to take prompt action when things are found to be out of control.

In this paper, we first start with focusing on the first type of actions, i.e., how to design contracting and certification mechanisms to promote supplier responsibility. The challenge faced by supply chain executives is that it is not clear how these mechanisms can materially improve the buyer’s sourcing performance and whether the supplier responsibility risk can be effectively reduced. While these questions can be addressed partially through empirical testing, we seek in this paper to gain some insights of these issues through analytical models. Such models enable us to understand the interactions of different influencing factors, explain relevant empirical observations, and provide theoretical guidance for practitioners in the field. We will also capture the effect of the second type of actions, namely, monitoring and audits, as part of the contract in which the buyer can levy penalties through monitoring to detect violations.

Specifically, we consider a short-term sourcing relationship between a buyer and a supplier. The supplier is a small business entity located in emerging economies, such as garment factories in Asia or coffee farmers in Latin America. Because of lax regulatory enforcement in these regions, the supplier may engage in unethical activities when facing heightened cost pressure. We first develop a model that captures the economic tradeoffs faced by a supplier who contemplates whether or not to cut corners. A key feature of the model is that the supplier will incur a self-imposed “moral” cost when engaging in unethical activities. This moral cost can be viewed as a measure of the supplier’s intrinsic ethical level or propensity to engage in unethical activities.

The buyer, on the other hand, is genuinely concerned with supplier responsibility, such as established multinationals who have invested in programs (training, promotion, awareness, inspection, etc.) related to responsibility. For these companies, supplier noncompliance is a low probability, high impact event. For example, Bartlett et al. (2006) estimated that various supplier noncompliance issues cost the global furniture retailer IKEA millions of dollars in the past decades. Such cost impact is usually ignored in traditional sourcing models. In this paper, we propose an ethical sourcing model that explicitly accounts for the cost impact on the buyer as a result of supplier responsibility problems.

What makes the ethical sourcing problem challenging is that it is often impractical for the big multinationals to levy a stiff penalty on the small suppliers in emerging economies, except to terminate the business relationship. Among all the contracting forms we have explored, we find that a delayed payment contract can serve as a potential incentive instrument for this problem. In recent years, the prevailing trend in global procurement has been the so-called “open account,” i.e., the suppliers have to finance it totally and the buyer delays all payments until the production is done
and shipped (Hausman et al. 2010). When the suppliers are in weak financial positions, some buyers (e.g., Li and Fung and PCH International) often provide some form of trade financing such as raw material financing, which corresponds to various degrees of delayed payment (see §4 for a detailed discussion). Thus, it is quite common in practice for buyers to withhold payments to suppliers for potential physical quality problems (private communication with K.L. Lee, Executive Director of Esquel Corporation, 2013). Here we propose to treat supplier responsibility problems as a form of quality problems and use partial or total delayed payment to mitigate supplier responsibility risk.

Under the delayed payment contract, the buyer can withhold a portion of the payment which is subject to forfeiture if the supplier is found to be noncomplying during the contract period. This contract can be viewed as a special two-part payments with the penalty being the payment forfeit. Although the maximum penalty in this case is limited to the total payment, it could still generate strong enough incentive for small suppliers in emerging economies—forfeiting the final payment could potentially put them in serious financial hardship. We show that, when the cost stake in supplier responsibility is high, the buyer should delay full payment and offer the supplier a price premium, both of which are in accord with the current industry practice of open account (i.e., delaying 100% of the payment) and using price premiums to promote supplier responsibility (see Lee et al. 2012).

When the supplier’s intrinsic ethical level is unobservable to the buyer, we study the optimal screening mechanism based on the delayed payment contract. Surprisingly, we find that the classic monopolistic screening mechanism (e.g., see Varian 1992) does not always apply to our ethical sourcing problem. When the cost stake in supplier responsibility is low (e.g., in a regime where traditional sourcing operates), the classic screening mechanism works and the buyer can offer different payment terms to separate suppliers with different ethical levels. However, when the cost stake in supplier responsibility is high (e.g., in a regime where ethical sourcing operates), the classic screening mechanism does not work and it is optimal for the buyer to offer a pooling contract to all suppliers. In this case, the optimal screening mechanism collapses to a random selection. This result shows the inherent difficulty in using screening contracts to distinguish different supplier types in ethical sourcing.

To remedy this problem, we further study two screening mechanisms involving supplier certification. In the first mechanism termed “voluntary certification,” the buyer offers a contract menu for both certified and uncertified suppliers. In the second mechanism termed “mandatory certification,” the buyer only contracts with certified suppliers. We show that a properly designed voluntary certification can help separate suppliers with different ethical levels (no informational
rent is needed), and it reduces supplier responsibility risk when the cost stake in supplier responsibility is low. However, voluntary certification also results in higher sourcing cost for the buyer when the cost stake in supplier responsibility is high. On the other hand, a properly designed mandatory certification can help the buyer to shut out suppliers with low ethical level and achieve the first-best performance when the cost stake in supplier responsibility is high. This explains why Starbucks sets a very high bar for certification in their Coffee and Farmer Equity (C.A.F.E.) Practices and why it strives to achieve sourcing 100% from C.A.F.E.-certified suppliers (www.starbucks.com/responsibility/global-report).

In this paper we make three main contributions to the literature. First, unlike the existing models that treat supplier responsibility risk as exogenously given, we develop a model that endogenizes the supplier responsibility risk and also captures the heterogeneity among suppliers through their intrinsic ethical levels. This approach enables us to understand the interactions of different influencing factors and to design incentive schemes to mitigate supplier responsibility risk. Second, we propose to treat supplier responsibility problems as a form of quality problems and use a delayed payment contract to mitigate supplier responsibility risk. When the supplier’s intrinsic ethical level is unobservable to the buyer and when the buyer anticipates a high cost impact as a result of supplier responsibility problems, we find that the optimal screening mechanism based on the delayed payment contract collapses to a random selection. To our knowledge, this is the first result to show that the classic screening mechanism may not work in ethical sourcing. Third, we further study screening mechanisms involving voluntary or mandatory supplier certification. We show that both certification mechanisms can help mitigate supplier responsibility risk in certain cases. Specifically, a properly designed mandatory certification can help the buyer to achieve the first-best performance when the cost impact from supplier responsibility problems is high. These results provide theoretical support for the current industry practice in ethical sourcing.

The rest of this paper is organized as follows. We provide a detailed literature review in §2. We then develop our supplier responsibility risk model in §3. Building on the supplier responsibility risk model, we present our analysis of contracting mechanisms in §4 and certification mechanisms in §5. §6 contains a discussion of other incentive schemes and our concluding remarks. All proofs are presented in the Appendix.

2. Literature Review

Our paper is closely related to two streams of research in the literature. The first stream of research concerns issues in sustainable and socially-responsible supply chains. For instance, motivated by
the ITC’s e-Choupal initiative, Devalkar et al. (2011) modeled the sustainable sourcing problem as an integrated optimization problem of procurement, processing, and trade of commodities. Chen et al. (2013) further studied the effect of supplier training on the buyer’s procurement performance. Drawing inspiration from the Starbucks C.A.F.E. Practices, Lewis et al. (2012) proposed a dynamic mechanism to ensure a long-term high quality supply when information asymmetry exists for both players along a supply chain. Plambeck and Taylor (2012) studied how a supplier’s evasion effort can negatively impact the effectiveness of a buyer’s auditing efforts. Guo et al. (2013) considered the effect of downstream competition and consumer awareness on selection decisions between responsible and normal suppliers. To understand the impact of certain regulatory policies on a firm’s disclosure decisions, Kalcanci et al. (2013) compared the effect of voluntary and mandatory disclosures on measures of social and environmental performance. Kim (2013) further studied the interplay between supplier voluntary disclosure and regulatory inspection policies.

Three modeling features set our paper apart from this growing literature. First, we endogenize the supplier responsibility risk by modeling the economic tradeoffs faced by a supplier contemplating unethical activities. We also assume the supplier faces a random production cost, which is different from the deterministic, quantity-dependent production cost models studied by Devalkar et al. (2011) and Chen et al. (2013). Second, we assume the supplier has an intrinsic ethical level that may or may not be fully observed by the buyer. This assumption enables us to model the ethical sourcing problem as a monopolistic screening problem. Third, we consider a short-term buyer-supplier relationship, with the buyer being the dominant player, which we believe captures the essence of business relationships between big multinationals and small suppliers in emerging economies. Under this model setup, we use the Stackelberg game framework, rather than the simultaneous-move Nash equilibrium framework used in other papers (e.g., Lewis et al. 2012 and Plambeck and Taylor 2012), and we do not consider the effect of competition between buyers in our model (see Guo et al. 2013 for a model of this effect).

The second stream of research related to our paper is the literature on quality control in supply chains. Most papers in this literature assume that there exist some cost sharing mechanisms between the buyer and the supplier when a product is found to be defective, such as price rebates or warranties (e.g., Reyniers and Tapiero 1995, Baiman et al. 2000, Lim 2001, Balachandran and Radhakrishnan 2005, Zhu et al. 2007, and Chao et al. 2009). Hwang et al. (2006) studied the effect of vendor certification on inducing a supplier to choose a high-quality production mode. In our problem, supplier certification serves as a screening mechanism to filter out suppliers with low ethical level. The work most closely related to ours is Babich and Tang (2012) and Rui
and Lai (2012). Motivated by recent industry product recall incidents, Babich and Tang (2012) proposed using a deferred payment mechanism to deter foreign suppliers from engaging in product adulteration. Their model was further extended by Rui and Lai (2012) to incorporate multiple-unit procurement quantities and positive leadtimes. We also consider a delayed payment mechanism in our problem. However, our model differs from their product adulteration models in the following aspects.

First, we study a monopolistic screening problem that aims to separate different supplier types under information asymmetry, whereas the contract mechanism in Babich and Tang (2012) and Rui and Lai (2012) is designed to deter the hidden action of product adulteration. Second, unethical activities (such as not paying minimum wages to workers or operating with excessive overtime hours) may go undetected in our model, whereas adulterated products would eventually be detected and would result in a liability cost for the buyer. Third, the production cost is random in our model, whereas the production cost is deterministic in Babich and Tang (2012) and Rui and Lai (2012). Fourth, we assume no interest rate discounting, whereas there is an interest rate and a deferred time variable in the product adulteration models. In addition, we do not explicitly model inspection as a decision variable in our problem, whereas Babich and Tang (2012) and Rui and Lai (2012) considered the case in which the buyer can determine whether or not to inspect the product.

Finally, our work contributes to the broader literature concerning supply chain sourcing and procurement. We refer readers to Elmaghraby (2000) and Cachon (2003) for comprehensive reviews of this extensive literature. Our paper is particularly related to the body of work on sourcing strategies under information asymmetry (with the buyer being the contract designer who lacks information). Most papers in this category assume that the suppliers are differentiated by their respective private cost information (e.g., Cachon and Zhang 2006, Chen 2007, Li and Debo 2009, Zhang 2010, Kim and Netessine 2013, and Bolandifar et al. 2013). In our paper, we assume that the suppliers, sharing a common production cost distribution, are differentiated by their intrinsic propensity to engage in unethical activities; information about this propensity (i.e., the supplier’s ethical level) is unobservable to the buyer, but plays an important role in determining the cost risk faced by the buyer. Moreover, in our problem the buyer offers a contract before the cost realization, and the supplier takes action after observing the realized production cost. This sequence of events is different from the mixed asymmetric information and moral hazard problem studied by Bolandifar et al. (2013), where both parties make decisions before the random demand realization.
3. Supplier Responsibility Risk Model

Consider a stylized sourcing problem in which a buyer sources one unit of a product from a supplier. For example, the total order quantity under a sourcing contract can be viewed as a single unit in our problem. The supplier’s production cost for such a unit can be affected by many factors. For example, supply disruption, random yield or capacity constraint can result in uncertain costs in production. The prices of raw material commodities can fluctuate widely. Labor shortages can also lead to unexpected wage increases. For these reasons, we model the supplier’s production cost as a nonnegative random variable. Let $C$ denote the (random) production cost, with $f(\cdot)$ being the density function and $F(\cdot)$ the cumulative distribution function (CDF). The complementary CDF is denoted as $\bar{F}(\cdot) = 1 - F(\cdot)$. The mean production cost is given by $m = E\{C\} = \int_0^\infty x f(x) \, dx$.

