Motivating Supplier Social Responsibility under Incomplete Visibility

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Problem Definition: We examine how a profit-driven firm (she) can motivate better social responsibility (SR) practices by a supplier (he) when these practices cannot be perfectly observed by the firm. We focus on the firm's investment in the supplier's SR capabilities. To capture the influence of consumer demands, we incorporate the potential for SR information to be disclosed by the firm or revealed by a third party. **Academic/Practical Relevance:** Most firms have limited visibility into the SR practices of their suppliers. However, there is little research on how a firm under incomplete visibility should (i) invest to improve a supplier's SR practices and (ii) disclose SR information to consumers. We address this gap. **Methodology:** We develop a game-theoretic model with asymmetric information to study a supply chain with one supplier and one firm. The firm makes her investment decision given incomplete information about the supplier's current SR practices. We analyze and compare two settings – the firm does not disclose versus she discloses SR information to the consumers. **Results:** The firm should invest a high (low) amount in the supplier's capabilities if the information she observes suggests the supplier's current SR practices are poor (good). She should always be more aggressive with her investment when disclosing (versus not disclosing). This more aggressive strategy ensures better supplier SR practices under disclosure. When choosing between disclosing and not disclosing, the firm most likely prefers *not* to disclose when the supplier's current SR practices appear to be average. **Managerial Implications:** (i) Greater visibility helps the firm to better tailor her investment to the level of support needed. (ii) Better visibility also makes the firm more "truthful" in her disclosure, while increased third-party scrutiny makes her more "cautious." (iii) Mandating disclosure is most beneficial for SR when the suppliers' current practices appear to be average.

Keywords: Social responsibility, supply chain transparency, supplier development, information disclosure, game theory, information asymmetry

1. Introduction

Establishing socially responsible (SR) practices in a supply chain is a difficult task.[1] This is especially true when a firm has limited visibility into its suppliers' practices. A recent study by The Sustainability Consortium found that 81% of the 1,700 companies surveyed lacked full visibility into their suppliers (TSC 2016). However, improving supply chain visibility can be costly and time-consuming (Doorey 2011). As a result, complete visibility is rarely achieved. In this paper, we examine how a profit-driven firm (she) can motivate better SR practices from a supplier (he) when these practices cannot be perfectly observed by the firm. We focus on the firm's investment to improve the supplier's SR capabilities; e.g., the firm developing training programs to educate suppliers on proper labor practices. To capture how consumer demands can influence the firm's and the supplier's decisions, we include the potential for SR information to be disclosed by the firm or revealed by a third party (e.g., an independent NGO). Our results address how the firm under incomplete supply chain visibility should (i) invest to improve the supplier's SR practices and (ii) disclose SR information to consumers. Based on these results, we further show when and how these decisions influence the supplier's SR practices.

To motivate a supplier to improve his SR practices, a firm can either offer the supplier incentives (e.g., investment in the supplier's capabilities) or threaten the supplier with penalties (e.g., termination of business). We focus on a firm's investment in a supplier's SR capabilities because it has been shown to be highly effective in improving supplier practices (Porteous et al. 2015); however, it remains an underutilized and understudied method (Gillai et al. 2013). Our choice is motivated by recent examples of companies investing in their suppliers' SR capabilities. For instance, Starbucks has invested more than $100 million in farmer loans and other programs aimed at improving farmers' livelihoods along its supply chain.[2] Nestlé invests $25 million in loans each year for dairy farmers in developing countries to improve their living conditions. Relatedly, companies such as Intel, L'Oréal, and Walmart have developed online platforms for suppliers to access training and educational materials on SR topics.

In this paper, we study a supply chain with one supplier and one firm, both of whom are profit driven. The firm sells a product in a market where at least some consumers care whether the product is made in a socially responsible manner. To capture incomplete visibility, we model the supplier's current SR level as his *private* information. The firm has a prior belief about this level and observes a signal about it. In practice, an audit report is a good example of a signal since it only provides a snapshot of

[1] We follow the European Commission's definition of social responsibility as "[companies integrating] social and environmental concerns in their business operations and in their interaction with their stakeholders on a voluntary basis," (Dahlsrud 2008). We specifically focus on social concerns in social responsibility.

[2] All examples discussed in this paper were obtained from the companies' websites and their annual SR reports.

a supplier's current practices, and therefore, is subject to noise (EY and UN Global Compact 2016). How likely the signal captures the supplier's true current SR level depends on the firm's visibility into her supply chain. As an example of companies having different levels of supply chain visibility, consider Patagonia and REI. Patagonia annually audits 100% of its tier-1 suppliers, while REI only audits 75% of its tier-1 suppliers. Given this discrepancy, we postulate that Patagonia has greater visibility into the SR practices of its suppliers. We focus on a single-period interaction between the two parties where the firm has to make investment and disclosure decisions based on the information currently available to her. That is, we examine the firm's decisions for a given level of visibility, and do not analyze how she should optimize her visibility (e.g., through more auditing).

In our model, the supplier is the only party that can directly improve the SR practices of the supply chain; the firm can only help to reduce the cost of SR by investing in the supplier's capabilities. The firm is motivated to invest in the supplier in part because the supplier's SR practices may be observed and revealed to the consumers by an external third party. The third party captures independent NGOs and activists, such as the Clean Clothes Campaign and Amnesty International, who monitor and publicize potential labor and human rights issues in companies' supply chains. Similar to Chen and Lee (2017), we treat SR performance as a "soft" quality attribute, which can only be observed and verified at the supplier's site (e.g., working conditions). This feature differentiates our work from most of the quality management literature (e.g., Zhu et al. 2007, Babich and Tang 2012) because the supplier's SR performance cannot be inferred via product inspection by either the firm or the consumers.

We analyze two settings: (i) The firm does not disclose SR information to the consumers (*No Firm Disclosure*), and (ii) the firm discloses SR information to the consumers based on her available information (*Firm Disclosure*). In the latter case, the firm can increase her demand by disclosing, but she may also incur a penalty if she overstates the supplier's SR level. We then compare the two settings to study when the firm prefers to voluntarily disclose SR information. Within the operations management literature, there is a growing interest in the topic of supply chain transparency, both with respect to companies' visibility into their supply chains and the disclosure of SR information to consumers (e.g., Kalkanci and Plambeck 2018, Chen and Lee 2017, Kraft et al. 2018). We contribute to this stream of work by studying how a firm's incomplete visibility into a supplier's SR practices impacts her investment to improve the supplier's capabilities and her decision to disclose SR information.

We derive a number of key results. First, for a given disclosure setting, the firm should invest a high (low) amount of resources to improve the supplier's capabilities if the information she observes suggests the supplier's current SR practices are poor (good). Greater visibility can help the firm identify

whether the supplier needs significant support, and thus, better tailor her level of investment. However, in some cases better visibility can also help the firm realize the supplier's practices are acceptable. As a result, she may make a low investment in her supplier and limit the improvement in SR. In contrast, an increase in third-party scrutiny always leads to a larger improvement in SR.

Second, if the firm plans to disclose SR information to consumers, then she should always be more aggressive with her investment in the supplier (as compared to if she plans not to disclose). This more aggressive strategy ensures better SR practices under disclosure. Regarding the SR level disclosed by the firm, given the information available to her, she is likely to overstate (understate) the supplier's SR level if the supplier appears to have very poor (very good) current practices. With greater visibility, she becomes less likely to either overstate or understate the SR level. Conversely, increased third-party scrutiny makes her more "cautious"; i.e., she is more likely to understate the supplier's SR level.

Third, when choosing between disclosing and not disclosing, the firm most likely prefers not to disclose when the observed signal suggests that the supplier currently has average SR practices. An increase in either visibility or third-party scrutiny can inadvertently cause the firm to prefer not to disclose. The firm's preference not to disclose lowers her investment in the supplier, thus limiting the improvement in SR. Our findings demonstrate conditions when mandating disclosure (e.g., through regulations) is most effective in improving suppliers' SR practices.

Related literature and contributions: Our work is closely related to two streams of research: socially responsible operations and supplier development. Within the socially responsible operations literature, research based on analytical models typically examines one of two topics: (I) addressing SR risks in a supply chain through tools such as audits and inspections (e.g., Plambeck and Taylor 2016, Wang et al. 2016, Caro et al. 2018, Cho et al. 2018a); and (II) motivating better supplier SR practices. Recent works examining (I) have begun to study the effect of a firm's voluntary disclosure decision on suppliers' SR performance (e.g., Chen et al. 2018, Kalkanci and Plambeck 2018). The papers examining (II) consider several different methods including sourcing strategy (e.g., Guo et al. 2016, Agrawal and Lee 2018), supply chain design (e.g., Letizia and Hendrikse 2016, Zhang et al. 2017, Orsdemir et al. 2018), and supplier development (e.g., Mendoza and Clemen 2013).

The works most closely related to ours consider both topics (I) and (II). Chen and Lee (2017) analyze how a company can design incentive schemes in sourcing contracts (e.g., contingency payments) and invest in screening mechanisms (e.g., supplier certifications and process audits) to prevent unethical actions by a supplier. Lewis et al. (2016) investigate a mechanism design problem where a company can invest to develop a supplier's capabilities to achieve sustainable quality. In their setting, both

the company's demand and the supplier's production cost are private information. Cho et al. (2018b) examine a company's choice of inspection policy and wholesale price to combat a supplier's use of child labor. They study two separate scenarios: one in which the company's inspection policy is only known to the company, and the other in which the policy is also known to the supplier and third parties.

We add to this nascent but growing literature in three key aspects. First, we develop a new modeling framework to jointly capture a richer set of practical factors affecting firms' and suppliers' decisions related to SR. In particular, our model incorporates (i) a firm's incomplete visibility into her supplier's SR practices (modeled as a game of asymmetric information), (ii) the firm's supplier investment and voluntary disclosure decisions under such information asymmetry, and (iii) the risk of third-party scrutiny. By capturing *both* a firm's visibility into a supplier's practices *and* the firm's disclosure of information to consumers, we examine supply chain transparency in a more holistic manner. Second, while a handful of papers have begun to consider incomplete visibility in a supply chain (e.g., Chen and Lee 2017, Chen et al. 2018, Cho et al. 2018a), they focus on scenarios where the supplier may be one of two types. In contrast, we model the supplier's private information (about his current SR practices) as following a continuous distribution. To the best of our knowledge, Lewis et al. (2016) is the only paper in the socially responsible operations literature with a similar asymmetric information setup as ours; however, they do not examine the firm's potential voluntary disclosure of information to consumers. Third, we address topic (II), motivating better supplier SR practices, by analyzing an understudied approach – a firm's investment in a supplier's SR capabilities. This analysis is timely, as firms are increasingly realizing the importance of going beyond monitoring to actually develop better capabilities at their suppliers when addressing SR challenges (Locke et al. 2007, EY and UN Global Compact 2016). Our results offer valuable guidance on how firms should better leverage this underutilized approach to improve suppliers' SR practices, particularly under the constraint of incomplete visibility.

In the supplier development literature, a number of papers analyze how a buyer can use a contracting approach (e.g., offer a price premium) to improve a supplier's quality or process (e.g., Corbett and DeCroix 2001, Iyer et al. 2005, Zhu et al. 2007, Kim and Netessine 2013). We do not consider supply chain contracts because (i) in practice, the use of price premiums is rare and often ineffective for improving a supplier's SR practices (Porteous et al. 2015); and (ii) a supplier's SR level is difficult to measure and verify, and thus, often noncontractible (Norman and MacDonald 2004). As stated by the International Association for Contract and Commercial Management, "CSR contractual clauses remain generally unilaterally imposed, vague and formally hardly enforceable" (IACCM 2013). A group of works outside the contracting literature have applied analytical models to examine buyers'

supplier development decisions (e.g., Kim 2000, Babich 2010, Liu et al. 2010, Talluri et al. 2010, Wang et al. 2010, Karaer et al. 2017). Of these papers, the studies that are most closely related to ours examine a company's investment in supplier reliability, where the investment addresses the uncertainty in the outcome (e.g., production yield) of a known supplier type (Babich 2010, Liu et al. 2010, Wang et al. 2010). We instead consider a setting with information asymmetry, where the firm invests in the supplier's SR capabilities when the supplier's type is unknown to the firm.

2. Model Setup

Next, we review our model formulation and assumptions. We first discuss the setting where the firm does not disclose SR information to the consumers. We then introduce the case where the firm discloses.