If the supplier’s realized production cost is observable to the buyer, then the sourcing problem becomes trivial as the buyer can simply use a cost-plus model, i.e., the actual production cost plus a fixed profit margin. This kind of cost transparency, however, is rarely available in practice. Thus, we shall focus below on the case in which the buyer knows only the supplier’s production cost distribution, but not the realized production cost.

We assume that the supplier is not perfectly ethical and may engage in unethical activities when facing heightened cost pressure. These activities can help the supplier lower the production cost by $\alpha C$ (with $0 < \alpha < 1$). If the buyer monitors all of the supplier’s activities, from payroll to pollution emissions, then there are fewer opportunities for the supplier to cut corners and the rate $\alpha$ will be small. According to a recent SCM World survey (Lee et al. 2012, p. 30), only a quarter of the surveyed companies were able to monitor violations of both social and environmental standards in their extended supply networks. Thus, if the buyer can increase its preventive monitoring efforts, the supplier’s monetary gains from engaging in unethical activities can be further reduced.

The supplier’s unethical activities can affect either the physical quality or the production process of the product. Violations of certain environmental or labor standards during the production process may not affect the physical quality of the product, but will tarnish the buyer’s brand and reputation if the violations are discovered by the general public. For this reason, unethical activities during the production process should be treated as a form of “soft” quality defects. Specifically, we assume that the supplier’s unethical activities can be discovered by the general public with a probability of $\varphi$ (with $0 < \varphi < 1$). The public discovery probability can be linked to the level of scrutiny from various sources, such as local governments, nongovernmental organizations (NGOs), internal whistle blowers, and actual accidents. Similar assumptions can also be found in the crime
and punishment models of Becker (1968) and Kaplow and Shavell (1994).

Unethical activities, if discovered, have punitive consequences for the supplier. Let us assume that the supplier will incur a monetary penalty cost of \( b \) (with \( b \geq 0 \)). Such a penalty cost can be viewed as a fine levied by the local government or a direct cost to rectify the problem (such as installing safety systems or equipment upgrades, etc.). We further assume that the supplier will incur a self-imposed “moral” cost of \( e \) (with \( e \geq 0 \)) whenever it engages in unethical activities. Such a moral cost could be the disutility from committing a harmful act to the downstream buyer or end consumers.\(^1\) Different suppliers may experience different disutility from committing such an act. This individual-specific moral cost can be viewed as the supplier’s intrinsic ethical level: When \( e = 0 \), the supplier is basically shameless; and when \( e = \infty \), the supplier is perfectly ethical.

Clearly, according to our model, the supplier would engage in unethical activities if and only if \( \alpha C > \varphi b + e \). In other words, the monetary gains from unethical activities must outweigh the expected total penalty costs associated with such activities. Thus, prior to the production cost realization, the probability of having supplier responsibility problems is given by

\[
\Pr\{\alpha C > \varphi b + e\} = \tilde{F}\left(\frac{\varphi b + e}{\alpha}\right).
\]

(1)

From this expression, we can obtain several quick insights on how to mitigate supplier responsibility risk.

**Increasing inspection efforts.** According to the above expression, the supplier responsibility risk can be mitigated by either increasing public discovery efforts (resulting in a larger \( \varphi \) value) or increasing preventive monitoring efforts (resulting in a smaller \( \alpha \) value). These are usually the first measures taken by companies to directly control supplier responsibility risk in practice. For example, Locke et al. (2007) reported that Nike had greatly increased monitoring of its supplier factories over the past several decades. Apple also reported that it had scaled up inspection efforts by 80% in 2012 (www.apple.com/supplierresponsibility).

**Lobbying for tighter regulatory control.** Another way to reduce supplier responsibility risk is to impose and enforce stiffer sanction costs for irresponsible supplier behaviors (see Locke 2013). In most developed economies, discovery of unethical activities can result in the supplier being put out of business, which amounts to a sufficiently large penalty cost \( b \). Thus, supplier responsibility risk is usually low in those regions. Toffel et al. (2013) found that supplier factories are more likely

\(^1\)There is an extensive behavioral economics literature on other-regarding preferences (see Cooper and Kagel 2013 for a comprehensive survey). Under such preferences, agents are not just selfish profit-maximizers; they also care about social welfare and fairness. As a result, an unethical activity that goes against the social welfare may cause disutility to the agent who commits it.
to comply with global labor standards when they are located in states that have highly protective labor regulation and high levels of press freedom. On the other hand, developing economies tend to have more lax regulatory enforcement and the sanction cost is much smaller compared with that in the developed economies. As a result, according to expression (1), the supplier responsibility risk in the developing economies becomes much higher than that in the developed economies.

**Providing supplier education.** The buyer also can invest in educating the supplier. For example, the buyer can make the supplier more aware of the magnitude of penalty cost. Education can also influence the supplier to increase its ethical level. This is not far-fetched, as supplier training often involves conveying the importance of responsible production and ethical practices. For example, Li and Fung has been setting up the Fung Academy to help train suppliers to improve their environmental and social practices (see www.funggroup.com/eng/knowledge/academy.php).

**Improving supplier production efficiency.** In a field study with Nike suppliers, Locke et al. (2007) observed that, when Nike helped suppliers to better schedule their work and to improve quality and efficiency, the number of supplier noncompliance incidents fell significantly. More recently, Distelhorst et al. (2014) found that adoption of lean manufacturing produced a 15% reduction in serious labor violations on average in Nike supplier factories. This lean production concept is similar to helping the supplier reduce its production costs through efficiency improvement. To see this point, let \( z (z \geq 1) \) be a measure of the production efficiency improvement. Given an improvement level \( z \), let us assume that the supplier’s production cost reduces to \( C/z \), and the mean production cost reduces to \( m/z \). With production efficiency improvement \( z \), the probability of having supplier responsibility problems becomes

\[
\Pr \left\{ \frac{\alpha C}{z} > \varphi b + e \right\} = \bar{F} \left( \frac{z(\varphi b + e)}{\alpha} \right).
\]

From the above expression, we observe that increasing \( z \) achieves the same risk-mitigating effect as does decreasing \( \alpha \) (i.e., increasing preventive monitoring efforts), but also mitigates risk more strongly than does increasing \( \varphi \) (i.e., increasing public discovery efforts). Moreover, increasing \( z \) yields the additional benefit of lowering the mean production cost, so the resulting sourcing cost for the buyer would also be lowered.\(^2\)

Besides the above strategies, companies can also invest in contracting and screening mechanisms to mitigate supplier responsibility risk. In what follows, we shall build on the above model to study

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\(^2\)Walmart reported in its 2010 Global Sustainability Report that they implemented a new supplier development program that transitions factory auditing to certified companies and focuses purely on improving supplier factories (www.walmartstores.com/sustainability), which is in accord with our analysis here that helping suppliers improve production efficiency can mitigate supplier responsibility risk.
the effectiveness of these mechanisms. To facilitate our subsequent analysis, from expression (1), we define \( u(e) = (\varphi b + e)/\alpha \), where \( u(e) \) represents the base threshold for the supplier to breach into unethical conduct. We further make the following technical assumption throughout the paper:

**Assumption 1** The cost density function \( f(x) \) is differentiable with \( f'(x) \leq 0 \) for \( x \geq u(0) \).

For a normal cost density function, the above assumption implies that the supplier responsibility risk is less than 50%. While it is difficult to infer the actual rate at which noncompliance problems occur in practice, we believe it is unlikely that the supplier responsibility risk would go beyond what is implied by the above assumption (i.e., greater than 50%). Businesses are increasingly pursuing “zero-tolerance” policies in supply management, so that repeated violators may not stay as a supplier for long (see, for example, Devnath and Dudley 2012). Indeed, the SCM World survey showed that about 50% of the executives claimed that they would immediately terminate the supplier relationship upon discovery of violations (Lee et al. 2012). Moreover, for most companies, they have also stepped up their inspection efforts, such that the base threshold \( u(0) \) becomes significantly high in our model. Apple, for example, has increased the number of audits of their suppliers from 39 in 2007, to 393 in 2012 (www.apple.com/supplierresponsibility). Thus, given the heightened awareness of supplier responsibility problems in recent years, we believe that the above assumption is reasonable and justifiable.

4. Contracting in Ethical Sourcing

In this section, we study contracting mechanisms for promoting supplier responsibility. Theoretically, the buyer can offer a supplier a contract with two-part payments: the first part being a fixed payment and the second part a penalty term contingent on whether or not the supplier breaches into unethical conduct during the contract period. A penalty set sufficiently high can deter the supplier from engaging in any unethical activities. Unfortunately, it is often impractical to enforce such a stiff penalty on small suppliers in emerging economies.\(^3\) Among other possible contracting forms, we find that a delayed payment contract can serve as a potential incentive instrument for promoting supplier responsibility.

Traditionally, all international transactions required letter of credit. With letter of credit, the supplier is guaranteed of payment before they commence production, which is equivalent to 100% pre-payment to the supplier. In recent years, less and less global companies are using letter of credit.\(^4\)

\(^3\)From our conversations with Starbucks executives, we learned that levying a penalty on a noncomplying coffee farmer in an emerging economy either was not enforceable, or it looked very bad from the public relations perspective—it gave the impression that a big guy was bullying a small guy, even though the penalty was for a good cause.

\(^4\)
to make procurements (see the PCH International case, Tung and Lee 2008). The prevailing trend is open account, i.e., the suppliers have to finance it totally and the buyer delays all payments until the production is done and shipped (Hausman et al. 2010). A recent industry report by OPUS and SWIFT (2013, p. 7) estimated that about 82% of global imports in 2011 were based on open account and 18% on letter of credit, and that the use of letter of credit will continue to decline to about 9% by 2020. When some suppliers are in weak financial positions, and could not get financing from financial institutions for the production, some buyers (e.g., Li and Fung and PCH International) often provide some form of trade financing. But such financing is not 100%, as it could be in the form of material financing (which constitutes a fraction of the total finance invoice). In this case, the material financing equates to a partial pre-payment and the remainder being delayed payment.

It is also quite common in practice for buyers to withhold payments to suppliers for potential physical quality problems, to be released only after quality checks have been completed and the quality has been found to be acceptable (private communication with K.L. Lee, Executive Director of Esquel Corporation, 2013). Here we propose to treat supplier responsibility problems as a form of quality problems and use partial or total delayed payment to mitigate supplier responsibility risk. Specifically, the buyer can withhold a portion of the payment that is subject to forfeiture if the supplier is found to be noncomplying during the contract period. This mechanism can be viewed as special two-part payments with the penalty being the payment forfeit. Although the maximum penalty in this case is limited to the total payment, it could still generate strong enough incentive for small suppliers in emerging economies—forfeiting the final payment could put them in serious financial hardship.

There is also a traceability issue associated with the delayed payment contract. While full traceability provides the strongest incentive power, it is generally impractical to implement, especially with small suppliers in emerging economies. We consider below a more practical case with limited traceability. Specifically, the buyer cannot impose additional penalty on the supplier if noncompliance is discovered after the final payment transaction. Thus, the public discovery probability by the time when the final payment is tendered is given by $\beta \varphi$, where $0 < \beta \leq 1$ is the conditional probability of the noncompliance problem being discovered by the general public before the final payment transaction. In addition, we assume that the buyer can implement a private discovery process for supplier noncompliance problems before the final payment transaction. Thus, the effective discovery probability that is linked to the delayed payment is given by $\theta = \theta(\varphi, \beta, \eta) = \beta \varphi + \eta(1 - \beta \varphi)$, where $0 \leq \eta \leq 1$ is the buyer’s private discovery probability. Thus, depending on the buyer’s private inspection and audit efforts (where $\eta$ increases as such
efforts increase), the effective discovery probability $\theta$ can be either greater or less than the eventual discovery probability $\varphi$ by the general public. Moreover, we assume that the buyer’s private scrutiny does not prevent a violation from being discovered by the general public ($\eta$ and $\varphi$ are independent), nor does it reduce the severity of the public penalties on either parties.\footnote{We note that some companies may also self-report certain statistics of supplier noncompliance problems at the aggregate level in their annual social responsibility report. But these aggregate statistics do not reveal the details of each violation incidents occurred, so they should have little effect on the public discovery process and the associated cost impact of a specific incident.}

Based on the above model assumptions, we assume the sequence of events of the contracting mechanism is given as follows. 1) At the beginning of the contracting stage, the buyer offers a contract menu. 2) The supplier then self-selects a contract that maximizes its expected payoff. When the supplier accepts a contract, we assume that the supplier requires a minimum reservation profit; without loss of generality, we normalize such a minimum reservation profit to be zero. 3) After entering the contract, the supplier observes the cost realization and decides whether to cut corners or not. Finally, 4) if the supplier is found engaging in unethical activities, the buyer incurs a (large) cost. An illustration of the sequence of events is provided in Figure 1.

\begin{figure}[h]
\begin{center}
\begin{tabular}{cccc}
Buyer offers a & Supplier self- & Supplier observes & Buyer incurs a (large) 
contract menu & selects a contract & cost realization and & cost if the supplier is 
(or certification & (or obtains a & decides whether to cut & found engaging in 
requirements) & contract) & corners or not & unethical activities \\
\hline Time 0 & Time 1 & Time 2 & Time 3 \\
\end{tabular}
\end{center}
\caption{Timeline of sequence of events.}
\end{figure}

Formally, let $p$ be the total payment and $\gamma p$ the delayed payment, where $\gamma$ is the delay term. Without loss of generality, we assume $0 \leq \gamma \leq 1$. Under the delayed payment mechanism, the supplier would engage in unethical activities if and only if $\alpha C > \theta \gamma p + \varphi b + e$. Thus, prior to the production cost realization, the supplier responsibility risk is given by

$$
Pr\{\alpha C > \theta \gamma p + \varphi b + e\} = \bar{F} \left( \frac{\theta \gamma p + \varphi b + e}{\alpha} \right) = \bar{F} \left( u(e) + \frac{\theta \gamma p}{\alpha} \right).
$$

(2)

From the above expression, it is clear that the buyer can increase $\gamma p$ to reduce supplier responsibility risk. The supplier’s expected profit under the delayed payment mechanism can be written as

$$
r(p, \gamma|e) = p - m + \int_{u(e)+\theta \gamma p/\alpha}^{\infty} \left[ \alpha x - \theta \gamma p - \varphi b - e \right] f(x) dx.
$$

(3)

To ensure the supplier’s participation, the buyer needs to set $r(p, \gamma|e) \geq 0$ as a constraint. It can be verified that $\partial r(p, \gamma|e)/\partial p = 1 - \theta \gamma \bar{F} \left( u(e) + \theta \gamma p/\alpha \right) > 0$. Thus, $r(p, \gamma|e)$ is increasing in
p. Also, note that \( r(0, \gamma|e) < 0 \) and \( r(\infty, \gamma|e) = \infty \). Hence, there exists a unique \( p_0(\gamma|e) > 0 \), such that \( r(p_0(\gamma|e), \gamma|e) = 0 \), where \( p_0(\gamma|e) \) is the minimum participation payment for the supplier given a delay term \( \gamma \). We can thus replace the supplier participation constraint \( r(p, \gamma|e) \geq 0 \) with \( p \geq p_0(\gamma|e) \).

**Lemma 1** The minimum participation payment \( p_0(\gamma|e) \) is less than the mean production cost \( m \). Moreover, \( p_0(\gamma|e) \) is increasing in \( e, \gamma \), and \( \eta \).

The intuition of the above lemma is that the supplier can cut corners to reduce its production cost, and thus it can accept a payment less than the mean production cost. This result provides a quick explanation for why some suppliers, such as those who operated unsafe factories in Bangladesh, were willing to do a job even though the buyer’s offered prices were lower than the perceived production cost (Srivastava 2013).

### 4.1 The Full-Information Benchmark

Let us first consider the full information case in which the buyer has full knowledge of the supplier’s intrinsic ethical level. When the supplier’s unethical activities are discovered by the general public, we assume the buyer incurs a cost of \( k \) (with \( k \geq 0 \)). Such a cost can be a demand loss, a product recall cost, or a brand damage cost for the buyer.\(^5\) The buyer’s sourcing problem can thus be formulated as

\[
\min_{p \geq p_0(\gamma|e), 0 \leq \gamma \leq 1} \left\{ p + (\varphi k - \theta \gamma p) \bar{F} \left( u(e) + \frac{\theta \gamma p}{\alpha} \right) \right\}.
\] (4)

Different buyers may have different cost stakes in supplier responsibility problems. If a buyer does not care about the supplier responsibility problems, we can set \( k = 0 \) and the problem becomes a traditional sourcing problem. On the other hand, if a buyer cares a lot about supplier responsibility problems, we can set \( k \) to a substantially high value and the problem becomes an ethical sourcing problem. Aware of this difference among different buyers, we shall focus on obtaining insight on how different \( k \) values affect the optimal sourcing decisions.

Let \((p^{**}, \gamma^{**})\) denote the optimal solution to the above problem. It can be verified that the above objective function is convex in \( p \) for \( \theta \gamma p \leq \varphi k \). Let \( p^0(e) = p_0(1|e) \), i.e., \( p^0(e) \) is the minimum participation payment when \( \gamma = 1 \). Further define

\[
k_0(e) = \frac{\theta p^0(e)}{\varphi} + \frac{\alpha(1 - \theta \bar{F}(u(e) + \theta p^0(e)/\alpha))}{\varphi \theta f(u(e) + \theta p^0(e)/\alpha)}.
\] (5)

\(^5\)According to the SCM World survey (Lee et al. 2012), 71% of the 1281 chief supply chain officer respondents associated investing in social and environmental responsibility with “create a positive customer image and enhance brand equity” and only 17% associated such investment with “increase sales revenue.” Thus, the cost \( k \) appears to be more related to the brand equity cost than to the demand loss cost in practice.
We can establish the following results:

**Proposition 1** Under the full information case, the following holds:

(a) If $k \leq k_0(e)$, the supplier receives the minimum participation payment and earns zero profit. Specifically, if $k < \theta p^0(e)/\varphi$, then $0 \leq \gamma^{**} < 1$, $p^{**} = p_0(\gamma^{**}|e)$, and the resulting supplier responsibility risk decreases as $k$ increases. If $\theta p^0(e)/\varphi \leq k \leq k_0(e)$, $\gamma^{**} = 1$, $p^{**} = p^0(e)$, and the resulting supplier responsibility risk remains constant as $k$ increases.

(b) If $k > k_0(e)$, the supplier receives a price premium and earns positive profit. Specifically, $\gamma^{**} = 1$, the first-order condition yields a unique optimal payment $p^{**} > p^0(e)$, and the resulting supplier responsibility risk decreases as $k$ increases.

Moreover, the thresholds $p^0(e)$ and $k_0(e)$ are both increasing in $e$, and the optimal delay term $\gamma^{**}$ is decreasing in $e$.

The above proposition shows that, when the cost stake in supplier responsibility is high, the buyer should delay full payment and offer the supplier a price premium. Both model predictions are in accord with the current industry practice of open account (i.e., delaying 100% of the payment) and using price premiums to promote supplier responsibility (see Lee et al. 2012). Moreover, the optimal delay term is decreasing in the supplier ethical level, suggesting that the buyer can potentially leverage on this property to design screening contracts based on different delay terms. We will investigate this idea in the next section.

### 4.2 Screening Contracts under Asymmetric Information

Let us now consider an asymmetric information case. Suppose that there are two types of suppliers, one with a high ethical level $e_H$ and the other with a low ethical level $e_L$ ($e_H > e_L$). A supplier belongs to the High type with probability $\pi$ and the Low type with probability $1 - \pi$ (with $0 < \pi < 1$). The buyer is assumed to have knowledge of the distribution probability $\pi$, but not the actual ethical level of a supplier.

If the buyer can infer the supplier’s intrinsic ethical level from its production cost information (e.g., a low-cost supplier may be more likely to engage in unethical activities), the ethical sourcing problem becomes a simple supplier selection problem in which the buyer makes tradeoff between cost and ethical risk. Moreover, in such a case, if the low-cost supplier is strategic enough, it can always mimic the High type by quoting a high cost, which makes the cost information uninformative of the supplier’s ethical level.
Therefore, in what follows we shall assume that the two supplier types face the same production cost distribution. As a result, the buyer cannot simply use the production cost information to infer supplier types. This assumption also enables use to isolate the effect of cost uncertainties that are out of the supplier’s control and to focus directly on the supplier’s intrinsic behaviors. We further assume different supplier types are subject to the same parameters in the supplier responsibility risk model, which is reasonable because the suppliers are often located in similar government regimes and many buyers increasingly use common third-party auditors, such as the Environment Defense Fund or the Fair Labor Association.6

As alluded in the previous section, the buyer can potentially design a screening mechanism to separate the two types based on different delay terms. Below we investigate the optimal design of such a screening mechanism. Let \( p_a(\gamma|e) \) be the point on the supplier iso-profit curve \( r(p,\gamma|e) = a \). From (3), we can show that the following holds on an iso-profit curve:

\[
\frac{dp_a(\gamma|e)}{d\gamma} = \frac{\theta p_a(\gamma|e)\bar{F}(u(e) + \theta \gamma p_a(\gamma|e)/\alpha)}{1 - \theta \gamma \bar{F}(u(e) + \theta \gamma p_a(\gamma|e)/\alpha)} > 0.
\]

Given an arbitrary point \((p,\gamma)\), with \( p_a(\gamma|e_H) = p_a'(\gamma|e_L) = p \). Because \( \bar{F}(u(e) + \theta \gamma p/\alpha) \) is decreasing in \( e \), it follows that \( dp_a(\gamma|e_H)/d\gamma < dp_a'(\gamma|e_L)/d\gamma \). In other words, the Low type has a steeper slope on the iso-profit curve than does the High type. This implies the following result:

**Lemma 2** Suppose that \( r(p,\gamma|e_H) = r(p',\gamma'|e_H) \) and \( r(p,\gamma|e_L) = r(p'',\gamma'|e_L) \). Then the following holds: if \( \gamma' < \gamma \), then \( p'' < p' < p \); otherwise, if \( \gamma' > \gamma \), then \( p < p' < p'' \).

![Figure 2: Illustration of iso-profit curves for the two types.](image)
The above result is essentially the single-crossing property of the iso-profit curves of the two types (see Figure 2 for an illustration). Let \( G(p, \gamma|e) = p + (\varphi k - \theta \gamma p) \bar{F} (u(e) + \theta \gamma p/\alpha) \). The buyer’s sourcing problem under a screening contract menu can be formulated as follows:

\[
\min_{(p_H, \gamma_H), (p_L, \gamma_L)} \left\{ \pi \cdot G(p_H, \gamma_H|e_H) + (1 - \pi) \cdot G(p_L, \gamma_L|e_L) \right\}
\]

s.t.

\[
r(p_H, \gamma_H|e_H) \geq 0 \quad \text{(participation condition for the High type)},
\]

\[
r(p_L, \gamma_L|e_L) \geq 0 \quad \text{(participation condition for the Low type)},
\]

\[
r(p_H, \gamma_H|e_H) \geq r(p_L, \gamma_L|e_L) \quad \text{(incentive compatibility for the High type)},
\]

\[
r(p_L, \gamma_L|e_L) \geq r(p_H, \gamma_H|e_L) \quad \text{(incentive compatibility for the Low type)},
\]

\[
0 \leq \gamma_H, \gamma_L \leq 1.
\]

It can be shown that the participation condition for the Low type and the incentive compatibility condition for the High type are not binding, and thus they can be removed. Moreover, we can show that the incentive compatibility condition for the Low type is binding (the detailed derivation is provided in the proof of Proposition 2 in the Appendix). Thus, the problem can be simplified as follows:

\[
\min_{(p_H, \gamma_H), (p_L, \gamma_L)} \left\{ \pi \cdot G(p_H, \gamma_H|e_H) + (1 - \pi) \cdot G(p_L, \gamma_L|e_L) \right\}
\]

s.t.

\[
r(p_H, \gamma_H|e_H) \geq 0,
\]

\[
r(p_L, \gamma_L|e_L) = r(p_H, \gamma_H|e_L),
\]

\[
0 \leq \gamma_H, \gamma_L \leq 1.
\]

We note that a pooling contract with \( p_H = p_L \) and \( \gamma_H = \gamma_L \) is a feasible solution to the above problem. Thus, intuitively, the buyer can achieve lower sourcing cost by offering screening contracts for different types. Recall from Proposition 1 that, when the cost stake \( k \) is sufficiently large, the buyer is willing to pay the supplier a price premium, and thus the participation constraint for the High type need not be binding in our problem. For this reason, our problem differs from the classic monopolistic screening problem (see Varian 1992). This nuanced difference will become evident in the results below.