2.1. No Firm Disclosure

We consider a supply chain with one firm (she) and one supplier (he). The firm sells a product in a market where at least some consumers care whether the product is made in a socially responsible manner. The supplier's current SR level, s_0, is his *private* information. We also refer to s_0 as the supplier's private type. The firm does not know the supplier's type but has a prior belief that s_0 is distributed on $[m, M]$ with cumulative distribution function (CDF) $\Phi(\cdot)$ and probability density function (PDF) $\phi(\cdot)$. We assume $\phi(x) > 0$ for all $x \in [m, M]$. We consider the supplier's current SR level as his private type because evidence exists that a majority of companies do not have full visibility into their suppliers' current SR practices (TSC 2016). Before any decision is made, the firm observes a signal (e.g., an audit report), $\tilde{s}$, that contains some information about s_0. The accuracy of the signal (i.e., how likely the signal is equal to s_0) depends on the firm's level of supply chain visibility, $v \in (0, 1)$. Specifically, with probability v, $\tilde{s} = s_0$; with probability $1 - v$, $\tilde{s}$ is equal to a random value drawn from the firm's prior belief. Therefore, with higher supply chain visibility (i.e., a higher value of v), the firm is more certain that the observed signal corresponds to the supplier's true current SR level. As an example of greater visibility, consider a company such as Patagonia that annually audits 100% of its tier-1 suppliers. We consider v as fixed and given, and the accuracy of $\tilde{s}$ as independent of s_0.

In our setting, the supplier is the only party that can directly impact the final SR level. Specifically, he can choose to increase SR from s_0 to any $s \geq s_0$.[3] We assume that the supplier will not reduce his

[3] Our model captures a hidden type (adverse selection) problem, not a hidden action problem; i.e., there is no stochastic outcome associated with the supplier's action in our model. The only asymmetric information (unknown to the firm) is the supplier's current SR level, s_0. Furthermore, we do not analyze a long-term interaction between the supplier and the firm where the supplier's SR level has evolved to a steady state. Instead, our modeling of s_0 as the supplier's private type (and subsequently his potential improvement of SR), is representative of a context where either SR has become a new requirement for the supplier or the firm has just started to work with the supplier.

SR level to $s < s_0$; i.e., he does not engage in practices that worsen his current SR level. The firm cannot directly impact SR, but she can indirectly influence the supplier's choice of s by investing in the supplier's capabilities. Our model setup captures the fact that while the firm can try to help, any actual improvement of the supplier's SR practices ultimately requires the supplier to take action to make the changes. The firm's investment decision is modeled as $\beta \in [0, 1]$, with β corresponding to the extent of reduction in the supplier's SR cost due to improved capabilities. In this regard, we operationalize improved supplier capabilities with a reduction in the supplier's SR cost. This approach captures practices of direct financial investments such as those offered by Starbucks and Nestlé. It also captures investments in supplier online training by companies such as Intel, whereby an empowered supplier with stronger capabilities can achieve the same SR improvement in a more cost-effective way.

The market consists of two types of consumers: An $\alpha \in (0, 1)$ fraction of the consumers are socially conscious (SC); the remaining $(1 - \alpha)$ fraction are socially neutral (SN). Demand from both types of consumers depends on the retail price r, which is fixed and exogenous. Demand from the SC consumers also depends on the supplier's final SR level if this information is revealed. Specifically, we model third-party scrutiny where the final SR level may be observed by a third party (e.g., an NGO) with a given, exogenous probability q. If the supplier's final SR level is below the consumers' minimum acceptable SR standard, then the third party reveals this information and the demand from SC consumers decreases.

The sequence of events is as follows: (i) After observing the signal $\tilde{s}$, the firm chooses her investment β to improve the supplier's SR capabilities. (ii) The supplier selects $s \geq s_0$ to be the final SR level. (iii) With probability q, the third party observes s. If s is below the SC consumers' minimum acceptable SR standard, then the third party reveals s to the consumers.[4] (iv) Finally, demand is realized, and the supplier and the firm earn their profits. Next, we discuss each step in more detail.

(i) Firm's investment in the supplier's SR capabilities: The firm makes her investment decision to maximize her expected profit, given signal $\tilde{s}$. Modeling a profit-maximizing firm is common in the socially responsible operations literature (e.g., Guo et al. 2016, Cho et al. 2018b, Orsdemir et al. 2018). The firm's expected profit can be written as

$$\mathbb{E}_{s_0}\left[\Pi_F\left(\beta, s^*(s_0, \beta)\right) | \, \tilde{s}\right] = \left(D_{SN} + \mathbb{E}_{s_0}\left[D_{SC}\left(s^*(s_0, \beta)\right) | \, \tilde{s}\right]\right)(r - w) - \delta(\beta). \tag{1}$$

Here D_{SN} is the demand from SN consumers; D_{SC} is the expected demand from SC consumers. The term $s^*(s_0, \beta)$ denotes the supplier's optimal decision on the final SR level given his current level s_0

[4] We model the third-party potentially observing and revealing the supplier's final SR level (rather than s_0). This approach is common in the literature (e.g., Plambeck and Taylor 2016, Chen and Lee 2017, Orsdemir et al. 2018).

and the firm's investment β. As the firm is a Stackelberg leader, by backward induction, she can fully anticipate $s^*(s_0, \beta)$ for every possible s_0 when choosing β. The final SR level does not affect demand D_{SN}, but it may affect demand D_{SC}. Since s_0 is the supplier's private information, when computing her expected profit, the firm takes the expectation over all possible values of s_0 based on her posterior belief given $\tilde{s}$. The term $(r - w)$ represents the firm's profit margin, where w is the wholesale price paid to the supplier. We model the wholesale price w as exogenous and independent of the supplier's SR level. Porteous et al. (2015) find in their survey of 334 companies that the top 3 most frequently used incentives to improve supplier social and environmental performance are preferred supplier status (56%), increased business (46%), and improved training (39%). Only 8% offer price premiums. Within the sustainable operations literature, a number of papers have examined settings with an exogenous wholesale price (e.g., Plambeck and Taylor 2016, Huang et al. 2017, Agrawal and Lee 2018). The function $\delta(\beta)$ captures the firm's cost to invest in the supplier's capabilities. We assume $\delta(\beta)$ to be strictly increasing, strictly convex, and twice-continuously differentiable in β with $\delta'(0) = 0$.

Investing in a supplier's SR capabilities could potentially help the firm gain better visibility into the supplier's practices in the long run. However, we focus on a single-period problem where the firm makes her decisions based only on the current signal she observes; we do not consider a multi-period setting where her current investment can influence her future level of visibility, which in turn affects future investment decisions. Our setup can be viewed as analyzing a firm's SR investment decision upon receiving a single audit report (and not taking into account audit reports received after the investment). As a result, we treat visibility v as fixed, exogenous, and independent of the firm's investment β.

(ii) Supplier's SR decision: The supplier selects $s \geq s_0$ to maximize his expected profit

$$\Pi_S(\beta, s) = \big(D_{SN} + D_{SC}(s)\big)\,(w - c) - (1 - \beta)\,\big(\rho(s) - \rho(s_0)\big). \tag{2}$$

The function $\rho(s)$ captures the supplier's fixed cost for his final SR level. We assume $\rho(s)$ to be strictly increasing, strictly convex, and twice-continuously differentiable in s. We model the supplier's cost of improving SR as $\rho(s) - \rho(s_0)$ to capture that the same increase in SR (from s_0 to s) is more costly at a higher value of s_0. We consider the supplier's current cost of SR at s_0 as a sunk cost.

The parameter c in Equation (2) represents the per-unit cost of production. This cost is exogenous, known to all parties, and independent of s and s_0. We make this choice because (i) our motivating examples involve non-production related SR investments, such as online supplier training; (ii) Rangan et al. (2015) find mixed evidence regarding the effect of SR investment on production costs – 32% (35%) of the 142 managers they surveyed reported decreased (increased) costs; and (iii) we capture

fixed rather than variable (i.e., per unit sold) costs of SR. The literature on supplier development has examined companies working to decrease suppliers' unit costs (e.g., Kim 2000, Kim and Netessine 2013) or fixed investment costs (e.g., Babich 2010, Mendoza and Clemen 2013). Our focus on reducing the supplier's fixed SR costs is in line with the common challenge that SR development typically requires high fixed costs but low variable costs (Borzaga and Becchetti 2010). Finally, we remark that investing in a supplier's capabilities (i.e., our model) differs from direct cost sharing. The former does not require the firm to know the supplier's actual cost of improving SR (which depends on the supplier's private information s_0). As a result, such an investment can be made under incomplete visibility, whereas cost sharing would be difficult if not impossible.

(iii) Third-party scrutiny: This modeling component captures the monitoring activities of independent NGOs and activists whose mission is to protect workers in developing countries and global supply chains. These groups allocate a majority of their time and resources to monitor and publicize SR issues in order to pressure companies to resolve them. As a result, they often have better insight into these issues than brand firms. For example, to investigate working conditions at factories, the Worker Rights Consortium (WRC) conducts independent, off-site worker interviews arranged by local organizations that the workers trust. To capture these practices, the third party in our model observes s with probability q after the firm and the supplier make their decisions. To delineate between what consumers feel are good and bad practices, we consider a minimum SR standard, $\hat{s} \in (m, M)$, such that the third party revealing $s = \hat{s}$ would have no impact on the demand from SC consumers. We focus on the third party only revealing bad practices with respect to SC consumers' minimum standard. That is, the third party reveals s to the consumers only if $s < \hat{s}$. If instead $s \geq \hat{s}$, then no information is revealed.

(iv) Demand and profits are realized: Following a common approach in the literature (e.g., Moorthy 1988, Bagnoli and Watts 2003), we model a continuum of consumers characterized by their private valuations of the product, θ, with θ being uniformly distributed on $[0, 1]$. Without loss of generality we normalize the total market size to 1. A consumer's type (SC or SN) is independent of his/her private valuation, and each consumer buys at most one unit of the product. We consider a given retail price $r < 1$ which applies to both types of consumers if they purchase the product.

SC consumers incur an additional utility equal to $\gamma(\min\{s, \hat{s}\})$ if they purchase the product and the third party reveals s (which occurs only if $s < \hat{s}$). The function $\gamma(\cdot)$ is assumed to be strictly increasing, strictly concave, and twice-continuously differentiable. As previously stated, revealing the minimum SR standard $\hat{s}$ has no impact on the demand from SC consumers; i.e., $\gamma(\hat{s}) = 0$. Since the third party only reveals $s < \hat{s}$, we have $\gamma(\min\{s, \hat{s}\}) < 0$ for any third-party revelation.

Given this setup, if no SR information is revealed, then all consumers behave in a similar manner (see, e.g., Dawkins 2004). A consumer with private valuation θ buys the product if and only if $\theta - r \geq 0$. If instead, the third party reveals s, then a SC consumer buys the product if and only if $\theta - r + \gamma(\min\{s, \hat{s}\}) \geq 0$, while a SN consumer buys the product if and only if $\theta - r \geq 0$. Recall that an α fraction of the consumers are SC. Thus, the expected demand for SN and SC consumers is written as

$$D_{SN} = (1-\alpha) \int_0^1 \mathbb{1}_{\theta \geq r} \, d\theta = (1-\alpha)(1-r),$$

$$\begin{aligned} D_{SC}(s) &= \alpha(1-q) \int_0^1 \mathbb{1}_{\theta \geq r} \, d\theta + \alpha q \int_0^1 \mathbb{1}_{\theta \geq r - \gamma(\min\{s,\hat{s}\})} \, d\theta \\ &= \alpha\big(1-q\big)(1-r) + \alpha q \max\Big\{0, \min\big\{1,\, 1 - r + \gamma(\min\{s,\hat{s}\})\big\}\Big\}, \end{aligned} \tag{3}$$

where $\mathbb{1}$ denotes the indicator function. We make the following assumption regarding demand.

Assumption 1. *A consumer with (i) the highest valuation $\theta = 1$ will always buy the product, i.e., $\gamma(m) > r - 1$; (ii) the lowest valuation $\theta = 0$ will never buy the product, i.e., $\gamma(s) < r$ for all s.*

Assumption 1 ensures that the firm captures at least some but not all of the market. Under this assumption, the term $\max\Big\{0, \min\big\{1,\, 1 - r + \gamma(\min\{s,\hat{s}\})\big\}\Big\}$ in Equation (3) simplifies to $1 - r + \gamma(\min\{s,\hat{s}\})$. The resulting total expected demand in the market (including both SN and SC consumers) is therefore equal to $1 - r + \alpha q \gamma(\min\{s,\hat{s}\})$.