Let \( p^0_H \) be the shorthand of \( p^0(e_H) \) as defined in §4.1, i.e., \( p^0_H \) is the minimum payment to the High type when \( \gamma = 1 \). Further define

\[
k_1 = \frac{\theta p^0_H}{\varphi} + \frac{\alpha(1 - \theta \bar{E}_i \{ F(u(e_i) + \theta p^0_H/\alpha) \})}{\varphi \theta \bar{E}_i \{ f(u(e_i) + \theta p^0_H/\alpha) \}},
\]

\[
k_2 = \frac{\theta p^0_H}{\varphi} + \frac{\alpha(1 - \theta \bar{F} (u(e_L) + \theta p^0_H/\alpha))}{\varphi \theta f(u(e_L) + \theta p^0_H/\alpha)},
\]

17
where it is easy to verify that $k_2 < k_1$. Figure 3 provides an illustration of the definition of $p^0_H$ and the results established in the proposition below.

**Proposition 2** The optimal contract menu $\{(p_L^*, \gamma_L^*), (p_H^*, \gamma_H^*)\}$ satisfies the condition: $\gamma_L^* \leq \gamma_H^*$ and $p_L^* \leq p_H^*$. The following holds:

(a) If $k < \theta p_0^H / \varphi$, a type-separating contract menu is optimal. Specifically, $\gamma_L^* < \gamma_H^*$ and $p_L^* < p_H^*$, where $r(p_H^*, \gamma_H^* | e_H) = 0$ and $(p_L^*, \gamma_L^*) = \arg\min_{r(p, \gamma | e_L) = r(p_H^*, \gamma_H^* | e_L)} G(p, \gamma | e_L)$. In addition, $\gamma_H^* > \gamma_H^{**}$, and $p_H^* > p_H^{**}$, where $(p_H^{**}, \gamma_H^{**})$ is the first-best solution under full information. The High type earns zero profit as it does under full information, and the Low type earns a positive informational rent. The resulting responsibility risk is lower than that under full information for both types.

(b) If $k \geq \theta p_0^H / \varphi$, a pooling contract is optimal. Specifically, $\gamma_L^* = \gamma_H^* = 1$ and $p_L^* = p_H^* \geq p_0^H$. If $\theta p_0^H / \varphi \leq k \leq k_1$, the High type earns zero profit and its responsibility risk remains the same as that under full information; if $k > k_1$, the High type earns more profit and its responsibility risk is lower than that under full information. On the other hand, if $\theta p_0^H / \varphi \leq k \leq k_2$, the Low type earns more profit and its responsibility risk is lower than that under full information; if $k > k_2$, the Low type earns less profit and its responsibility risk is higher than that under full information.

Moreover, $\theta p_0^H / \varphi$ is increasing in $\eta$. Thus, if the buyer increases its private inspection and audit efforts, the screening contract menu becomes optimal for larger $k$ values.
From the above proposition, we obtain the following interesting insight. On the one hand, when the cost stake in supplier responsibility is low (i.e., \( k < \frac{\theta p^0_H}{\varphi} \)), our problem is essentially the same as the classic monopolistic screening problem. Thus, the optimal mechanism possesses the usual features of a monopolistic screening mechanism, i.e., achieving efficiency for one type and having a distortion for the other type (see Varian 1992). The difference here is that the undesired (Low ethical) type gets a positive informational rent. On the other hand, when the cost stake in supplier responsibility is high (i.e., \( k \geq \frac{\theta p^0_H}{\varphi} \)), which is the main premise for ethical sourcing, it is optimal to offer a pooling contract with the maximum delay term allowed by industry practice. In this case, the optimal screening mechanism collapses to a random selection. This result shows the inherent difficulty in using screening contracts to distinguish different supplier types in ethical sourcing. Given the heightened awareness of supplier responsibility problems in recent years, the prevalent industry practice of open account (i.e., delaying 100% of the payment) seems to corroborate with this theoretical prediction.

The intuition of the pooling contract result is as follows: When the cost stake \( k \) becomes large, the buyer wants to fully delay the payment for the Low type to reduce the supplier responsibility risk. On the other hand, the incentive compatibility condition would require the delay term for the High type to be no less than the delay term for the Low type. As a result, it becomes impossible to separate the two types by different delay terms, and the buyer is forced to use a pooling contract in this case. This phenomenon is related to a less known effect in contract theory termed “nonresponsiveness” (Laffont and Martimort 2002, p. 54)—when there exists a conflict between the principal’s preferences and the incentive constraints, the agents may become nonresponsive to type-separating screening mechanisms. There have been very few documented accounts of problems that give rise to the nonresponsiveness effect (the only account we know of is by Guesnerie and Laffont 1984). Here we find that this effect emerges unexpectedly in our ethical sourcing problem.

There are several other interesting points we want to make. First, we observe that, when a screening mechanism is feasible, the supplier responsibility risk is lower than that under full information for both types. In this case, information asymmetry induces the buyer to pay more than what is required under full information, which helps lower the supplier responsibility risk. Second, increasing the buyer’s private inspection and audit efforts (which results in a higher effective discovery probability \( \theta \) for the buyer) is complementary to the screening mechanism in two ways: 1) it augments the region where the screening contract menu is applicable, and 2) in the case of a pooling contract, it directly lowers the expected supplier responsibility risk and thus helps the buyer achieve lower sourcing cost. Finally, from the supplier perspective, the result of Proposition 2 shows
that information asymmetry actually makes the High type better off, i.e., the good supplier receives more payments because of the presence of the bad supplier. For this reason, the High type would have little incentive to signal its type information voluntarily, which presents another challenge for the buyer in the case of asymmetric information. We will discuss using supplier certification as a remedy to address this problem in the next section.

5. Supplier Certification in Ethical Sourcing

In recent years, emerging Asian markets have seen a surge in demand for compliance certification, according to Worldwide Responsible Accredited Production (WRAP), one of the largest labor and environmental certification programs for the apparel manufacturing sector (O’Kelly 2012). In this section, we study the effectiveness of supply certification as a screening instrument to promote supplier responsibility.

Specifically, we focus on certification programs for initial supplier qualification purposes, i.e., screening test that checks if a supplier meet a set of basic sustainability standards and approves it to be on the approved vendor list, or classifies it as a preferred supplier. In the former case, the company would only source from “approved” vendors. In the latter cases, certified suppliers would be given preferred supplier status, which may enable the suppliers to enjoy some special terms of trade. Starbucks C.A.F.E. Practices and the WRAP certification program are such examples.

The one-time certification test may require different cost/effort for different suppliers to pass. For example, besides the required fees, suppliers also need to spend time and effort to accommodate auditors’ requests, such as providing access to various documents and facilitating confidential interviews with employees (who need to stop working to attend). A supplier with high ethical level may have good ethical practices established already, which makes it easy to pass the certification. For a supplier with low ethical level, it may have to spend time and effort to make up for whatever is required by the certification. Therefore, the Low type may incur additional cost/effort to pass the certification. This cost difference in obtaining certification can be used for designing a screening contract menu. Specifically, let us assume the High type incurs a cost of $t_H > 0$ to obtain the certification and the Low type incurs a cost of $t_L > 0$.

Because the certification program is a one-time qualification for a supplier to be chosen as a business partner of the buyer, the Low type could just patch things up for the sake of passing certification. After obtaining the certification, the Low type may revert back to its old norm or may still be prone to engage in unethical activities when such needs arise. For this reason, we assume that passing the certification does not affect the supplier’s intrinsic ethical level. This assumption
is in accord with the empirical observation by Locke et al. (2007) that trying to get suppliers to comply under a certification program does not fundamentally change their ethical practices. For ongoing certification programs that may affect the supplier’s ethical practices, such as periodic audits of the suppliers under contract, please see a discussion in §5.3.

In practice, the certification cost accrued by the supplier is usually compensated by the buyer through favorable contract terms. For example, Starbucks requires coffee farmers to pay for their certification cost under the C.A.F.E. Practices. After a farmer is certified, Starbucks is willing to reward the farmer with a premium (ranging from 4-8%) above market price (Lee et al. 2006). Therefore, in what follows we shall assume that the buyer uses contract terms to (indirectly) compensate the supplier for the certification cost, so as to ensure the supplier’s participation.

5.1 Voluntary Certification

Let us first consider a voluntary certification mechanism. Specifically, the contract menu is designed in such a way that the High type would voluntarily obtain the certification and receive a contract designed for the certified \((p_H, \gamma_H)\), while the Low type would choose not to get certified and receive a contract designed for the uncertified \((p_L, \gamma_L)\). This is essentially how Starbucks C.A.F.E. certification program operates as discussed above. Formally, the buyer’s sourcing problem under the voluntary certification mechanism can be formulated as follows:

\[
\begin{align*}
\min_{(p_H, \gamma_H), (p_L, \gamma_L)} & \left\{ \pi \cdot G(p_H, \gamma_H | e_H) + (1 - \pi) \cdot G(p_L, \gamma_L | e_L) \right\} \\
\text{s.t.} & \quad r(p_H, \gamma_H | e_H) - t_H \geq 0 \quad \text{(participation condition for the High type)}, \\
& \quad r(p_L, \gamma_L | e_L) \geq 0 \quad \text{(participation condition for the Low type)}, \\
& \quad r(p_H, \gamma_H | e_H) - t_H \geq r(p_L, \gamma_L | e_H) \quad \text{(incentive compatibility for the High type)}, \\
& \quad r(p_L, \gamma_L | e_L) \geq r(p_H, \gamma_H | e_L) - t_L \quad \text{(incentive compatibility for the Low type)}, \\
& \quad 0 \leq \gamma_H, \gamma_L \leq 1.
\end{align*}
\]

With the additional certification costs \(t_H\) and \(t_L\), the constraints in the above problem cannot be simplified as in the original screening problem (6). Moreover, when \(t_H > 0\), due to the incentive compatibility constraint for the High type, a pooling contract is no longer feasible for this problem. Therefore, the voluntary certification mechanism ensures a separation of the two types.

**Proposition 3** If \(t_H > 0\) and \(t_H \geq t_L\), then the buyer achieves higher sourcing cost under the voluntary certification mechanism than it does under the original screening mechanism without certification.
The above proposition shows that, to make a voluntary certification mechanism cost effective for the buyer, the certification cost for the Low type needs to be greater than that of the High type. For example, Starbucks sets a very high bar for certification in their C.A.F.E. Practices. As a result, a supplier with low ethical level would have to spend a great deal more effort to get certified, and therefore is more likely to be screened out. Below we shall focus on the ideal case in which the certification mechanism is properly designed such that \( t_H \) is relatively low and \( t_L \) is sufficiently high. Let \( p_{HC}^0 \) denote the payment to keep the High type earning zero profit under the voluntary certification mechanism with \( \gamma = 1 \), i.e., \( p_{HC}^0 = \{ p \geq 0 : r(p, 1|e_H) = t_H \} \). Figure 4 provides an illustration of the definitions of \( p_{HC}^0 \) as well as the results established in Proposition 4 below.