2.2. Firm Disclosure

The key difference between the Firm Disclosure and No Firm Disclosure settings is the following: After step (ii) (the supplier's SR decision) and before step (iii) (third-party scrutiny), the firm chooses a (final) SR level, s_D, to disclose to the consumers. The value s_D is the SR level that the firm chooses to communicate to the consumers based on the information available to her. It does not necessarily match the supplier's final SR level (which is unknown to the firm). The firm discloses s_D before the third party may observe s. If the third party observes s, then it reveals s to the consumers only if the firm has overstated the supplier's SR level; i.e., if $s < s_D$. As a result, the firm incurs a penalty proportional to $(s_D - s)$ and the demand from SC consumers depends on s instead of s_D. If instead, the third party observes $s \geq s_D$ (i.e., the firm has not overstated the supplier's SR level) or if the third party does not observe s, then no information is revealed by the third party, and the demand from SC consumers depends on s_D. Disclosing SR information to consumers while still lacking full visibility into their supply chains is not uncommon for companies. For example, in 2014 Unilever published a

progress report about its Sustainable Palm Oil Policy and disclosed that 58% of the palm oil in their supply chain was traceable to known mills. Despite lacking visibility into the remaining 42%, they still shared information about some of the SR initiatives occurring in their palm oil supply chain.

In this setting, the firm's expected profit for a given signal $\tilde{s}$ can be written as

$$\mathbb{E}_{s_0}\big[\Pi_F(\beta, s_D, s^*(s_0,\beta))|\,\tilde{s}\big] = \Big(D_{SN} + \mathbb{E}_{s_0}\big[D_{SC}\big(s_D,\, s^*(s_0,\beta)\big)\,|\,\tilde{s}\big]\Big)(r-w) - \delta(\beta) - p\,q\,\mathbb{E}_{s_0}\big[\max\{s_D - s^*(s_0,\beta), 0\}\,|\,\tilde{s}\big]. \tag{4}$$

The impact of SR information on the expected value of D_{SC} depends on how $\min\{s^*, s_D\}$ (s_D) compares to $\hat{s}$ if the third party reveals (doesn't reveal) s^*. Besides the potential impact on demand, the firm may also incur a penalty if she overstates the supplier's SR level in her disclosure. The last term in Equation (4) corresponds to the expected penalty incurred by the firm if $s^* < s_D$. This penalty captures the loss of goodwill the firm suffers (e.g., brand damage) due to the third party revealing that she has overstated the supplier's SR level (see, e.g., Plambeck and Taylor 2016, Chen and Lee 2017, for similar goodwill costs). Thus, when selecting the optimal value of s_D to disclose, the firm must balance the tradeoff between possibly increasing demand and the risk of incurring a penalty from overstating.

The supplier's expected profit remains the same as in the No Firm Disclosure setting except that the expected value of D_{SC} now depends on both s and s_D. We do not include a penalty for the supplier because (i) we are not investigating a compliance setting where the firm imposes a penalty on the supplier for the discovery of poor practices (as in Plambeck and Taylor 2016); and (ii) levying penalties on suppliers in developing countries can be difficult (as discussed in Chen and Lee 2017). Note however that like the firm, the supplier does potentially suffer a loss of demand if the third party reveals $s < \hat{s}$.

With respect to demand, a SC consumer will buy the product if and only if $\theta - r + \gamma(y) \geq 0$, where $y = s_D$ when the third party does not observe or reveal s, and $y = \min\{s, s_D\}$ when the third party observes and reveals s (which occurs only if $s < s_D$). Given Assumption 1 stated earlier, the expected demand from SC consumers can be written as $D_{SC}(s_D, s) = \alpha\,(1-q)\int_0^1 \mathbb{1}_{\theta \geq r-\gamma(s_D)}\,d\theta + \alpha\,q\int_0^1 \mathbb{1}_{\theta \geq r-\gamma(\min\{s,s_D\})}\,d\theta = \alpha\,(1-q)\big(1-r+\gamma(s_D)\big) + \alpha\,q\,\big(1-r+\gamma(\min\{s,s_D\})\big)$.

We next analyze the firm's and the supplier's decisions in the No Firm Disclosure (§3) and Firm Disclosure (§4) settings. In §5 we compare the two settings and study when the firm prefers to disclose versus not disclose SR information. In each section we examine how the firm's decisions and the supplier's final SR level depend on the level of visibility and the probability of third-party scrutiny. Results presented in Appendix A and the online appendix are referenced as A.X and O.X. We discuss in Appendix B four extensions to our model: (i) the firm is penalized for not disclosing; (ii) the third

Table 1 Notation

Decision Variables	
β	Firm's investment to improve the supplier's SR capabilities; $\beta \in [0,1]$
s	Supplier's final SR level; $s \geq s_0$
s_D	Firm's *disclosed* final SR level (Firm Disclosure setting only)
SR-related Variables	
s_0	Supplier's current SR level; $s_0 \in [m, M]$ and is the supplier's private information
$\tilde{s}$	Signal the firm observes regarding s_0
$\hat{s}$	Minimum SR standard of SC consumers; $\hat{s} \in (m, M)$
q	Probability that the third party observes s; $q \in (0,1)$
v	Level of supply chain visibility the firm has; $v \in (0,1)$
Cost and Demand Parameters	
r	Unit retail price
w	Unit wholesale price paid by the firm to the supplier
c	Supplier's per-unit cost of production
p	Penalty factor the firm incurs if the third party discloses $s < s_D$ (Firm Disclosure setting only); $p > 0$
θ	Consumers' private valuation for the product; $\theta \sim U[0,1]$
α	Fraction of consumers who are socially conscious; $\alpha \in (0,1)$
$\delta(\beta)$	Firm's cost to invest β in the supplier's SR capabilities; $\delta'(\beta) > 0$ for $\beta > 0$, $\delta'(0) = 0$, and $\delta''(\beta) > 0$
$\rho(s)$	Supplier's fixed cost of SR at level s; $\rho'(s) > 0$ and $\rho''(s) > 0$
$\gamma(\cdot)$	SC consumer's additional utility from the disclosure of SR information; $\gamma'(\cdot) > 0$ and $\gamma''(\cdot) < 0$

party reveals any value of s that it observes; (iii) an incorrect signal always inflates s_0; and (iv) the firm incorporates SR into her objective function. In general, most of our conclusions and insights from the main model remain true in these extensions. Table 1 summarizes our notation.

3. Results: No Firm Disclosure

We first analyze the setting where the firm does not disclose any SR information to the consumers. We address the following questions: (i) What is the firm's optimal investment to improve the supplier's SR capabilities? (ii) Given this investment, what is the supplier's optimal choice of SR? (iii) How are these decisions affected by the signal about the supplier's type, the firm's visibility, and the probability of third-party scrutiny? Throughout our analysis we define $R_f(x)$ as the ratio $\frac{f''(x)}{f'(x)}$ for any function $f(x)$ and make the following assumptions.

Assumption 2. *(i) For any investment $\beta > 0$, the lowest supplier type (with $s_0 = m$) always increases his SR level. (ii) It is never optimal for the firm to choose β so high that the highest supplier type (with $s_0 = M$) would increase his SR level.*

Assumption 3. *$R_\rho(s)$ is non-decreasing in s and $R_\gamma(s)$ is non-increasing in s.*

Assumption 4. *For any $\beta \in (0,1]$, $R_\delta(\beta)(1-\beta) \geq 1 + \frac{\phi(s_m^*)}{\Phi(s_m^*)} \frac{1}{R_\rho(s_m^*) - R_\gamma(s_m^*)}$, where $s_m^* \equiv s^*(m, \beta)$.*

Assumption 2 ensures interior solutions to both the firm's and the supplier's optimization problems. Assumption 3 means that when s is already high, the supplier's cost of SR, $\rho(s)$, increases sharply as s increases, and when s is already low, SC consumers' additional utility from SR, $\gamma(s)$, decreases sharply as s decreases. That is, the cost of SR increases rapidly if the supplier attempts to achieve very good SR practices. Conversely, SC consumers' demand for the product drops significantly when the supplier's SR practices approach a very poor level. Finally, Assumption 4 captures that investing to improve the supplier's practices is very costly to the firm when she has limited visibility into her supplier. The term $R_\delta(\beta)\,(1-\beta) \geq 1$ implies that as the investment β increases, the relative increase in the firm's cost (captured by $R_\delta(\beta)$) is greater than the relative reduction in the supplier's cost (captured by $(1-\beta)$). The second term on the right-hand side further implies that under incomplete visibility the relative increase in the firm's cost is even greater. Assumptions 3 and 4 are sufficient conditions that ensure the firm's objective function is bimodal in β. Note that our assumptions are satisfied by the following families of functions, all of which are commonly used in the literature (e.g., Mendoza and Clemen 2013, Plambeck and Taylor 2016, Cho et al. 2018b): $\rho(s) = e^{as}$ with $a > 0$; $\gamma(s) = K_1 - e^{-bs}$ with $K_1 \in (0, r]$ and $b > 0$; $\delta(\beta) = \frac{K_2 \beta^y}{(1-\beta)^z}$ with $K_2 > 0$, $y \geq 2$, and $z \geq 1$; and s_0 uniformly distributed on $[m, M]$.[5]

We first analyze the supplier's optimal choice of SR for a given value of β. Following §2.1, the supplier's problem can be specified as

$$\max_{s \geq s_0} \Big(1 - r + \alpha\, q\, \gamma\big(\min\{s, \hat{s}\}\big)\Big)\,(w - c) - (1-\beta)\,\big(\rho(s) - \rho(s_0)\big). \tag{5}$$

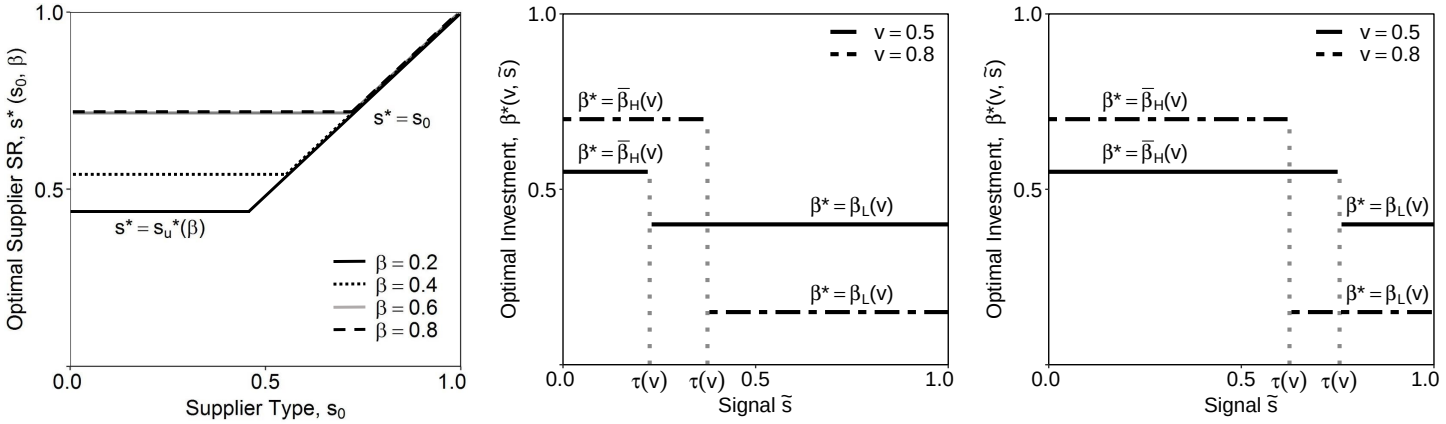
We define the *unconstrained supplier's problem* as the maximization problem in Equation (5) without the constraint $s \geq s_0$. Let $s_u^*(\beta)$ denote the unique optimal solution to the unconstrained problem. The following theorem characterizes the supplier's optimal decision.