![Figure 4: Illustration of two cases in Proposition 4.](image)

**Proposition 4** Suppose that \( 0 < t_H < t_L \) and \( t_L \) is high enough such that \( t_L > r(p_H^*, \gamma_H^*|e_L) - r(p_L^*, \gamma_L^*|e_L) \), where \( \{(p_L^*, \gamma_L^*), (p_H^*, \gamma_H^*)\} \) is the optimal contract menu under voluntary certification. Further assume that \( t_H \) is relatively low such that \( k^2 \geq \theta p_{HC}^0/\varphi \), where \( k^2 \) is defined in (9). Then the following holds:

(a) If \( k \leq k_2 \), then the optimal contract menu can be determined separately, with \( (p_H^*, \gamma_H^*) = \arg \min_{r(p, \gamma|e_H) = t_H} G(p, \gamma|e_H) \) and \( (p_L^*, \gamma_L^*) = \arg \min_{r(p, \gamma|e_L) \geq 0} G(p, \gamma|e_L) \). The resulting sourcing cost with the Low type attains the first-best performance under full information. The responsibility risk for the Low type is the same as that under full information, and the responsibility risk for the High type is lower than that under full information.

(b) If \( k > k_2 \), then \( \gamma_H^* = \gamma_L^* = 1 \) and \( p_H^* > p_L^* \geq p_H^0 \). The responsibility risk for the High type is lower than that under full information, and the responsibility risk for the Low type is higher.
than that under full information. The buyer’s sourcing cost is greater than that under the original screening mechanism without certification (where a pooling contract is optimal).

Under a properly designed certification mechanism (i.e., \( t_H \) is relatively low and \( t_L \) is sufficiently high), the above proposition shows that, if the cost stake in supplier responsibility is low (i.e., \( k < k_2 \)), the resulting sourcing cost with the Low type attains the first-best performance under full information. In this case, unlike the original screening mechanism without certification, the buyer does not need to pay informational rent to the Low type. The responsibility risk for the High type is also reduced due to the increased payment from obtaining the certification. However, when the cost stake in supplier responsibility is high (i.e., \( k \geq k_2 \)), in order to incentivize the High type to get certified under the voluntary certification mechanism, the buyer needs to set the payment for the uncertified supplier (the Low type) at a much lower level, which leads to increased responsibility risk for the Low type. As a result, the buyer’s expected sourcing cost becomes greater than that of a pooling contract without certification. In this case, forcing a separation of the two types leads to higher sourcing cost for the buyer and higher responsibility risk for the Low type.

In practice, most companies selling children products (e.g., Barnes and Noble and Mattel) have mandatory requirement for vendors to be certified for safety and environmental compliance. In this case, voluntary certification is replaced by mandatory certification, because the cost stake of supplier noncompliance is very high—the general public is often intolerant of any violations related to children products, meaning that any breach would result in very high damage to the brand. Below we investigate the effectiveness of such a mandatory certification mechanism.

5.2 Mandatory Certification

Consider a mandatory certification mechanism in which the buyer shuts out uncertified suppliers and sources only from certified suppliers. If the certification process is effective enough to screen out the Low type, then the buyer can simply offer a single contract to the High type without worrying about the incentive compatibility between different types (the main constraints in the voluntary certification mechanism). Implementing such a mechanism requires the supplier pool to be large enough, because a portion of the supplier base will be shut out. For example, Starbucks has been striving to source from only C.A.F.E.-certified suppliers. In 2013, 95% of the coffee were bought from C.A.F.E.-certified suppliers, and the company planned to achieve sourcing 100% from C.A.F.E.-certified suppliers by 2015. To study the full benefit of such a mechanism, let us assume the ideal case in which there exists a large pool of suppliers to choose from. Under this assumption,
the buyer’s sourcing problem can be formulated as follows:

\[
\begin{align*}
\min_{(p_H, \gamma_H)} & \quad \left\{ G(p_H, \gamma_H | e_H) \right\} \\
\text{s.t.} & \quad r(p_H, \gamma_H | e_H) - t_H \geq 0 \quad \text{(participation condition for the High type)}, \\
& \quad r(p_H, \gamma_H | e_L) - t_L < 0 \quad \text{(shutout condition for the Low type)}, \\
& \quad 0 \leq \gamma_H \leq 1.
\end{align*}
\] (11)

From the shutout condition for the Low type, it is clear that the certification cost for the Low type needs to be large enough to ensure the existence of a feasible solution. Let \( p_0^{0, LC} \) denote the payment that keeps the Low type earning zero profit under the certification program with \( \gamma = 1 \), i.e., \( p_0^{0, LC} = \{ p \geq 0 : r(p, 1 | e_L) = t_L \} \). Let \( (p^{*}_{HL}, \gamma^{*}_{HL}) \) denote the intersection point between the participation conditions of the two types, i.e., \( (p^{*}_{HL}, \gamma^{*}_{HL}) = \{(p, \gamma) : r(p, \gamma | e_H) = t_H, r(p, \gamma | e_L) = t_L \} \). Further define

\[
k_3 = \frac{\theta p^{0, HC}}{\varphi} + \frac{\alpha(1 - \theta F(u(e_H) + \theta p^{0, HC}/\alpha))}{\varphi \theta f(u(e_H) + \theta p^{0, HC}/\alpha)},
\] (12)

\[
k_4 = \frac{\theta p^{0, LC}}{\varphi} + \frac{\alpha(1 - \theta F(u(e_H) + \theta p^{0, LC}/\alpha))}{\varphi \theta f(u(e_H) + \theta p^{0, LC}/\alpha)},
\] (13)

where it is easy to verify that \( k_3 < k_4 \). Figure 5 provides an illustration of the definitions of \( p_0^{0, LC} \) and \( p^{*}_{HL} \) as well as the results established in Proposition 5.

![Figure 5: Illustration of the two cases in Proposition 5.](image)

**Proposition 5** Suppose that \( 0 < t_H < t_L \) and \( t_L \) is large enough such that \( t_L > r(p^{0, HC}, 1 | e_L) \). Let \( (p^{*}_{H}, \gamma^{*}_{H}) \) be the optimal contract under mandatory certification. The following holds:
(a) If \( k \leq k_3 \), then \( \gamma_{HL} < \gamma_H^* \leq 1 \) and \( p_{HL} < p_H^* \leq p_{HC}^0 \). The responsibility risk for the High type is lower than that under full information.

(b) If \( k > k_3 \), then \( \gamma_H^* = 1 \) and \( p_{HC}^0 < p_H^* < p_{LC}^0 \). Specifically, if \( k_3 < k < k_4 \), the resulting sourcing cost with the High type attains the first-best performance under full information, and the supplier responsibility risk for the High type is the same as that under full information.

If \( k \geq k_4 \), the responsibility risk for the High type is higher than that under full information.

From the above proposition, we obtain the following interesting insight. When the cost stake in supplier responsibility is relatively high (i.e., \( k_3 \leq k < k_4 \)), the buyer can design a contract that shuts out the Low type, and the resulting sourcing cost with the High type is the same as the first-best performance under full information. In this case, the first-best payment under full information is to pay the High type a price premium that makes the High type profitable even after subtracting the required certification cost. As a result, the same first-best payment becomes feasible under mandatory certification, and the buyer can leverage this to achieve the first-best performance. However, when the cost stake in supplier responsibility risk is very high (i.e., \( k \geq k_4 \)), the first-best payment for the High type would become so high such that it attracts the Low type to overcome the certification hurdle to participate. Therefore, the first-best payment becomes infeasible as it violates the shutout condition for the Low type. As a compromise, the buyer needs to pay the High type less than the first-best payment, which leads to higher responsibility risk for the High type and results in possibly higher sourcing cost.

In the above analysis, we have assumed that the certification cost for the Low type is fixed, regardless of the cost stake \( k \). In practice, the buyer can potentially design the certification requirements such that the certification cost for the Low type \( t_L \) can vary based on the cost stake \( k \). It is easy to verify that \( p_{LC}^0 \) is an increasing function in \( t_L \) and the threshold \( k_4 \) is also increasing in \( p_{LC}^0 \). Hence, as \( t_L \) increases, the threshold \( k_4 \) also increases. Therefore, given a high cost stake \( k \), the buyer can always increase \( t_L \) to make sure that \( k < k_4 \). As a result, according to Proposition 5, the resulting sourcing cost with the High type can always attain the first-best performance under full information. This explains why Starbucks sets a very high bar for certification in their C.A.F.E. Practices and why it strives to achieve sourcing 100% from C.A.F.E.-certified suppliers.

In summary, as the cost stake in supplier responsibility increases due to the heightened public awareness (e.g., Bangladesh factory problems), the certification tests should be also made sophisticated enough. If the certification involves only some outward conditions of the suppliers, it is possible for the Low type to dress things up to pass. However, if the certification involves at-
tributes like worker interviews, community data, and other health and safety records, then they are harder to fabricate and so the costs to pass for the Low type would be much greater than those of the High type.

Comparing the voluntary and mandatory certification mechanisms, we note the following nuanced differences. Under the voluntary certification, both types participate. Thus, the main driver in the problem is the incentive compatibility conditions between the two types. Increasing the certification cost for the Low type only deters the Low type from getting certified (it is still allowed to participate), which helps to separate the two types but does not necessarily improve the cost performance for the buyer. On the other hand, under the mandatory certification, only the High type participates. In this case, increasing the certification cost for the Low type helps to shut out the Low type, which also enables the buyer to achieve the first-best performance as discussed above. Thus, the mandatory certification mechanism appears to be more suitable for ethical sourcing (where the cost stake in supplier responsibility is high).

5.3 General Discussion

In our analysis, we have assumed that the certification is properly designed such that the certification cost for the Low type is significantly higher than that of the High type. In practice, the cost/effort required for passing a certification may not always depend on the supplier ethical types. Specifically, when \( t_H = t_L = t > 0 \), it is easy to show that the Low type will always participate as long as the High type participates. Thus, one cannot shut out the Low type under the mandatory certification mechanism. In this case, the sourcing problem under mandatory certification becomes the following:

\[
\begin{align*}
\min_{(p_H, \gamma_H), (p_L, \gamma_L)} & \left\{ \pi \cdot G(p_H, \gamma_H | e_H, \rho) + (1 - \pi) \cdot G(p_L, \gamma_L | e_L, \rho) \right\} \\
\text{s.t.} & \quad r(p_H, \gamma_H | e_H) - t \geq 0 \quad \text{(participation condition for the High type)}, \\
& \quad r(p_L, \gamma_L | e_L) - t \geq 0 \quad \text{(participation condition for the Low type)}, \\
& \quad r(p_H, \gamma_H | e_H) \geq r(p_L, \gamma_L | e_H) \quad \text{(incentive compatibility for the High type)}, \\
& \quad r(p_L, \gamma_L | e_L) \geq r(p_H, \gamma_H | e_L) \quad \text{(incentive compatibility for the Low type)}, \\
& \quad 0 \leq \gamma_H, \gamma_L \leq 1.
\end{align*}
\]  

We note that, when \( t = 0 \), the above problem reduces to the original screening mechanism problem (6). Comparing the above problem with the voluntary certification problem (10) and the original screening mechanism problem (6), we can obtain the following result:
Proposition 6 Suppose that the certification cost is independent of supplier types, i.e., $t_H = t_L$. Then the buyer achieves lower sourcing cost under the mandatory certification mechanism than it does under the voluntary certification mechanism. However, the buyer’s sourcing cost under the mandatory certification mechanism is higher than that under the original screening mechanism without certification.