THEOREM 1. *Given β, the supplier's optimal SR decision is $s^*(s_0, \beta) = \max\big\{s_0, s_u^*(\beta)\big\}$. Furthermore, $\dfrac{\partial s^*(s_0,\beta)}{\partial \beta} \geq 0$, $\dfrac{\partial s^*(s_0,\beta)}{\partial q} \geq 0$, and $s_u^*(\beta) \leq \hat{s}$ for all $\beta \in [0,1]$.*

Figure 1a illustrates Theorem 1. For any s_0, the supplier's best response to the firm's investment is as follows: if s_0 is strictly lower than $s_u^*(\beta)$, then the supplier increases his SR level to $s_u^*(\beta)$; otherwise, the supplier does not improve his SR level (i.e., $s^*(s_0, \beta) = s_0$). Furthermore, since the third party never communicates values of s greater than $\hat{s}$ to consumers, the supplier has no incentive to improve his SR level beyond $\hat{s}$. Thus, $s_u^*(\beta) \leq \hat{s}$ for all β. This explains why the supplier's best response is identical for $\beta = 0.6$ and $\beta = 0.8$ in Figure 1a.

[5] The denominator in $\delta(\beta)$ ensures that the firm's investment cost goes to ∞ as β goes to 1; i.e., the firm can never reduce the supplier's SR cost to zero. We numerically analyze a number of other commonly-studied functional forms and distributions that do not satisfy Assumptions 3 and 4. These include $\gamma(s) = b\sqrt{s} - K_1'$, $\delta(\beta) = K_2'\beta^4$, $\rho(s) = as^2$, and s_0 distributed Beta(d_1,d_2), with different values of K_1', K_2', a, b, d_1, and d_2. All of our results in the paper continue to hold.

Figure 1 Illustrative Examples: Supplier's Optimal SR Decision (1a); Firm's Optimal Investment (1b and 1c)



(a) $s^*(s_0, \beta)$ for different values of β (b) $\tau(v)$ increases in v (Eq. (7) holds) (c) $\tau(v)$ decreases in v (Eq. (7) doesn't hold)

Based on the supplier's best response, we next characterize the firm's optimal investment to improve the supplier's SR capabilities. The firm solves the following problem:

$$\max_{\beta \in [0,1]} \left(1 - r + \alpha\, q\, \mathbb{E}_{s_0}\Big[\gamma\big(\min\{s^*(s_0,\beta), \hat{s}\}\big) \,\Big|\, \tilde{s}\Big]\right)(r - w) - \delta(\beta), \tag{6}$$

where $\mathbb{E}_{s_0}\Big[\gamma\big(\min\{s^*(s_0,\beta), \hat{s}\}\big) \,\Big|\, \tilde{s}\Big]$ captures the expected change in demand from SC consumers if the third party observes and reveals the supplier's final SR level. We define $\hat{\beta}$ such that $s_u^*(\hat{\beta}) = \hat{s}$; i.e., $\hat{\beta}$ is the minimum investment needed from the firm to ensure that the supplier's final SR level is at least $\hat{s}$. Our next result characterizes the firm's optimal investment decision for a given level of visibility, v.

THEOREM 2. *For a given level of visibility v, there exist $\beta_L(v)$ and $\beta_H(v)$ such that $0 \le \beta_L(v) \le \beta_H(v) < 1$, and the firm's optimal investment, $\beta^*(v, \tilde{s})$, is defined as follows:*

(a) If $\beta_L(v) \ge \hat{\beta}$, then $\beta^*(v, \tilde{s}) = \hat{\beta}$ for all $\tilde{s}$.

(b) If $\beta_L(v) < \hat{\beta}$, then there exists a threshold $\tau(v) \in (m, \hat{s})$ such that:

(i) If $\tilde{s} \le \tau(v)$, then $\beta^*(v, \tilde{s}) = \bar{\beta}_H(v) \equiv \min\{\beta_H(v), \hat{\beta}\}$;

(ii) If $\tilde{s} > \tau(v)$, then $\beta^*(v, \tilde{s}) = \beta_L(v)$.

In Theorem 2(a), motivating the supplier to increase his SR level to at least $\hat{s}$ requires a low investment from the firm. Hence, the firm invests $\hat{\beta}$ for any signal observed. Theorem 2(b) is illustrated in Figures 1b and 1c for two levels of visibility. In this case, the firm's optimal investment can take two possible values: a low investment $\beta_L(v)$ or a high investment $\bar{\beta}_H(v)$. If the observed signal $\tilde{s}$ is below the threshold $\tau(v)$, then it is optimal for the firm to make a high investment, $\bar{\beta}_H(v)$. This is because the signal indicates that the supplier may currently have poor SR practices. Conversely, if $\tilde{s}$ is above $\tau(v)$, then it is optimal for the firm to make a low investment, $\beta_L(v)$, because the signal indicates that

the supplier may already have good SR practices. The firm makes this low investment only to help improve the supplier's SR level in case s_0 is in fact low (i.e., the observed signal does not represent the true value of s_0). If the observed signal is correct (i.e., $s_0 = \tilde{s} > \tau(v)$), then the supplier's best response to $\beta_L(v)$ is simply to stay at s_0. In our subsequent analysis, we focus on case (b) in Theorem 2, when it is too costly for the firm to motivate all supplier types to achieve a final SR level that is at least $\hat{s}$.

Theorem 2(b) aligns with investment strategies observed in practice. For example, Starbucks focuses most of its efforts on improving the practices of disadvantaged farmers in developing countries. More generally, a recent study by the Organization for Economic Cooperation and Development (OECD) and the World Trade Organization (WTO) found that over 65% of the 219 companies surveyed engaged in supplier development activities in developing countries. Of these activities, more than 40% were driven by the companies' SR agendas, with 31% of the companies citing better working conditions as one of the main results achieved (OECD/WTO 2013).

3.1. The Effect of Visibility on the Firm's Optimal Investment Strategy and the Supplier's Final SR Level

The following proposition demonstrates how improved supply chain visibility helps the firm to better tailor her investment in the supplier's SR capabilities. However, such an increase in visibility may not lead to an improvement in (expected) supplier SR. To simplify notation, hereafter we drop the argument (v) and write β_H, $\bar{\beta}_H$, β_L, and τ.

PROPOSITION 1. *(i) β_L is strictly decreasing in v and β_H is strictly increasing in v. (ii) The threshold τ is increasing in v if and only if*

$$\delta\big(\bar{\beta}_H\big) - \delta\big(\beta_L\big) > \alpha\, q\,(r-w)\,\mathbb{E}_{s_0}\Big[\gamma\big(\min\{s^*(s_0,\bar{\beta}_H),\hat{s}\}\big) - \gamma\big(\min\{s^*(s_0,\beta_L),\hat{s}\}\big)\,\Big|\,\tilde{s}\neq s_0\Big]. \tag{7}$$

(iii) Define the expected final SR level given supplier type s_0 as $ES(v,s_0) \equiv v s^*\big(s_0,\beta^*(v,s_0)\big) + (1-v)\int_{\tilde{s}\in[m,M]} s^*\big(s_0,\beta^*(v,\tilde{s})\big)\phi(\tilde{s})\mathrm{d}\tilde{s}$. There exists a range of supplier types $s_0 \in (m,M)$ such that, for high enough v, the expected final SR level is strictly decreasing in v.

Proposition 1(i) shows how the two potential investment values in the firm's optimal strategy change with visibility. As v increases, the firm becomes more confident that the signal she observes captures the supplier's true current SR level. As a result, the firm increases (decreases) her investment if the supplier likely has poor (good) SR practices as suggested by the signal; i.e., if $\tilde{s} \le \tau$ $(\tilde{s} > \tau)$. Thus, greater visibility into the supplier's practices allows the firm to utilize her resources more efficiently.[6]

[6] The special cases of $v=0$ and $v=1$ further illustrate how visibility impacts the firm's investment. If the firm had no visibility ($v=0$ and hence, the signal is uninformative), then she should invest the same amount regardless of $\tilde{s}$ (i.e., $\beta_L(0) = \beta_H(0)$). Conversely, if she had full visibility ($v=1$ and hence, $\tilde{s} = s_0$ with certainty), then she should not invest at all in high supplier types (i.e., $\beta_L(1) = 0$).

Proposition 1(ii) specifies the condition under which the threshold τ increases or decreases with v. The left-hand side of Equation (7) captures the firm's cost difference between a high and a low investment. The right-hand side of Equation (7) captures the firm's expected revenue gain from making a high versus a low investment *if* she observes an incorrect signal (i.e., $\tilde{s} \neq s_0$). The intuition behind Proposition 1(ii) is as follows. If the cost difference between a high and a low investment is large relative to the expected revenue gain, then the firm is reluctant to choose a high investment. In this case, greater visibility – i.e., increased confidence that the signal captures the true supplier type – can convince her that investing $\bar{\beta}_H$ is worthwhile for a wider range of $\tilde{s}$ values. Thus, the threshold τ increases as v *increases* (Figure 1b). Conversely, if the cost difference is small relative to the expected revenue gain, then the firm is willing to make a high investment in general. With worse visibility, she is less confident that the signal is correct. Hence, she opts for investing $\bar{\beta}_H$ for a wider range of $\tilde{s}$ values to ensure that the supplier's final SR level is acceptable. As a result, the threshold τ increases as v *decreases* (Figure 1c).

Even though higher visibility allows the firm to better tailor her investment in the supplier, Proposition 1(iii) demonstrates that this does not necessarily generate a higher (expected) level of SR.[7] Numerically, we observe that while greater visibility generally increases the expected SR level, it can lead to a lower expected SR level if the supplier's type takes an intermediate value. In this case, when visibility is not high (hence the signal is often incorrect), the firm makes a high investment to ensure good practices. The (intermediate) supplier responds to this high investment by increasing his SR level. When visibility is instead high, the firm is more likely to observe s_0 correctly and realize that the supplier's current practices are acceptable. As a result, she reduces her investment when observing $\tilde{s} = s_0$, leading to a lower expected final SR level. Proposition 1(iii) shows that this case always exists for some intermediate s_0 values.

3.2. The Effect of Third-Party Scrutiny on the Firm's Optimal Investment Strategy and the Supplier's Final SR Level

As NGOs and activists become more sophisticated, they are increasingly leveraging technology to monitor and pressure companies to establish good SR practices in their supply chains (IISD 2018). For example, in its recent "Coconut Campaign," Dutch NGO Fair Food used blockchain technology to ensure that Indonesian coconut farmers are given a fair wage for their produce (Nyamadzawo 2017).

[7] Note that visibility impacts SR in two ways: (i) it affects the accuracy of the signal $\tilde{s}$, and (ii) it affects the firm's investment given $\tilde{s}$. Therefore, to understand the combined effect, we analyze how visibility impacts the *expected* final SR level for a given supplier type s_0, with the expectation taken over all possible signals that the firm may observe.

We next examine the effect of such third-party scrutiny on the firm's investment strategy and on the supplier's final SR level.

PROPOSITION 2. *(i)* β_L *and* β_H *are not monotone in* q*. (ii) The threshold* τ *is strictly increasing in* q*. (iii)* $\mathrm{d}s^*(s_0, \beta^*(\tilde{s}, q), q)/\mathrm{d}q \geq 0$ *for all* $s_0, \tilde{s} \in [m, M]$*.*

Proposition 2(i) indicates that the values of β_L and β_H can be either increasing or decreasing in q. In particular, if the sensitivity of the SR cost, $\rho(s)$, with respect to s is similar to that of SC consumers' valuation of SR, $\gamma(s)$, then β_L and β_H are likely to increase in q. Conversely, if the sensitivity of these two terms with respect to s is drastically different, then the two investment values are likely to decrease in q (see Appendix O.2). However, regardless of how q impacts β_L and β_H, Proposition 2(ii) shows that as the probability of third-party scrutiny increases, the firm prefers the high investment $\bar{\beta}_H$ over the low investment β_L for a wider range of signals. To understand the reason behind this result, consider the signal $\tilde{s} = \tau$ for which the firm is indifferent between making a high or a low investment. As q increases, the final SR level $s^*(\tau, \beta)$ is more likely to be revealed to the consumers. Hence, it is in the firm's best interest to make a high investment to ensure acceptable practices at the supplier. Therefore, she prefers $\bar{\beta}_H$ over β_L for a wider range of signals when q increases.