When the certification cost is independent of the supplier types, the above proposition further shows that mandatory certification is a better choice than voluntary certification. However, mandatory certification is also more costly compared with the original screening mechanism without certification. Nevertheless, companies may still choose mandatory supplier certification in practice for the sake of fending off the increasing pressure from environmental and labor activists (Gereffi et al. 2001 and Raynolds et al. 2007). The added cost from mandatory certification in this case becomes part of the way of doing business in order to source from emerging economies.\footnote{In addition, mandatory certification could potentially serve as an informal insurance to shield some blame for the buyer. For example, suppose that a supplier, certified by a well-respected third-party NGO, is found to be engaging in unethical activities. The buyer may receive less blame from the public compared with the case if the supplier were uncertified.}

So far we have focused on the one-time certification process for initial supplier qualification. In practice, there also exist certification processes as ongoing audits for the supplier to stay in the approved vendor list. Such ongoing, periodic certification processes can be viewed as a form of monitoring efforts that increase the buyer’s effective discovery probability $\theta$ during the contract period and thus reduce the supplier responsibility risk as discussed above. In addition, ongoing certification may also have an educational aspect to it. Intuitively, the repeated audits may educate the supplier to start making more permanent, systematic changes in its practice, which may amount to the improvement of the supplier’s ethical level. However, Locke et al. (2007) showed that after years of audits, Nike suppliers still exhibited the same level of ethical practices. Moreover, periodic audits may also cause the so-called “audit fatigue” among suppliers. Such audit fatigue is not just for the audit fees the supplier has to pay repeatedly, but also for the time and effort that they need to spend to accommodate auditors’ requests. In fact, industry groups have now been formed to find ways to reduce such audit fatigue (e.g., the Global Apparel, Footwear and Textile Initiative, see Barrie, 2012).

To avoid overburdening suppliers with repeated audits, companies have shifted their focus to investing in supplier development. Supplier development efforts can be of two types: 1) to help suppliers to meet the standards required by the buyer (e.g., Grameen helping the Ghana shea butter farmers to learn about the stringent quality requirements of cosmetic manufacturers so that they...
could sell to them; see Rammohan 2010); or 2) to help productivity improvements so that they can be cost-competitive and therefore can become part of the supplier pool (as we have discussed in §3). Thus, with supplier development, the buyer can actively change the distribution of the supplier types, to have more suppliers with high ethical level in the mix. This is what Li and Fung claimed to do: They provided financial help for small and medium-sized suppliers who would not be included as a supply source without such help. These were otherwise good suppliers (with high ethical standards), so Li and Fung were willing to invest in them, and as a result, they had more ethical suppliers to choose from (Private communication with Dr. William Fung, 2012).

6. Concluding Remarks

In this paper, we have developed a supplier responsibility risk model that endogenizes the probability of a supplier engaging in unethical activities. In particular, the supplier is assumed to have an intrinsic ethical level that may not be observable to the buyer. Based on this model, we derive the business rationale behind various industry ethical sourcing initiatives, such as increasing inspection efforts, lobbying for tighter regulatory control, providing supplier education, and improving supplier production efficiency. When the supplier’s intrinsic ethical level is unobservable to the buyer, we find that the classic monopolistic screening mechanism does not always apply to our problem. When the cost stake in supplier responsibility is high, it is optimal for the buyer to offer a pooling contract to all supplier types. To remedy this problem, we show that both voluntary and mandatory certification can help mitigate supplier responsibility risk in certain cases. Specifically, we find that the mandatory certification mechanism is more suitable for ethical sourcing (where the cost stake in supplier responsibility is high), and the buyer can achieve the first-best performance under mandatory certification if the certification test can be made sophisticated enough.

Besides the contracting and certification mechanisms considered in the paper, companies can also take more proactive measures to promote supplier responsibility. For example, under our ethical sourcing model framework, we can show that offering a long-term contract can provide a positive incentive for the supplier to stay in contract to earn positive future profits, and thus can help reduce supplier responsibility risk. Specifically, we can show that increasing the payment under a long-term contract has an increasing marginal effect on reducing supplier responsibility risk (a formal proof is available from the authors). In order to retain the flexibility to shift production to lower cost regions, many buyers in practice would prefer to stay with short-term sourcing contracts. In this case, companies need to provide additional incentives to reduce supplier responsibility risk. According to the SCM World survey (Lee et al. 2012), 25% of the 1127 surveyed companies used “better terms
and conditions,” 32% used “public recognition,” 48% used “increased business engagements,” and 58% used “preferred supplier status” to incentivize suppliers to be more responsible, all of which can be viewed as some form of “nonmonetary” rewards in contrast to the pure monetary incentive of price premiums. Based on our ethical sourcing model framework, we can show under some mild technical conditions that the nonmonetary rewards are more effective compared with the price premium incentive (a formal proof is available from the authors).

Local governments can also do more to promote supplier responsibility. To improve welfare for factory workers, some local governments in emerging economies have been seeking to increase minimum wages. For example, Bangladesh Minimum Wage Board has recommended a 77% increase of minimum wage recently (Kenneally 2013), and 12 province governors in Indonesia have agreed to increase monthly minimum wages for 2014 by an average of 19% (Donaldson 2013). Suppose that a minimum wage hike will add a fixed cost to the original production cost. We can show that having a wage hike can introduce two opposing effects: on the positive side, it may induce a higher payment to the supplier and thus reduces the supplier responsibility risk; on the negative side, if the buyer is not absorbing the full cost of wage increase, it increases the cost pressure for the supplier and thus also increases the supplier responsibility risk (a formal proof of this result is available from the authors). To neutralize the negative effect, the local government should increase the sanction cost for violations while implementing a wage hike (such as we have discussed in §3).

Several model extensions merit further investigation. First, we have assumed a take-it-or-leave-it contract setting. In the real world, business relationships between buyers and suppliers can evolve over time. Thus, it would be interesting to study our ethical sourcing problem under different contract settings, such as long-term relational contracts with trigger strategies (e.g., Taylor and Plambeck 2007ab, Belavina and Girotra 2014) and review strategies (e.g., Ren et al. 2010). Second, we have left out potential supplier competitions in our model. In a traditional sourcing model, Li (2013) showed how supply-base designs and pricing mechanisms can foster supplier competition and induce supplier cost reduction efforts. It would be interesting to consider similar research problems under our ethical sourcing framework, i.e., to study whether ethical sourcing strategies would induce more responsible behaviors from competing suppliers. Finally, more empirical or behavioral research could be done in this area to further shed light on the driving factors for the supplier’s intrinsic ethical level and to prescribe additional strategies to promote supplier responsibility.
References


**Appendix (For Online Companion)**

**Lemma A3** Let $G(p, \gamma | e) = p + (\varphi k - \theta \gamma p) \bar{F}(u(e) + \theta \gamma p / \alpha)$. The following holds:

(a) If $k \leq \theta \gamma p / \varphi$, then $\partial G(p, \gamma | e) / \partial p > 0$. If $k \geq \theta \gamma p / \varphi$, then $\partial G(p, \gamma | e) / \partial \gamma < 0$.

(b) Let $(p^*, \gamma^*) = \arg\min_{(p,\gamma | e) = a} G(p, \gamma | e)$. Then, $\partial G(p, \gamma | e) / \partial \gamma < 0$ for any point $(p', \gamma')$ that satisfies $r(p', \gamma' | e) = a$ and $\gamma' \leq \gamma^*$.

(c) Let $(p^{**}, \gamma^{**}) = \arg\min_{(p,\gamma | e) = \gamma^{**}} G(p, \gamma | e)$. Let $p^0(e)$ be the point where $r(p^0(e), 1 | e) = 0$. If $k \leq \theta \gamma^0(e) / \varphi$, then $r(p^{**}, \gamma^{**} | e) = 0$, with $\gamma^{**} < 1$, $p^{**} < p^0(e)$, and $\gamma^{**} p^{**} = \varphi k / \theta$. If $k \geq \theta \gamma^0(e) / \varphi$, then $\gamma^{**} = 1$ and $p^{0}(e) \leq p^{**} \leq \varphi k / \theta$.

**Proof** For Part (a), the first-order derivatives of $G(p, \gamma | e)$ with respect to $p$ and $\gamma$ are given by

$$
\frac{\partial G(p, \gamma | e)}{\partial p} = 1 - \theta \gamma \bar{F} \left( u(e) + \frac{\theta \gamma p}{\alpha} \right) - \frac{\theta \gamma}{\alpha} (\varphi k - \theta \gamma p) f \left( u(e) + \frac{\theta \gamma p}{\alpha} \right),
$$

$$
\frac{\partial G(p, \gamma | e)}{\partial \gamma} = -\theta p \bar{F} \left( u(e) + \frac{\theta \gamma p}{\alpha} \right) - \frac{\theta p}{\alpha} (\varphi k - \theta \gamma p) f \left( u(e) + \frac{\theta \gamma p}{\alpha} \right).
$$

Thus, if $k \leq \theta \gamma p / \varphi$, then $\partial G(p, \gamma | e) / \partial p > 0$; and if $k \geq \theta \gamma p / \varphi$, then $\partial G(p, \gamma | e) / \partial \gamma < 0$.

For Part (b), let $p_a(\gamma | e)$ be the point on the iso-profit curve of $r(p, \gamma | e) = a$. It is easy to verify that

$$
\frac{dG(p_a(\gamma | e), \gamma | e)}{d\gamma} = -\theta p_a(\gamma | e)(\varphi k - \theta \gamma p_a(\gamma | e)) f \left( u(e) + \theta \gamma p_a(\gamma | e) / \alpha \right) / \left( 1 - \theta \gamma \bar{F} \left( u(e) + \theta \gamma p_a(\gamma | e) / \alpha \right) \right).
$$

Thus, for $\gamma' \leq \gamma^*$, suppose that $k < \theta \gamma p_a(\gamma' | e) / \varphi$. Then, it follows that $k < \theta \gamma p_a(\gamma' | e) / \varphi$ for all $\gamma \geq \gamma'$. This implies that $dG(p_a(\gamma | e), \gamma | e) / d\gamma > 0$ for all $\gamma \geq \gamma'$, which contradicts the optimality of $\gamma^*$. Hence, it must be true that $k \geq \theta \gamma p_a(\gamma' | e) / \varphi$, which, from Part (a), implies $\partial G(p, \gamma | e) / \partial \gamma < 0$ at the point of $(p_a(\gamma' | e), \gamma')$. Moreover, if $k < \theta \gamma p' / \varphi$ with $p' = p_a(\gamma' | e)$, by the same argument above we have $dG(p_a(\gamma | e), \gamma | e) / d\gamma > 0$ for any $\gamma \geq \gamma'$. Thus, it follows that $\gamma^* < \gamma'$ and $p^* < p_a(\gamma | e) = p'$. By the first-order condition, it follows that $\gamma^* p^* = \varphi k / \theta$. Similarly, it follows that, if $k \geq \theta \gamma p' / \varphi$, then $\gamma^* \geq \gamma'$ and $p^* \geq p'$.

For Part (c), let $p_0(\gamma | e)$ be the point on the iso-profit curve of $r(p, \gamma | e) = 0$. Thus, $p^0(e) = p_0(1 | e)$. When $k < \theta \gamma^0(e) / \varphi$, suppose that $p^{**}$ is an interior point, i.e., $p^{**} > p_0(\gamma^{**} | e)$. Then, it must be true that $\partial G(p, \gamma | e) / \partial p = 0$, which implies $\varphi k - \theta \gamma^{**} p^{**} > 0$. From Part (a), it follows that $\partial G(p, \gamma | e) / \partial \gamma = 0$ at the point $(p^{**}, \gamma^{**})$. Hence, it must be true that $\gamma^{**} = 1$ and $p^{**} > p^0(e)$. But in this case, we have $\varphi k - \theta \gamma^{**} p^{**} < \theta (p^0(e) - p^*) < 0$, which results in a
contradiction. Therefore, we conclude that, when \( k < \theta p^0(e) / \varphi \), the constraint must be binding, i.e., \( r(p^{**}, \gamma^{**}|e) = 0 \). Furthermore, because \( k < \theta p^0(e) / \varphi \), from Part (b), it immediately follows that \( \gamma^{**} < 1 \) and \( p^{**} < p^0(e) \). By the first-order condition, it follows that \( \gamma^{**} p^{**} = \varphi k / \theta \).

On the other hand, when \( k \geq \theta p^0(e) / \varphi \), consider two cases. Case 1): suppose \( p^{**} \) is on the boundary. Because \( k \geq \theta p^0(e) / \varphi \geq \theta \gamma p_0(\gamma|e) / \varphi \), from Part (b), we have \( dG(p_0(\gamma|e), \gamma|e) / d\gamma < 0 \) for all \( \gamma \). So it must be true that \( \gamma^{**} = 1 \) and \( p^{**} = p^0(e) \). Case 2): suppose \( p^{**} \) is an interior point. Then, from Part (a), it follows that \( \partial G(p, \gamma|e) / \partial \gamma < 0 \) at the point \( (p^{**}, \gamma^{**}) \). Therefore, it must be true that \( \gamma^{**} = 1 \) and \( p^{**} > p^0(e) \). Combining these two cases, we conclude \( \gamma^{**} = 1 \) and \( p^{**} \geq p^0(e) \). It is also easy to verify that \( p^{**} \leq \varphi k / \theta \). Thus, the desired result follows. □

**Proof (Lemma 1)** Because \( r(m, \gamma|e) > 0 \) and \( r(p, \gamma|e) \) is increasing in \( p \), it must be true that \( p_0(\gamma|e) < m \). From the supplier’s profit function (3), it is easy to verify that \( r(p, \gamma|e) \) is decreasing in \( \gamma \) and \( e \). Thus, the minimum participation payment \( p_0(\gamma|e) \) is increasing in \( \gamma \) and \( e \). Similarly, it is easy to verify that \( r(p, \gamma|e) \) is decreasing in \( \eta \). Thus, \( p_0(\gamma|e) \) is increasing in \( \eta \). □

**Proof (Proposition 1)** The result follows directly from Lemma A3 (c). Specifically, consider the case of \( k \geq \theta p^0(e)/\varphi \), where from Lemma A3 (c) we have \( \gamma^{**} = 1 \). In this case, \( G(p, 1|e) = p + (\varphi k - \theta p) \bar{F}(u(e) + \theta p / \alpha) \). We have \( dG(p, 1|e) / dp = 1 - \theta \bar{F}'(u(e) + \theta p / \alpha) - \theta (\varphi k - \theta p) f(u(e) + \theta p / \alpha) / \alpha \). Also note that for \( p^0(e) \leq p < \varphi k / \theta \),

\[
\frac{d^2G(p, 1|e)}{dp^2} = \frac{2\theta^2}{\alpha} f(u(e) + \theta p / \alpha) - \frac{\theta^2}{\alpha^2} (\varphi k - \theta p) f'(u(e) + \theta p / \alpha) \geq 0.
\]

Thus, \( G(p, 1|e) \) is convex in \( p \) over \([p^0(e), \varphi k / \theta] \). Hence, if \( dG(p^0(e), 1|e) / dp < 0 \), or, equivalently, \( k > k_0(e) \), where \( k_0(e) \) is defined in (5), then the first-order condition yields a unique solution \( p^{**} > p^0(e) \). Otherwise, if \( \theta p^0(e)/\varphi \leq k \leq k_0(e) \), then \( p^{**} = p^0(e) \). It is also easy to verify that the optimal payment \( p^{**} \) is increasing in \( k \) in the regions of \( 0 \leq k < \theta p^0(e)/\varphi \) and \( k > k^0(e) \). Thus, the resulting supplier responsibility risk is decreasing in \( k \) in these two regions. Also, the optimal payment \( p^{**} \) does not change in the region of \( \theta p^0(e)/\varphi \leq k \leq k_0(e) \), so does the resulting supplier responsibility risk. Moreover, from Lemma 1, we have \( p^0(e) \) is increasing in \( e \). Leveraging this result, it is easy to verify that \( k_0(e) \) is also increasing in \( e \). Thus, if \( k \geq \theta p^0(e)/\varphi \), it is clear \( \gamma^{**} \) could only decrease from 1 as \( e \) increases. Now consider the case with \( k < \theta p^0(e)/\varphi \). It is easy to verify that \( \partial G(p, \gamma|e) / \partial \gamma \) is increasing in \( e \). Suppose that we have \( e_L < e_H \). From Lemma A3 (b), we have \( \partial G(p, \gamma|e_L) / \partial \gamma \leq \partial G(p, \gamma|e_H) / \partial \gamma < 0 \) for all \( \gamma \leq \gamma^{**}(e_H) \). It follows that \( \gamma^{**}(e_L) \geq \gamma^{**}(e_H) \). Thus, we conclude that the optimal delay term \( \gamma^{**} \) is decreasing in \( e \). □

**Proof (Lemma 2)** It follows directly from the fact that \( dp_a(\gamma|e_H) / d\gamma < dp_a'(\gamma|e_L) / d\gamma \) for any point \((p, \gamma)\) with \( p_a(\gamma|e_H) = p_a'(\gamma|e_L) = p \). □

**Proof (Proposition 2)** Let us first analyze the four constraints of the problem (6). Because
\[ r(p_H, \gamma_H|e_L) > r(p_H, \gamma_H|e_H), \]
from the incentive compatibility condition for the Low type and the participation condition for the High type, we have \[ r(p_L, \gamma_L|e_L) \geq r(p_H, \gamma_H|e_L) > r(p_H, \gamma_H|e_H) \geq 0. \]

Hence, the participation condition for the Low type is not binding and we can remove it. Next, let \((p_H^*, \gamma_H^*, p_L^*, \gamma_L^*)\) be the optimal solution to the problem. Consider two cases. Case 1): Suppose that \((p_L^*, \gamma_L^*) = (p_H^*, \gamma_H^*)\). Then it is clear that the two incentive compatibility conditions are met trivially and we can remove them. Case 2): Suppose that \((p_L^*, \gamma_L^*) \neq (p_H^*, \gamma_H^*)\).

Further suppose that the incentive compatibility condition for the High type is binding. Then for the optimal solution \((p_H^*, \gamma_H^*, p_L^*, \gamma_L^*)\), we have \[ r(p_L^*, \gamma_L^*)|e_J = r(p_H^*, \gamma_H^*)|e_J. \] By the single-crossing property of Lemma 2, it follows that \[ r(p_L^*, \gamma_L^*)|e_J > r(p_H^*, \gamma_H^*)|e_J. \] Let \((p_L^{**}, \gamma_L^{**}) = \arg \min_{\gamma_L} r(p, \gamma)|e_J \geq 0 \leq 1 G(p, \gamma|e_J). \) Suppose that \(\gamma_L^{**} > \gamma_L^*\). Then, one can always decrease \(\gamma_L^*\) along the iso-profit curve \(r(p, \gamma)|e_J = r(p_L^*, \gamma_L^*)|e_J\) to lower cost while meeting all the constraints, which contradicts the optimality of \(\gamma_L^*\). Thus, it must be \(\gamma_L^* \leq \gamma_L^{**}\). By Lemma A3 (b), it follows that \(\partial G(p, \gamma)|e_J/\partial \gamma < 0\) at the point of \((p_L^*, \gamma_L^*)\). Then, one can increase \(\gamma_L^*\) by an epsilon value to lower cost while meeting all the constraints, which contradicts the optimality of \(\gamma_L^*\). Therefore, we conclude that the incentive compatibility condition for the High type cannot be binding and we can remove it. Finally, suppose that the incentive compatibility condition for the Low type is not binding. By the same argument, we can always increase \(\gamma_L^*\) by an epsilon value to lower cost while meeting all the constraints. Therefore, the incentive compatibility condition for the Low type must be binding.

Combining the two cases, we arrive at the simplified problem (7). From (7), we can make two quick observations. First, suppose that \(\gamma_L^* > \gamma_H^*\). Then, because \(r(p_L^*, \gamma_L^*)|e_J = r(p_H^*, \gamma_H^*)|e_J\), by Lemma 2, it follows that \(p_L^* > p_L\), where \(r(p_L^*, \gamma_L^*)|e_J = r(p_H^*, \gamma_H^*)|e_J\). Thus, \(r(p_L^*, \gamma_L^*)|e_J > r(p_L^*, \gamma_L^*)|e_J\), which violates the incentive compatibility condition for the High type. Thus, it must be true that \(\gamma_L^* \leq \gamma_H^*\). Second, from the fact that on an iso-profit curve, \(p\) is increasing in \(\gamma\), it follows that \(p_L^* \leq p_H^*\).

Let us now prove Part (a). When \(k < \theta p_H^0/\varphi\), suppose that the participation condition for the High type for problem (7) is not binding, i.e., \(p_H^*\) is an interior point. Consider two cases here. Case 1): \(\gamma_H^* = 1\) and \(p_H^* > p_H^0\). In this case we have \(k < \theta p_H^0/\varphi < \theta \gamma_H^* p_H^*/\varphi\). From Lemma A3 (a), it follows \(\partial G(p, \gamma)|e_J/\partial p > 0\) at the point \((p_H^*, \gamma_H^*)\). Thus, we can decrease \(p_H^*\) by an epsilon value to lower cost while meeting all constraints of (6), which contradicts the optimality of \(p_H^*\). Case 2): \(\gamma_H^* < 1\). From Lemma A3 (a), either \(\partial G(p, \gamma)|e_J/\partial p > 0\) or \(\partial G(p, \gamma)|e_J/\partial \gamma < 0\) at the point \((p_H^*, \gamma_H^*)\). Thus, one can either decrease \(p_H^*\) or increase \(\gamma_H^*\) correspondingly by an epsilon value to lower cost while meeting all constraints of (6), which contradicts the optimality of \((p_H^*, \gamma_H^*)\). Combining these two cases, we conclude that the participation condition for the High type must be binding in this case, i.e., \(r(p_H^*, \gamma_H^*)|e_H = 0\). Now let \((p_H^*, \gamma_H^*) = \arg \min_{r(p, \gamma)|e_J = 0} G(p, \gamma|e_J),\) which, by Lemma A3 (c), is also the optimal solution for the High type under full information (because \(k < \theta p_H^0/\varphi\)). Also, from Lemma A3 (c), it must be true that \(\gamma_H^* < 1\). Suppose that \(\gamma_H^* \leq \gamma_H^{**}\). By Lemma A3 (b), we have \(\partial G(p, \gamma)|e_J/\partial \gamma < 0\) at the point of \((p_H^*, \gamma_H^*)\). In this case, we can increase increase \(\gamma_H^*\) by an epsilon value to lower cost while meeting all constraints of (6),
which contradicts the optimality of \((p_H^*, \gamma_H^*)\). Therefore, it must be true that \(\gamma_H^* > \gamma_H^{**}\). By Lemma A3 (b), it follows that \(\gamma_H^* P_H^* > \gamma_H^{**} P_H^{**} = \varphi k/\theta\). Now given \((p_H^*, \gamma_H^*)\), the optimal solution \((p_L^*, \gamma_L^*)\) is just \(\arg \min_{r(p, \gamma|e_L)} = r(p_L, \gamma_L^*|e_L), 0 \leq \gamma_L^* \leq 1 G(p, \gamma|e_L)\). Because we have \(\gamma_H^* P_H^* > \varphi k/\theta\), from Lemma A3 (b), it follows that \(\gamma_L^* P_L^* = \varphi k/\theta\). From the above analysis, it is clear that the High type earns zero profit, just as it does under full information. Because \(k < \theta p_H^*/\varphi\), from Proposition 1, it follows that the Low type’s profit under full information is less than \(r(p_H^*, 1|e_L)\). By Lemma 2, it follows that \(r(p_L^*, \gamma_L^*|e_L) \geq r(p_H^*, 1|e_L)\). Therefore, the Low type earns more profit under the screening contract than it does under full information. Moreover, because \(\gamma_L^* P_L^* > \gamma^{**} L^* P_L^{**}\), the supplier responsibility risk for the High type is lower than that under full information. Also, we know that \(\gamma_L^* P_L^* = \varphi k/\theta\). From Lemma A3 (c), under full information we have \(\gamma_L^* P_L^* \leq \varphi k/\theta\). Therefore, we conclude that the supplier responsibility risk for the Low type is also lower than that under full information.