Interestingly, even though by Proposition 2(i) an increase in q can lead to a decrease in the firm's investment, we find that it never decreases the supplier's final SR level. In our model, third-party scrutiny impacts the supplier's SR decision in two ways. First, by changing the demand from SC consumers, a higher q directly results in a higher SR decision by the supplier. Second, q indirectly impacts the supplier's SR level through its (nonmonotone) effect on the firm's investment. Proposition 2(iii) shows that the direct impact of q on demand dominates the indirect impact of q on the firm's investment. Thus, the supplier is always more motivated to improve his SR practices when there is a higher chance that these practices will be observed and publicized by the third party.

4. Results: Firm Disclosure

We next examine the setting where the firm discloses SR information to the consumers. In this setting, the firm may increase demand by disclosing, but she may also suffer a penalty if the third party later discovers and reveals that she has overstated the supplier's final SR level. We address the same questions raised at the start of §3 and an additional question: What SR level should the firm disclose? We will use subscript D on the relevant variables to indicate the Firm Disclosure setting.

First, we analyze the supplier's optimal choice of SR given the firm's investment β_D and the final SR level disclosed, s_D.[8] The supplier's problem can be written as

$$\max_{s \geq s_0} \Big(1 - r + \alpha\,(1-q)\,\gamma(s_D) + \alpha\,q\,\gamma\big(\min\{s, s_D\}\big)\Big)\,(w-c) - (1-\beta_D)\,\big(\rho(s) - \rho(s_0)\big). \tag{8}$$

Comparing to Equation (5), the only change in the Firm Disclosure setting is that the expected demand from SC consumers is now affected by the firm's disclosure, s_D. That is, if the third party does not observe the supplier's final SR level (which occurs with probability $1-q$), then the demand from SC consumers (α fraction of the market) depends on $\gamma(s_D)$. If instead the third party observes the final SR level (which occurs with probability q), then it reveals this information only if the firm has overstated the supplier's SR level. In this case, the impact to the demand from SC consumers is $\gamma\big(\min\{s, s_D\}\big)$. Still, the structure of the supplier's optimal SR decision, $s^*(s_0, \beta_D)$, remains the same as in Theorem 1, except that now the unconstrained optimal solution satisfies $s^*_{uD}(\beta_D) \leq s_D$ (Theorem A.1).[9]

We next analyze the firm's investment in the supplier's SR capabilities and her choice of what final SR level to disclose. The firm solves the following problem:

$$\max_{\beta_D \in [0,1]} \Bigg\{ \max_{s_D \in [m, M]} \Bigg\{ \Big(1 - r + \alpha\,(1-q)\,\gamma(s_D) + \alpha\,q\,\mathbb{E}_{s_0}\Big[\gamma\big(\min\{s^*(s_0, \beta_D), s_D\}\big) \,\Big|\, \tilde{s}\Big]\Big)(r-w) \\ - \delta(\beta_D) - p\,q\,\mathbb{E}_{s_0}\Big[\max\big\{s_D - s^*(s_0, \beta_D), 0\big\} \,\Big|\, \tilde{s}\Big]\Bigg\}\Bigg\}. \tag{9}$$

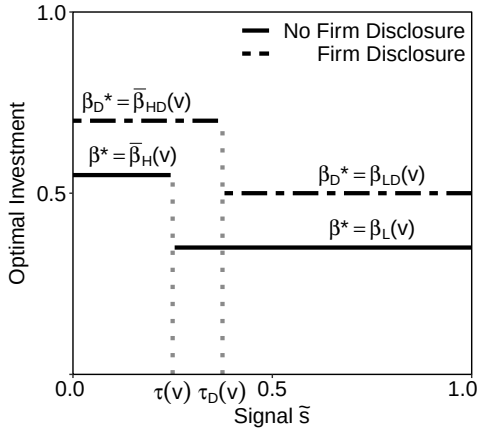
The inner maximization solves for the firm's optimal disclosure decision given the investment she has made in the supplier. The outer maximization solves for the firm's optimal investment, taking into account its effect on the supplier's SR decision and the firm's own disclosure decision. The firm anticipates the supplier's optimal SR decision $s^*(s_0, \beta_D)$ for each possible s_0 when making her decisions. The last term in Equation (9) captures the expected penalty incurred by the firm if she overstates the supplier's SR level and the third party later reveals the supplier's actual final SR level.

The structure of the firm's optimal investment $\beta^*_D(v, \tilde{s})$ in this setting remains the same as in the No Firm Disclosure setting (Theorem A.2). As illustrated in Figure 2, the firm makes a high investment $\bar{\beta}_{HD}(v) \equiv \min\{\beta_{HD}(v), \hat{\beta}_D\}$ if the observed signal $\tilde{s}$ is less than or equal to a threshold $\tau_D(v)$. Otherwise,

[8] Since the firm does not observe the true supplier type s_0 due to incomplete visibility, she cannot condition her disclosure decision on s_0 or the corresponding optimal SR decision by the supplier. Thus, from a mathematical standpoint, the supplier's SR decision and the firm's disclosure decision can be considered as being made simultaneously.

[9] Technically, s^* also depends on s_D. We do not include s_D in the expression of s^* because (i) s_D affects s^* only by imposing an upper bound on s^*, and (ii) in equilibrium, this upper bound is already captured by the maximum investment, $\hat{\beta}_D$, that the firm may make.

Figure 2 Firm's Optimal Investment under No Firm Disclosure versus Firm Disclosure

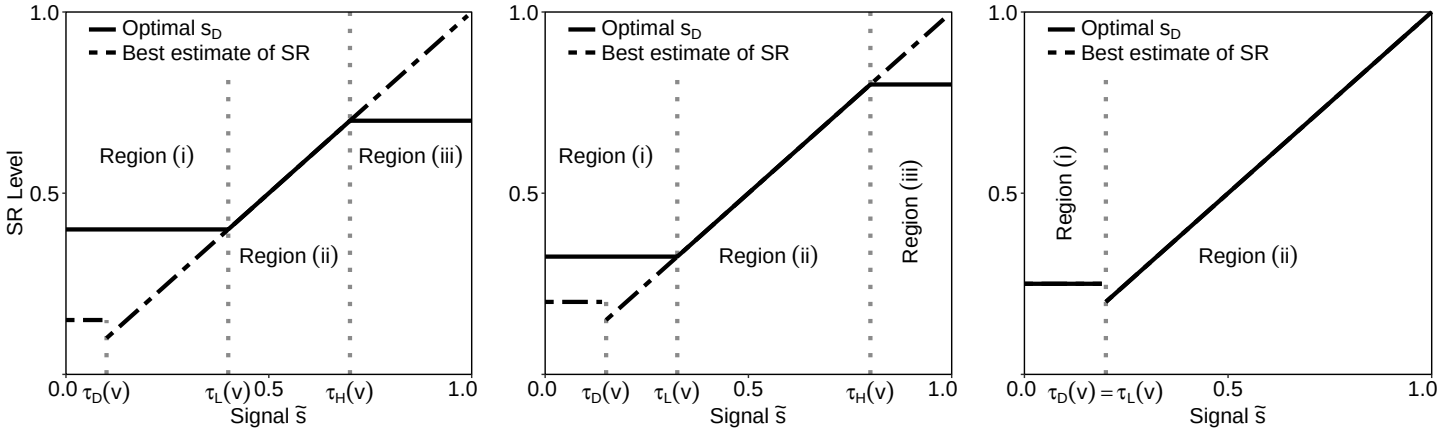


if $\tilde{s} > \tau_D(v)$, then the firm makes a low investment $\beta_{LD}(v)$.[10] The effects of v and q on the firm's optimal investment decision are also qualitatively the same as in the No Firm Disclosure setting (Propositions A.2–A.3). To simplify notation, hereafter we drop the argument (v) and write $\bar{\beta}_{HD}$, β_{HD}, β_{LD}, and τ_D.

Although the structure of the firm's optimal investment remains the same, we note that the firm's optimal investment in the Firm Disclosure setting is strictly higher than that in the No Firm Disclosure setting. In particular, for any level of visibility v and signal $\tilde{s}$, $\beta_{LD} > \beta_L$, $\bar{\beta}_{HD} > \bar{\beta}_H$, and $\tau_D > \tau$. *Therefore,* $\beta_D^*(v, \tilde{s}) > \beta^*(v, \tilde{s})$ *always holds* (Proposition A.1). This result follows from the fact that in the Firm Disclosure setting, there is always a positive chance that the firm incurs a penalty for overstating the supplier's final SR level. Thus, when the firm discloses SR information to the consumers, she invests a *strictly higher* amount of resources to improve the supplier's SR capabilities as compared to when she does not disclose SR information (Figure 2). In practice, regulators and third parties are increasingly pressuring companies to disclose SR information. For example, in a 2017 survey of 4,900 companies, KPMG found that one of executives' biggest concerns regarding CSR reporting was regulation and how it is only going to increase in the coming years (KPMG 2017). Similarly, in 2017, the NGO Human Rights Watch (HRW) campaigned for 72 companies in the apparel industry to sign a transparency pledge and to agree to disclose their tier-1 supplier lists (HRW 2017). Given this trend, our results suggest that firms should be prepared to increase their investments in suppliers going forward.

[10] As in Theorem 2(a), if it is inexpensive to motivate the supplier to improve his SR practices, then regardless of the signal, it is optimal for the firm to make a high (and uniform) investment, $\hat{\beta}_D$. We focus here on the more interesting case when this strategy is too costly for the firm.

Figure 3 Optimal Disclosed SR Level by the Firm



(a) Low Visibility ($v = 0.5$) (b) Medium Visibility ($v = 0.7$) (c) High Visibility ($v = 0.9$)

4.1. What SR Level Should the Firm Disclose?

When deciding the SR level to disclose, s_D, the firm faces a tradeoff: capturing additional demand from disclosing a high s_D versus risking a penalty if s_D turns out to be higher than the supplier's actual final SR level. The firm's optimal disclosed level $s_D^*(v, \tilde{s})$ is characterized by the following theorem.

THEOREM 3. *(a) If $\beta_{LD} \geq \hat{\beta}_D$, then $s_D^*(v, \tilde{s}) = s^*(m, \hat{\beta}_D)$ for any v and $\tilde{s}$.*

(b) If $\beta_{LD} < \hat{\beta}_D$ and $\alpha(1-q)(r-w)\gamma'(M) \geq pq$, then $s_D^*(v, \tilde{s}) = M$ for any v and $\tilde{s}$.

(c) If $\beta_{LD} < \hat{\beta}_D$ and $\alpha(1-q)(r-w)\gamma'(M) < pq$, then for a given level of visibility v, there exists thresholds $\tau_L(v)$ and $\tau_H(v)$ satisfying $m < \tau_D \leq \tau_L(v) < \tau_H(v) \leq M$, such that $s_D^*(v, \tilde{s})$ is as follows:

Region (i) If $\tilde{s} < \tau_L(v)$, then $s_D^*(v, \tilde{s}) \in [s^*(\tilde{s}, \beta_D^*(v, \tilde{s})), M)$. In addition, $s_D^*(v, \tilde{s})$ is either constant or piece-wise constant in $\tilde{s}$, with at most one discontinuous drop at $\tilde{s} = \tau_D$.

Region (ii) If $\tau_L(v) \leq \tilde{s} \leq \tau_H(v)$, then $s_D^*(v, \tilde{s}) = s^*(\tilde{s}, \beta_D^*(v, \tilde{s})) = \tilde{s}$.

Region (iii) If $\tilde{s} > \tau_H(v)$, then $s_D^*(v, \tilde{s}) = \tau_H(v) < s^*(\tilde{s}, \beta_D^*(v, \tilde{s})) = \tilde{s}$.

Theorem 3(a) captures a scenario when an overstated disclosure is very costly to the firm (e.g., under a high penalty factor p or a high possibility of third-party scrutiny q). In this case, the firm is overly cautious. She invests the maximum amount $\hat{\beta}_D$ regardless of the supplier type but discloses the lowest possible final SR level given her investment; i.e., $s^*(s_0 = m, \hat{\beta}_D)$. In contrast, Theorem 3(b) captures the opposite scenario when the potential penalty associated with an overstated disclosure is very small (e.g., under a low p and q). As a result, the firm discloses the highest possible final SR level, M, regardless of the observed signal $\tilde{s}$.