For Part (b), consider two cases. Case 1): suppose \(p_H^*\) is on the boundary, i.e., \(r(p_H^*, \gamma_H|e_H) = 0\). Because \(k \geq \theta p_H^*/\varphi \geq \theta \gamma_H^* P_H^*/\varphi\), from Lemma A3 (c), we know \(\gamma_H^{**} = 1\), where \(\gamma_H^{**}\) is the optimal solution to the problem \(\min_{r(p, \gamma|e_H)} = 0, 0 \leq \gamma \leq 1 G(p, \gamma|e_H)\). Thus, by replacing point \((p_H^*, \gamma_H^*)\) with \((p_L^*, \gamma_L^*)\), we can lower cost while meeting all constraints of (6), which implies it must be the case that \(\gamma_H^* = 1\) and \(p_H^* = p_L^*\). Now given \((p_H^*, \gamma_H^*)\), the optimal solution \((p_L^*, \gamma_L^*)\) is \(\arg \min_{r(p, \gamma|e_L)} = r(p_L^*, \gamma_L^*|e_L), 0 \leq \gamma_L^* \leq 1 G(p, \gamma|e_L)\). Because \(k \geq \theta p_H^*/\varphi = \theta \gamma_H^* P_H^*/\varphi\), by Lemma A3 (b), it must be true that \(\gamma_L^* \geq \gamma_H^*\) and \(p_L^* \geq p_H^*\). But recall that we have shown earlier \(\gamma_L^* \leq \gamma_H^*\) and \(p_L^* \leq p_H^*\). So it follows that \(\gamma_L^* = \gamma_H^* = 1\) and \(p_L^* = p_H^*\). Case 2): suppose \(p_H^*\) is an interior point. Then, by Lemma A3 (c) and a similar argument used in Case 1), we can show it must be true that \(\gamma_H^* = 1\) and \(p_H^* > p_L^*\). Suppose that \(k \leq \theta \gamma_H^* P_H^*/\varphi\). By Lemma A3 (a), we have \(\partial G(p, \gamma|e_H)/\partial p > 0\) at the point \((p_H^*, \gamma_H^*)\). By increasing \(p_H^*\) by an epsilon value, we can lower cost while meeting all constraints of (6), which contradicts the optimality of \((p_H^*, \gamma_H^*)\). Thus, it must be true that \(k > \theta \gamma_H^* P_H^*/\varphi\). Then, by Lemma A3 (b), it follows that \(\gamma_L^* \geq \gamma_H^*\) and \(p_L^* \geq p_H^*\). But recall that we have shown earlier \(\gamma_L^* \leq \gamma_H^*\) and \(p_L^* \leq p_H^*\). So it follows that \(\gamma_L^* = \gamma_H^* = 1\) and \(p_L^* = p_H^*\). Combining these two cases, we conclude that, when \(k \geq \theta p_H^*/\varphi\), \(\gamma_L^* = \gamma_H^* = 1\) and \(p_L^* = p_H^*\), i.e., a pooling contract is optimal. Under the pooling contract, by a similar argument used in Proposition 1, the condition \(k > k_1\), where \(k_1\) is defined in (8), ensures \(p_L^* = p_H^* > p_H^0\); otherwise if \(\theta p_H^*/\varphi \leq k \leq k_1\), we have \(p_L^* = p_H^* = p_H^0\). Thus, in the case of \(\theta p_H^*/\varphi \leq k \leq k_1\), it is clear that the High type earns zero profit as it does under full information. Moreover, note that \(k_1 < k_0(e_H)\). From Proposition 1, we know that \(\gamma_H^* P_H^* = \gamma_H^* P_H^{**}\) in this case. Therefore, the supplier responsibility risk for the High type remains the same as under full information. On the other hand, in the case of \(k < k_1\), it is easy to verify that \(p_H^* < p_H^* = p_L^* < p_H^{**}\) and \(\gamma_H^* = \gamma_H^* = \gamma_L^* = \gamma_L^{**} = 1\). Thus, it follows that the High type earns more profit than it does under full information and its responsibility risk is lower than that under full information. When \(\theta p_H^*/\varphi \leq k < k_2\), where \(k_2\) is defined in (9), from Proposition 1, we know that the Low type earns more profit than it does under full information and \(\gamma_L^* P_L^* \leq p_L^* \leq \gamma_L^* P_L^*\). Therefore, the supplier responsibility risk for the Low type is lower than that under full information when \(k > k_2\), by similar argument, it is easy to show
that the Low type earns less profit than it does under full information, and its responsibility risk is higher than that under full information. Finally, from Lemma 1, we know that \( p_H^0 \) is increasing in \( \eta \). Thus, increasing the buyer’s private inspection efforts will increase \( \theta p_H^0 / \varphi \), which makes the screening contract menu optimal for larger \( k \) values (from the condition of Part a).

**Proof (Proposition 3)** Suppose that \( t_H \geq t_L \). From the incentive compatibility constraint for the Low type, we have

\[
 r(p_L, \gamma_L | e_L) \geq r(p_H, \gamma_H | e_L) - t_L > r(p_H, \gamma_H | e_H) - t_L \geq r(p_L, \gamma_L | e_H) + t_H - t_L \geq r(p_L, \gamma_L | e_H),
\]

where the second inequality follows from the fact that \( r(p_H, \gamma_H | e_L) > r(p_H, \gamma_H | e_H) \) and the third inequality follows from the incentive compatibility condition for the High type. Thus, the above constraint for the Low type is more restrictive than the corresponding constraint in (6). Moreover, the incentive compatibility constraint for the High type is also more restrictive than the corresponding constraint in (6). Therefore, the result follows.

**Proof (Proposition 4)** If \( t_L > r(p_H^* | \gamma_H^* | e_L) - r(p_L^* | \gamma_L^* | e_L) \), the incentive compatibility constraint for the Low type can be removed. Because \( k \leq k_2 \), from Proposition 1, we know that \( \gamma_L^{**} \leq 1 \) and \( p_L^{**} < p_H^0 \), where \( (p_L^*, \gamma_L^*) = \arg \min_{r(p, \gamma | e_L) \geq 0} G(p, \gamma | e_L) \). Therefore, by the single-crossing property of Lemma 2, we have \( r(p_L^*, \gamma_L^{**} | e_H) < r(p_H^0, 1 | e_H) = 0 \leq r(p_H^0, \gamma_H^* | e_H) - t_H \). Thus, the incentive compatibility constraint for the High type can also be removed. Furthermore, because \( k < \theta p_H^0 / \varphi + \alpha (1 - \theta F(u(e_H) + \theta p_H^0 / \alpha)) / \varphi \theta f(u(e_H) + \theta p_H^0 / \alpha) \), it follows that \( p_H^* < p_H^0 \). Hence, the optimal contract menu can be determined separately, with \( (p_H^*, \gamma_H^*) = \arg \min_{r(p, \gamma | e_H) = t_H} G(p, \gamma | e_H) \) and \( (p_L^*, \gamma_L^*) = \arg \min_{r(p, \gamma | e_L) \geq 0} G(p, \gamma | e_L) \). Thus, the resulting sourcing cost with the Low type attains the first-best performance under full information. Also, as in Proposition 2, it is straightforward to verify that the responsibility risk for the High type is lower than that under full information.

Now consider the case of \( k > k_2 \). Because \( k_2 > \theta p_H^0 / \varphi \), from Proposition 1, we have \( \gamma_H^* = 1 \) and \( p_H^* \geq p_H^0 \). Similarly, because \( k > k_0(e_L) \), from Proposition 1, we have \( \gamma_L^* = 1 \) and \( p_L^* \geq p_H^0 \). By the incentive compatibility condition for the High type, it follows that \( p_H^* > p_H^0 \). In this case, it is easy to verify that \( p_H^* \geq p_H^{**} \) and \( p_L^* < p_L^{**} \), where \( p_H^{**} \) and \( p_L^{**} \) are the optimal payment under full information for each type. Hence, the responsibility risk for the High type is lower than that under full information, and the responsibility risk for the Low type is higher than that under full information. Now consider two cases. First, suppose that \( k \leq k \leq k_1 \), where \( k_1 \) is defined in (8). By convexity, it can be verified that \( \pi G(p, 1 | e_H) + (1 - \pi) G(p, 1 | e_L) \) is decreasing in \( p \) for \( p \geq p_H^0 \). Therefore, we have \( \pi G(p_H^0, \gamma_H^* | e_H) + (1 - \pi) G(p_L^*, \gamma_L^* | e_L) \geq \pi G(p_L^*, 1 | e_H) + (1 - \pi) G(p_L^*, 1 | e_L) \geq G(p_H^0, 1 | e_H) + (1 - \pi) G(p_H^0, 1 | e_L) \). From Proposition 2, the optimal solution to the original screening problem without certification in this case, denoted by \( \{(p_L^*, \gamma_L^*), (p_H^*, \gamma_H^*)\} \), is a pooling contract with \( \gamma_L^* = \gamma_H^* = 1 \) and \( p_L^* = p_H^* = p_H^0 \). Hence, from the above inequality, we conclude that sourcing cost under voluntary certification is higher than that without certification. Second, suppose that \( k > k_1 \). In this case, from Proposition 2, we know that the original screening problem without
certification becomes an unconstrained problem. On the other hand, the voluntary certification problem has an additional incentive compatibility constraint for the High type. Thus, it follows that sourcing cost under voluntary certification is higher than that without certification. Combining the two cases, we obtain the desired result.

Proof (Proposition 5) If \( t_L \leq r(p_{HC}^0, 1|e_L) \), by definition \( r(p_{LC}^0, 1|e_L) \leq r(p_{HC}^0, 1|e_L) \), which implies \( p_{HC}^0 \geq p_{LC}^0 \). By Lemma 2, the iso-profit curves of \( r(p, \gamma|e_H) = t_H \) and \( r(p, \gamma|e_L) = t_L \) do not cross in the region \( 0 \leq \gamma < 1 \). Therefore, the conditions \( r(p, \gamma|e_H) \geq t_H \) and \( r(p, \gamma|e_L) < t_L \) produce no feasible solution. Hence, the problem (11) has a feasible solution if and only if \( t_L > r(p_{HC}^0, 1|e_L) \). Under this condition, the feasible region for \( \gamma_H \) is given by \( \gamma_{HL} < \gamma_H \leq 1 \). The optimal solutions specified in Parts (a) and (b) follow from the same proof steps of Proposition 1 by replacing the High type reservation profit 0 with \( t_H \). In Part (a), the condition \( k \leq k_3 \) ensures the High type participation constraint is binding, by similar argument used in Proposition 2, we can show that the responsibility risk for the High type is lower than that under full information. In Part (b), the condition \( k > k_3 \) ensures the High type participation constraint is not binding. Moreover, it can be verified that, when \( k_3 < k < k_4 \), both constraints in problem (11) are not binding; therefore, the buyer achieves the first-best cost as under full information. When \( k \geq k_4 \), the shutout constraint for the Low type becomes binding. Therefore, the responsibility risk for the High type becomes higher than that under full information.

Proof (Proposition 6) Suppose that \( t_H = t_L = t \). From the incentive compatibility constraint for the Low type in the problem (10), we have

\[
r(p_L, \gamma_L|e_L) \geq r(p_H, \gamma_H|e_L) - t > r(p_H, \gamma_H|e_H) - t \geq r(p_L, \gamma_L|e_H),
\]

where the second inequality follows from the fact that \( r(p_H, \gamma_H|e_L) > r(p_H, \gamma_H|e_H) \) and the third inequality follows from the incentive compatibility condition for the High type. Thus, the above constraint is more restrictive than the incentive compatibility constraint in (14). Moreover, the incentive compatibility constraint for the High type is also more restrictive than the corresponding constraint in (14). Therefore, we conclude that the sourcing cost under voluntary certification must be higher than that of mandatory certification. Furthermore, we note that the participation constraints in (14) are more restrictive than those in the original screening mechanism without certification (6), while the incentive compatibility constraints remain the same. Therefore, the sourcing cost under mandatory certification must be higher than that under the original screening mechanism without certification.