Figure 3 illustrates Theorem 3(c). First note that in our setup, given v and $\tilde{s}$, the most likely value of s_0 from the firm's perspective is $s_0 = \tilde{s}$. Thus, the value $s^*(\tilde{s}, \beta_D^*(v, \tilde{s}))$ represents the final

SR level of the most likely supplier type from the firm's standpoint. We refer to this value as the firm's *best estimate* of the supplier's final SR level. The firm does not always communicate her best estimate when disclosing. For example, when she observes a low signal (i.e., Region (i) of Theorem 3(c) and Figure 3), she may choose to overstate the final SR level with respect to her best estimate ($s_D^*(v,\tilde{s}) \geq s^*\big(\tilde{s},\beta_D^*(v,\tilde{s})\big)$). This is in part because if the low signal was incorrect, then the actual supplier type would likely be higher than the signal (i.e., $s_0 > \tilde{s}$ is likely). Thus, the risk of overstating and incurring a potential penalty is small relative to the benefit of attracting higher demand from SC consumers with a higher s_D. The firm's decision when she observes a high signal (i.e., Region (iii) of Theorem 3(c) and Figure 3) is just the opposite. She now faces a high risk from overstating if the signal is wrong (i.e., the actual supplier type is lower). Hence, she chooses to be conservative and understates the final SR level compared to her best estimate ($s_D^*(v,\tilde{s}) < s^*\big(\tilde{s},\beta_D^*(v,\tilde{s})\big)$). Our result that the firm possibly understates the supplier's SR level in her disclosure relates to recent works on brownwashing in the strategy literature (e.g., Kim and Lyon 2015).

Finally, when the firm observes a signal that lies in the intermediate range (i.e., Region (ii) of Theorem 3(c) and Figure 3), she discloses her best estimate, $s^*\big(\tilde{s},\beta_D^*(v,\tilde{s})\big)$, to the consumers. In Region (ii), her best estimate is exactly equal to $\tilde{s}$. This is because for $\tilde{s} > \tau_D$, it is optimal for the firm to make a low investment (i.e., $\beta_D^*(v,\tilde{s}) = \beta_{LD}$; Theorem A.2). As a result, the best response of a supplier with type $s_0 = \tilde{s} > \tau_D$ is to simply stay at $\tilde{s}$ (Proposition A.4). In our subsequent analysis, we focus on case (c) in Theorem 3 when the firm's optimal disclosure varies by the signal she observes.

4.2. The Effects of Visibility and Third-Party Scrutiny on the Firm's Disclosure

We first show that greater visibility motivates the firm to be more "truthful" in her disclosure.

PROPOSITION 3. *(a) $\tau_L(v)$ is strictly decreasing in v and $\tau_H(v)$ is non-decreasing in v.*

(b) The firm's optimal disclosed level $s_D^*(v,\tilde{s})$ is

(i) non-increasing in v if $\tilde{s} < \tau_L(v)$;

(ii) independent of v if $\tilde{s} \in \big[\tau_L(v), \tau_H(v)\big]$; and

(iii) increasing in v if $\tilde{s} > \tau_H(v)$.

Proposition 3(a) implies that as the firm becomes more confident that the signal she observes accurately captures the supplier's current SR level (i.e., visibility increases), she is more likely to neither overstate nor understate relative to her best estimate (i.e., Region (ii) in Figure 3 widens).

For the range of $\tilde{s}$ values where the firm finds it optimal to overstate relative to her best estimate (i.e., Region (i) in Figure 3), the optimal disclosed level decreases as visibility increases (Proposition

3(b)-(i)). Since the firm's best estimate mostly increases with v in Region (i), the decreased disclosed level implies that the extent to which she overstates decreases as visibility increases.[11] This is because as the firm becomes more certain what she observes is the true supplier type, the benefit of overstating decreases and she becomes more cautious about the risk of a potential penalty. Conversely, for the range of $\tilde{s}$ values where the firm finds it optimal to understate relative to her best estimate (i.e., Region (iii) in Figure 3), the optimal disclosed level increases as visibility increases (Proposition 3(b)-(iii)). Hence, the extent to which the firm understates decreases with visibility. Again, the firm's increased certainty that the signal is correct makes her less concerned about the potential penalty risk. As a result, she finds it beneficial to disclose a level closer to her best estimate. When visibility is sufficiently high, Region (iii) no longer exists and thus, the firm does not understate the supplier's SR performance for any $\tilde{s}$ value (see Figure 3c).

Next, we show that increased third-party scrutiny motivates the firm to be more "cautious" in her disclosure. Define $\Omega(v,\tilde{s}) \equiv s_D^*(v,\tilde{s}) - s^*\big(\tilde{s}, \beta_D^*(v,\tilde{s})\big)$ as the difference between the firm's optimal disclosed level and her best estimate of the supplier's final SR level. We obtain the following result.

PROPOSITION 4. *For any given v and $\tilde{s}$, $\Omega(v,\tilde{s})$ is non-increasing in q. Furthermore, τ_H is non-increasing in q, and strictly decreasing in q if $\tau_H < M$.*

By Proposition 4, for low signals (i.e., $\tilde{s} < \tau_L$; Region (i) in Figure 3), the firm discloses a level that is closer to her best estimate. Conversely, for high signals (i.e., $\tilde{s} > \tau_H$; Region (iii) in Figure 3 if it exists), she understates with respect to her best estimate even more as q increases. Furthermore, τ_H being non-increasing in q (and strictly decreasing when Region (iii) exists) implies that as q increases, the firm understates the supplier's SR level for a wider range of high signals.

Regarding the effects of v and q on the supplier's final SR level, our findings in the Firm Disclosure setting are qualitatively the same as in the No Firm Disclosure setting, and hence, will not be repeated.

5. When Does the Firm Prefer to Voluntarily Disclose SR Information?

In many countries and industries, a firm's SR disclosure is voluntary and a strategic choice. For example, as part of its transparency campaign, HRW targeted 72 companies in the apparel industry to disclose their tier-1 supplier lists. While 17 companies fully met the standard put forth by HRW, 25 companies declined to disclose at all. We next study when the firm prefers to disclose versus not

[11] One possible exception to this result occurs for $\tilde{s}$ values close to the threshold τ_D, when τ_D is decreasing in visibility. In this case, the firm's best estimate decreases with v for some $\tilde{s} < \tau_D$ because her optimal investment decreases from $\bar{\beta}_{HD}$ to β_{LD}. Thus, the gap between her optimal disclosed level and her best estimate can increase with visibility.

disclose SR information to the consumers. Define $\Pi_F^*(v,\tilde{s})$ and $\Pi_{FD}^*(v,\tilde{s})$ as the firm's optimal expected profits in the No Firm Disclosure and the Firm Disclosure settings. For a given level of visibility v and signal $\tilde{s}$, the firm will choose to disclose SR information if and only if $\Pi_{FD}^*(v,\tilde{s}) > \Pi_F^*(v,\tilde{s})$. Theorem 4 describes how the difference between these two profits, $\Delta_\Pi(v,\tilde{s}) \equiv \Pi_{FD}^*(v,\tilde{s}) - \Pi_F^*(v,\tilde{s})$, depends on $\tilde{s}$.

THEOREM 4. *For a given level of visibility v, $\Delta_\Pi(v,\tilde{s})$ is continuous and*

(i) constant in $\tilde{s}$ for $\tilde{s} \in [m,\tau)$;

(ii) non-increasing in $\tilde{s}$ for $\tilde{s} \in [\tau,\tau_D)$; and

(iii) if $\tau_L \geq \hat{s}$, then non-decreasing in $\tilde{s}$ for $\tilde{s} \in [\tau_D, M]$; otherwise if $\tau_L < \hat{s}$, negative for $\tilde{s} \in [\tau_D,\hat{s})$ and non-decreasing in $\tilde{s}$ for $\tilde{s} \in [\hat{s}, M]$.

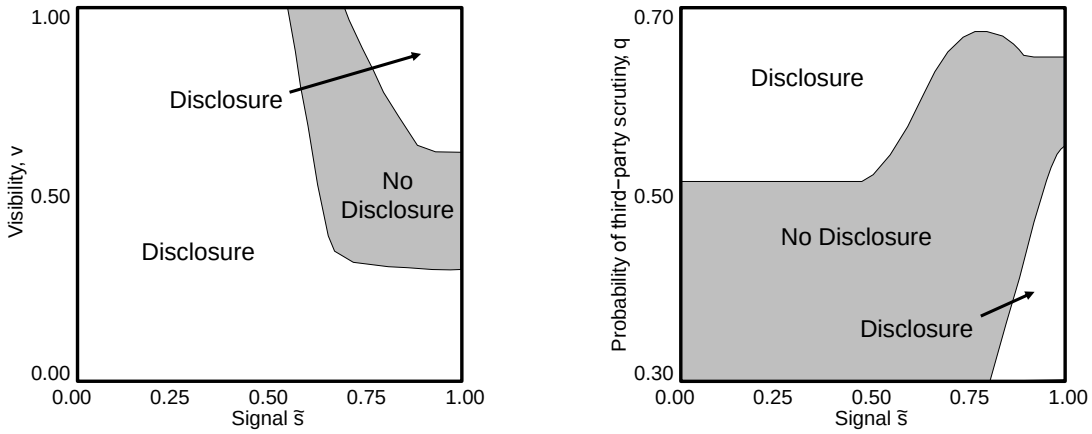
COROLLARY 1. *The firm is least likely to disclose SR information when $\tilde{s}$ is equal to τ_D.*

Theorem 4 can be interpreted as follows (also see Figure 2). When the signal is low (i.e., $\tilde{s} \in [m,\tau)$), the firm infers that the supplier's current practices are poor and thus makes a high investment to improve the supplier's SR capabilities, regardless of whether she discloses SR information. In this case, the supplier's optimal SR level is independent of $\tilde{s}$; i.e., for $\tilde{s} \in [m,\tau)$, $s^*\big(\tilde{s},\bar{\beta}_H\big) = s_u^*\big(\bar{\beta}_H\big)$ in the No Firm Disclosure setting and $s^*\big(\tilde{s},\bar{\beta}_{HD}\big) = s_{uD}^*\big(\bar{\beta}_{HD}\big)$ in the Firm Disclosure setting (Proposition A.4). Thus, neither $\Pi_F^*(v,\tilde{s})$ nor $\Pi_{FD}^*(v,\tilde{s})$ depends on $\tilde{s}$, and $\Delta_\Pi(v,\tilde{s})$ is constant in $\tilde{s}$ (Theorem 4(i)).

When the observed signal is in the intermediate range (i.e., $\tilde{s} \in [\tau,\tau_D)$), the firm continues to make a high investment ($\bar{\beta}_{HD}$) if she plans to disclose (and hence, $\Pi_{FD}^*(v,\tilde{s})$ remains constant in $\tilde{s}$). In doing so she reduces the potential penalty in case of overstating. If instead the firm plans not to disclose, then she prefers a low investment (β_L). Note that $s^*(\tilde{s},\beta_L) = \tilde{s}$ for $\tilde{s} > \tau$ (Proposition A.4). Thus, $\Pi_F^*(v,\tilde{s})$ is strictly increasing in $\tilde{s}$ for $\tilde{s} \in [\tau,\hat{s})$ and constant thereafter (since the third party does not reveal any SR level above $\hat{s}$). Consequently, $\Delta_\Pi(v,\tilde{s})$ is non-increasing for $\tilde{s} \in [\tau,\tau_D)$ (Theorem 4(ii)).

Finally, for Theorem 4(iii), when the observed signal is high enough (i.e., $\tilde{s} \in [\tau_D, M]$), the firm chooses a low investment in both disclosure settings. We consider three cases. First, if $\tau_L \geq \hat{s}$, then the firm can potentially increase demand by disclosing SR information. Hence, $\Pi_{FD}^*(v,\tilde{s})$ increases in $\tilde{s}$ at a faster or equal rate as $\Pi_F^*(v,\tilde{s})$, and $\Delta_\Pi(v,\tilde{s})$ is non-decreasing in $\tilde{s}$. Second, if $\tau_L < \hat{s}$ and $\tilde{s} < \hat{s}$, then in the Firm Disclosure setting, the firm would disclose the maximum between her best estimate and τ_L (i.e., $s_D^* = \max\{\tilde{s},\tau_L\}$). Since both $\tilde{s}$ and τ_L are less than $\hat{s}$, the firm would suffer a loss in demand if she disclosed. As a result, $\Delta_\Pi(v,\tilde{s}) < 0$ if $\tilde{s} \in [\tau_D,\hat{s})$. Third, if $\tau_L < \hat{s}$ and $\tilde{s} \geq \hat{s}$, then our discussion for the first case applies and $\Delta_\Pi(v,\tilde{s})$ is non-decreasing in $\tilde{s}$ for $\tilde{s} \in [\hat{s}, M]$.

Figure 4 Firm's Optimal Disclosure Strategy



(a) As a function of $\tilde{s}$ and v ($q = 0.6$)

(b) As a function of $\tilde{s}$ and q ($v = 0.6$)

Note. Parameters: $\alpha = 0.4$, $r = 0.5$, $w = 0.15$, $c = 0$, $p = 17.5$, market size equals 100. Functions: $\rho(s) = e^{1.75\,s}$, $\gamma(s) = 0.5 - e^{-s}$, $\delta(\beta) = \frac{0.5\,\beta^2}{1-\beta}$. The supplier's type s_0 is distributed uniformly between $m = 0$ and $M = 1$.

Taken together, Theorem 4 parts (ii) and (iii) indicate that the firm is least likely to disclose when $\tilde{s} = \tau_D$ (Corollary 1). By the continuity of $\Delta_\Pi(v, \tilde{s})$ in $\tilde{s}$, Corollary 1 further implies that the firm is least likely to prefer the Firm Disclosure setting for intermediate signals that lie in the neighborhood of τ_D. Theorem 4 leads to five possible disclosure strategies for the firm.

COROLLARY 2. *There exist five possible firm disclosure strategies based on the signal $\tilde{s}$:*

(i) Do not disclose for all $\tilde{s} \in [m, M]$;

(ii) Disclose for all $\tilde{s} \in [m, M]$;

(iii) Do not disclose if $\tilde{s} \le \kappa$ and disclose if $\tilde{s} > \kappa$, where $\kappa > \tau_D$;

(iv) Disclose if $\tilde{s} \le \kappa'$ and do not disclose if $\tilde{s} > \kappa'$, where $\kappa' < \tau_D$;

(v) Do not disclose if $\tilde{s} \in (\kappa_L, \kappa_H)$, and disclose if $\tilde{s} \le \kappa_L$ or $\tilde{s} \ge \kappa_H$, where $\kappa_L < \tau_D < \kappa_H$.

Strategies (i) and (ii) are more likely to be optimal under a low level of visibility. For example, if visibility is low and both the possibility of third-party scrutiny (q) and the penalty factor for overstating the SR level (p) are very high, then the firm may prefer to be cautious and not disclose any information to the consumers, regardless of the signal (strategy (i)). If instead pq is not too high, then the firm may prefer to disclose SR information regardless of the signal (strategy (ii); see, e.g., Figure 4a when $v < 0.3$) because the benefit from increased demand outweighs the risk of a potential penalty. Strategies (iii)–(v), in contrast, are more likely to be optimal under higher levels of visibility. With greater visibility, the signal is more informative. As such, the firm's profit difference between disclosing and not disclosing, and hence her disclosure choice, becomes more sensitive to the value of the signal.

When strategies (iv) and (v) can be optimal is less intuitive; Figure 4a presents an illustrative example. First observe that strategy (iv) is optimal when v is in the intermediate range (e.g., when $v \in (0.3, 0.6)$) whereas strategy (v) is optimal when v is higher. Recall from Theorems 2 and A.2 that the firm makes a high (low) investment when the observed signal is low (high). The high investment (and the resulting high final SR level) at low signals motivates the firm to disclose to increase demand (the middle left region of Figure 4a). In contrast, the firm is more cautious when observing a high signal, especially when v is not high enough. In this case, she is not very confident that the signal is correct and faces a considerable risk of penalty from disclosing and overstating her supplier's SR level. She therefore prefers to not disclose (the middle right region of Figure 4a) and instead saves on her investment cost (by Proposition A.1 her optimal investment is lower if she does not disclose). With greater visibility, the firm becomes more certain that a high signal indicates the supplier has good SR practices and she chooses to disclose (the upper right corner of Figure 4a). However, for intermediate signals, the firm still prefers not to disclose even under high visibility (the middle top region of Figure 4a). This most likely occurs for $\tilde{s} \in (\tau, \tau_D)$, where τ and τ_D are the threshold signals at which the firm decreases her investment under No Firm Disclosure and Firm Disclosure. Within this range, the firm invests a high (low) amount of resources if she plans to disclose (not to disclose). The substantially higher investment cost under disclosure cannot be justified by the moderate increase in demand from disclosing. Thus, the firm prefers to not disclose and instead save on her investment cost in this region.

5.1. The Effects of Visibility and Third-Party Scrutiny on the Firm's Disclosure Choice

The reasoning behind strategy (v) above also explains why increasing visibility (i.e., going from the bottom to the top of Figure 4a) may cause the firm to switch from disclosing to not disclosing for intermediate signals (e.g., the region where $\tilde{s}$ is close to 0.6 in Figure 4a). This situation occurs when τ and τ_D change with v such that $\tilde{s}$ falls inside (τ, τ_D). In particular, for some intermediate signals, as visibility increases, the firm switches from a high to a low investment under No Firm Disclosure because she is more certain that the supplier's current SR level is acceptable. However, her investment remains high under Firm Disclosure so that she can better support her claim in case of third-party scrutiny. The substantial investment savings (when not disclosing) cause the firm to switch from disclosing to not disclosing SR information as visibility increases.

Figure 4b shows how an increase in the probability of third-party scrutiny q can affect the firm's choice between disclosing and not disclosing. We observe that for a large range of $\tilde{s}$ values that are not too high (e.g., when $\tilde{s} \leq 0.75$ in Figure 4b), increased scrutiny motivates the firm to switch from not

disclosing to disclosing. This change is driven by the fact that increased scrutiny (i.e., a higher value of q) incentivizes the supplier to improve his SR practices (see Proposition 2(iii)). As a result, the firm finds it beneficial to disclose and increase demand. However, for higher values of $\tilde{s}$ (e.g., $\tilde{s} > 0.8$ in Figure 4b), we observe that as q increases, the firm may switch from disclosing to not disclosing, and then back to disclosing. The first switch is because a higher q implies a larger potential penalty for disclosing and overstating the supplier's SR level. Hence, the firm becomes more cautious and chooses not to disclose. As q further increases, the direct effect that q has on increasing the supplier's SR decision outweighs the potential penalty. As a result, the firm again finds it beneficial to disclose SR information. The observation that increasing q could discourage the firm from disclosing SR information is in line with the concept of "greenhushing" established in the strategy literature (Lyon and Maxwell 2011).

5.2. The Effect of the Firm's Disclosure Choice on the Final SR Level

The firm's decision of whether to disclose can have a significant impact on the supplier's final SR level. Specifically, for any supplier type s_0, the final SR level in the Firm Disclosure setting is greater than or equal to that in the No Firm Disclosure setting, with the inequality being strict for some supplier types (Corollary A.1). This result follows directly from the fact that the firm's optimal investment is strictly higher under Firm Disclosure than under No Firm Disclosure (Proposition A.1). It holds true when evaluating the final SR level given a fixed signal and in expectation over all possible signals.

Given the above result and Corollary 1 (i.e., the firm is least likely to disclose when $\tilde{s} = \tau_D$), we postulate that the firm having the discretion to choose whether or not to disclose could limit the improvement of SR when the supplier appears to currently have average practices. An example related to this result involves Inditex (the parent company of Zara). Inditex is considered a leader in terms of supply chain transparency. However, a 2016 report from the European workers' rights campaign Labour Behind the Label found that footwear workers at Zara's suppliers in Albania "were earning as little as 49p [pound pennies] an hour including overtime" (The Guardian 2016). Interestingly, Inditex's 2015 annual report primarily discusses its work with suppliers operating in developing countries such as Bangladesh, Cambodia, and India, and does not discuss much about Inditex's Eastern European suppliers. This lack of disclosure suggests that Inditex may not have invested enough in its average suppliers (i.e., those located in Eastern Europe) to improve their SR practices.

As discussed in §5.1, an increase in visibility or third-party scrutiny may lead the firm to switch from disclosing to not disclosing SR information (see Figure 4). Therefore, an increase in either v or q can result in a *lower* final SR level from the supplier.

COROLLARY 3. *An increase in v or q can result in a lower final SR level from the supplier if such an increase motivates the firm to prefer not disclosing SR information over disclosing.*

This result is noteworthy given our findings that for each individual disclosure setting, an increase in third-party scrutiny *never* decreases the supplier's final SR level (Propositions 2(iii) and A.3(iii)). In other words, when disclosure is not mandatory but instead a voluntary option for the firm, intensifying third-party scrutiny can actually be counterproductive and limit the SR improvement at the supplier.

6. Conclusions and Managerial Insights

Companies are increasingly facing pressure from consumers and external stakeholders to guarantee good SR practices in their supply chains. However, most companies do not have good visibility into their suppliers' practices. Our research provides guidance to profit-driven companies on how to improve a supplier's SR practices under incomplete supply chain visibility, when a portion of consumers are socially conscious. We conclude the paper by discussing insights on a firm's strategy for (i) investing in a supplier's SR capabilities, (ii) disclosing SR information to consumers, and (iii) deciding when to voluntarily disclose. We show how these decisions are impacted by the firm's available information about her supplier's current practices, her level of supply chain visibility, and the extent of third-party scrutiny. To capture the social impact of the firm's actions, we examine the effect of her decisions on the resulting SR practices of the supplier.

First, we show that for a given disclosure setting, the firm should invest a high (low) amount of resources to improve the supplier's SR capabilities if the information she observes suggests poor (good) current practices. *Greater supply chain visibility helps the firm to trust the available information more and better tailor her investment. This can have both positive and negative implications for SR.* If the supplier currently appears to have poor practices, then greater visibility can motivate the firm to provide more support to improve the supplier's SR practices. If instead, the supplier currently appears to have average practices, then greater visibility may help the firm realize that the supplier's current practices are acceptable, and hence, she can potentially save costs by making a low investment. This in turn limits the improvement in the supplier's SR level. Unlike the above opposing effects of greater visibility on SR, an increase in third-party scrutiny always leads to a larger improvement in SR.

If a firm plans to disclose, then she should be more aggressive with her investment (as compared to if she does not disclose). With a more aggressive strategy, the firm can reduce the potential impact of a third party uncovering her overstating the supplier's SR level. The higher investment also ensures a larger improvement in the supplier's SR practices when the firm discloses. When

deciding the SR level she wants to disclose to consumers, given the information available to her, the firm is likely to overstate (understate) the supplier's SR level if the supplier appears to have very poor (very good) current practices. *With greater visibility, the firm becomes more "truthful" in her disclosure*; i.e., she is less likely to either overstate or understate the supplier's SR level. Conversely, *as third-party scrutiny increases, she becomes more "cautious"*; i.e., she is more likely to understate the supplier's SR level.

Finally, when the firm has the discretion to choose whether to disclose, *an increase in either visibility or third-party scrutiny can backfire* and cause the firm to prefer not to disclose, resulting in a lower SR level (as compared to when she discloses). In addition, we observe that the firm is least likely to voluntarily disclose SR information to consumers when the supplier appears to currently have average practices. This is in large part due to the fact that if the firm discloses, then she would need to offer an average supplier significant support. Conversely, if the firm does not disclose, then she would not need to offer this same supplier as much support. Due to this difference in investment strategy, she may find it more economical to invest fewer resources and not disclose SR information.

An increasing number of regulations and pacts are pressuring firms to disclose SR information. For example, in 2013, European retailers associated with the Rana Plaza collapse in Bangladesh signed an accord which requires them (among other things) to publicly disclose their supplier lists and the associated audit reports. Our results suggest that disclosure mandates such as this will always have a positive impact on suppliers' SR, and they are most effective in improving SR if the supplier is believed to currently have average practices. In addition, when/if regulations also require firms to demonstrate sufficient levels of supply chain visibility, then the SR practices of suppliers in developing countries could be further improved due to increased investments from their buying firms.

Supply chain transparency is an emerging topic both in practice and in the academic literature. With limited visibility into their suppliers' SR practices, many companies are now facing the challenge of (i) how to invest resources to improve suppliers' SR practices and (ii) whether and what SR information to disclose to consumers. We hope that our work will motivate researchers to further study SR issues under the context of incomplete supply chain visibility. For example, analyzing alternative types of information asymmetry (e.g., in the supplier's cost of SR), or studying a multi-period setting in which the firm could learn about the supplier's practices through investments, would both be valuable.

Appendix A: Additional Analytical Results

THEOREM A.1. *Given β_D and s_D, the supplier's optimal SR decision is $s^*(s_0,\beta_D) = \max\left\{s_0, s^*_{uD}(\beta_D)\right\}$. Furthermore, $\frac{\partial s^*(s_0,\beta_D)}{\partial \beta_D} \geq 0$, $\frac{\partial s^*(s_0,\beta_D)}{\partial q} \geq 0$, and $s^*_{uD}(\beta_D) \leq s_D$ for all $\beta_D \in [0,1]$.*

THEOREM A.2. *For a given level of visibility v, there exist $\hat{\beta}_D$, $\beta_{LD}(v)$, and $\beta_{HD}(v)$ such that $0 \le \beta_{LD}(v) \le \beta_{HD}(v) < 1$, and the firm's optimal investment, $\beta_D^*(v,\tilde{s})$, is defined as follows:*
(a) If $\beta_{LD}(v) \ge \hat{\beta}_D$, then $\beta^*(v,\tilde{s}) = \hat{\beta}_D$ for all $\tilde{s}$.
(b) If $\beta_{LD}(v) < \hat{\beta}_D$, then there exists a threshold $\tau_D(v) \in (m, \hat{s}_D)$ with $\hat{s}_D \equiv s_{uD}^*(\hat{\beta}_D)$ such that if $\tilde{s} \le \tau_D(v)$, then $\beta_D^*(v,\tilde{s}) = \bar{\beta}_{HD}(v) \equiv \min\{\beta_{HD}(v), \hat{\beta}_D\}$; otherwise, $\beta_D^*(v,\tilde{s}) = \beta_{LD}(v)$.

PROPOSITION A.1. *For any level of visibility v and signal $\tilde{s}$, $\beta_{LD} > \beta_L$, $\bar{\beta}_{HD} > \bar{\beta}_H$, $\tau_D > \tau$, and therefore, $\beta_D^*(v,\tilde{s}) > \beta^*(v,\tilde{s})$.*

PROPOSITION A.2. *(i) β_{LD} is strictly decreasing in v and β_{HD} is strictly increasing in v. (ii) The threshold τ_D is increasing in v if and only if $\delta(\beta_{HD}) - \delta(\beta_{LD}) > \mathbb{E}_{s_0}\left[\Theta(\beta_{HD}, s_{D_H}) - \Theta(\beta_{LD}, s_{D_L}) \,|\, \tilde{s} \ne s_0\right]$, where $\Theta(\beta_D, s_D) \equiv \left(D_{SN} + \mathbb{E}_{s_0}\left[D_{SC}(s_D, s^*(s_0,\beta)) \,|\, \tilde{s}\right]\right)(r-w) - p\,q\,\mathbb{E}_{s_0}\left[\max\{s_D - s^*(s_0,\beta), 0\} \,|\, \tilde{s}\right]$, and s_{D_H} (s_{D_L}) is equal to the optimal value of s_D given a signal immediately to the left (right) of $\tilde{s} = \tau_D(v)$.*

PROPOSITION A.3. *(i) β_{LD} and β_{HD} are not monotone in q. (ii) The threshold τ_D is strictly increasing in q. (iii) $\frac{\mathrm{d}s^*(s_0, \beta_D^*(\tilde{s},q),q)}{\mathrm{d}q} \ge 0$ for all $s_0, \tilde{s} \in [m, M]$.*

PROPOSITION A.4. *For any level of visibility v, the firm's best estimate of the supplier's final SR level can be characterized as follows. Under No Firm Disclosure: (i) If $\tilde{s} \le \tau(v)$, then $s^*(\tilde{s}, \beta^*(v,\tilde{s})) = s^*(\tilde{s}, \bar{\beta}_H) = s_u^*(\bar{\beta}_H)$; (ii) If $\tilde{s} > \tau(v)$, then $s^*(\tilde{s}, \beta^*(v,\tilde{s})) = s^*(\tilde{s}, \beta_L) = \tilde{s}$. Under Firm Disclosure: (iii) If $\tilde{s} \le \tau_D(v)$, then $s^*(\tilde{s}, \beta_D^*(v,\tilde{s})) = s^*(\tilde{s}, \bar{\beta}_{HD}) = s_{uD}^*(\bar{\beta}_{HD})$; (iv) If $\tilde{s} > \tau_D(v)$, then $s^*(\tilde{s}, \beta_D^*(v,\tilde{s})) = s^*(\tilde{s}, \beta_{LD}) = \tilde{s}$.*
Furthermore, $\lim_{\tilde{s}\uparrow\tau(v)} s^*(\tilde{s}, \beta^*) > \lim_{\tilde{s}\downarrow\tau(v)} s^*(\tilde{s}, \beta^*)$ and $\lim_{\tilde{s}\uparrow\tau_D(v)} s^*(\tilde{s}, \beta_D^*) > \lim_{\tilde{s}\downarrow\tau_D(v)} s^*(\tilde{s}, \beta_D^*)$; i.e., the best estimates are discontinuous at $\tau(v)$ [$\tau_D(v)$] under No Firm Disclosure [Firm Disclosure].

COROLLARY A.1. *For any supplier type s_0, the final SR level in the Firm Disclosure setting is greater than or equal to that in the No Firm Disclosure setting. Furthermore, there exists $\tau_{SR} < \tau_D$ such that it is strictly greater for $s_0 \in [m, \tau_{SR}]$.*

Appendix B: Model Extensions

To test the robustness of our results we examine four extensions to our model.

Penalizing the firm if she does not disclose: We discuss two alternative setups in which the firm could incur a penalty when she does not disclose SR information. In the first setup, SC consumers may choose not to purchase the product if the firm does not disclose. In particular, under No Firm Disclosure, the fraction of SC consumers considering buying the product becomes $\alpha' \le \alpha$ (while the fraction of SN consumers remains $1-\alpha$). We show that all of our results are qualitatively the same under this new setup. The main difference is that when we compare the No Firm Disclosure and Firm Disclosure settings, the firm now prefers to disclose for a larger parameter region. In the second setup, we directly subtract from the firm's objective function under No Firm Disclosure a penalty that is proportional to the difference between s and the minimum SR standard acceptable to SC consumers, $\hat{s}$. That is, we subtract $p'\,q\,\mathbb{E}_{s_0}\left[\max\{\hat{s} - s^*(s_0,\beta), 0\} \,|\, \tilde{s}\right]$ from Equation (1), similar to how we

incorporate the penalty under Firm Disclosure in Equation (4). We show that, as long as $p > p'$ (i.e., the penalty from overstating is stronger than the penalty from no disclosure), most of our results continue to hold.

The third-party reveals any value of s that it observes: We examine a scenario where if the third party observes s, then it always communicates s to the consumers regardless of how s compares to $\hat{s}$ (under No Firm Disclosure) or s_D (under Firm Disclosure). We confirm that most of our results and insights remain unchanged. When we compare this setup with our main model we find that under No Firm Disclosure, the firm's optimal investment in the new setup is greater than or equal to that in the main model. This is because in the new setup, the third party's communication is no longer bounded above by $\hat{s}$, and hence, the optimal investment is also not bounded. Conversely, under Firm Disclosure, the firm's optimal investment in the new setup is lower than or equal to that in the main model. In addition, her optimal disclosed value is lower than or equal to that in the main model. This is in part due to the fact that in the main model the firm is more limited in terms of SR values being communicated. Thus, in order to increase the chance that "good" SR values are revealed to consumers, she is motivated to disclose a higher SR level in the main model. The lower disclosed value in the new setup implies that the firm overstates to a smaller extent and understates to a larger extent.

An incorrect signal always inflates s_0: We study a setting where, if the signal is not correct, then only $\tilde{s} > s_0$ is possible. We do not consider the opposite case (i.e., $\tilde{s} < s_0$), since in this situation there would not be a penalty for disclosing. In this new setup, with probability v, $\tilde{s} = s_0$; and with probability $1 - v$, $\tilde{s} > s_0$. We find that most of our main results still hold. The main difference is with respect to when the firm prefers not to disclose. The new setup requires an additional condition that v must be sufficiently high for Corollary 1 to still be true; i.e., the firm is least likely to disclose SR information when the supplier appears to have average practices. The threshold is necessary because in the new setup, an average signal suggests that the supplier has either average or poor practices (as $\tilde{s} \geq s_0$). Thus, when visibility is not sufficiently high, the firm may invest a high amount and disclose.

The firm incorporates SR into her objective function: We examine a setting where the firm incorporates SR into her objective function. Specifically, her objective is to maximize a weighted sum of her expected profit and the expected final SR level (see, e.g., Nagurney and Nagurney 2010, Marufuzzaman et al. 2014, for a similar approach). We show that our main results continue to hold. When we compare this setup with our main model we find that as expected, the final SR level in the new setup is greater than or equal to the final SR level in the main model. The final SR level is most likely to be equal (or close to equal) between the two models under No Firm Disclosure, when (i) q is high, or (ii) v is high and the observed signal is low. In these cases, the firm explicitly considering SR does not yield higher SR performance, as compared to a purely profit-maximizing firm. On the other hand, the largest difference in the firm's investment between the two models occurs when the signal is slightly greater than the threshold signal (i.e., τ or τ_D) at which the firm drops her investment in the supplier from high to low (in either disclosure setting). In these cases, when the signal is slightly greater than the threshold, a profit-maximizing firm invests a low amount, whereas the firm in the new setup invests a high amount. The difference in the firm's investment in this region is larger with greater visibility.

References

Agrawal V, Lee D (2018) The effect of sourcing policies on a supplier's sustainable practices, *Prod. Oper. Manag.*, forthcoming.

Babich V (2010) Independence of capacity ordering and financial subsidies to risky suppliers. *Manuf. Serv. Oper. Manag.* 12(4):583–607.

Babich V, Tang C (2012) Managing opportunistic supplier product adulteration: Deferred payments, inspection, and combined mechanisms. *Manuf. Serv. Oper. Manag.* 14(2):301–314.

Bagnoli M, Watts S (2003) Selling to socially responsible consumers: Competition and the private provision of public goods. *J. Econ. Manag. Strategy* 12(3):419–445.

Borzaga C, Becchetti L (2010) *The Economics of Social Responsibility* (Routledge).

Caro F, Chintapalli P, Rajaram K, Tang CS (2018) Improving supplier compliance through joint and shared audits. *Manuf. Serv. Oper. Manag.* 20(2):363–380.

Chen L, Lee H (2017) Sourcing under supplier responsibility risk: The effects of certification, audit, and contingency payment. *Manag. Sci.* 63(9):2795–2812.

Chen S, Zhang Q, Zhou Y (2018) Impact of supply chain transparency on sustainability under NGO scrutiny. Working paper, University of Washington, Seattle, WA.

Cho S, DeMiguel V, Hwang W (2018a) Cover-up of vehicle defects: The role of regulator investigation announcements. Working paper, Carnegie Mellon University, Pittsburgh, PA.

Cho S, Fang X, Tayur S, Xu Y (2018b) Combating child labor: Incentives and information transparency in global supply chains. Working paper, Carnegie Mellon University, Pittsburgh, PA.

Corbett C, DeCroix G (2001) Shared-savings contracts for indirect materials in supply chains: Channel profits and environmental impacts. *Manag. Sci.* 47(7):881–893.

Dahlsrud A (2008) How corporate social responsibility is defined: An analysis of 37 definitions. *Corp. Soc. Responsib. Environ. Management* 15(1):1–13.

Dawkins J (2004) Corporate responsibility: The communication challenge. *J. Commun. Manag.* 9(2):108–119.

Doorey DJ (2011) The transparent supply chain: From resistance to implementation at Nike and Levi-Strauss. *J. Bus. Ethics* 103(4):587–603, ISSN 0167-4544.

EY, UN Global Compact (2016) The state of sustainable supply chains: Building responsible and resilient supply chains, `www.unglobalcompact.org`.

Gillai B, Porteous A, Rammohan S, Lee H (2013) The relationship between responsible supply chain practices and performance. White paper, Stanford University, Stanford, CA.

Guo R, Lee H, Swinney R (2016) Responsible sourcing in supply chains. *Manag. Sci.* 62(9):2722–2744.

HRW (2017) Follow the thread: The need for supply chain transparency in the garment and footwear industry, `hrw.org`.

Huang L, Song J, Swinney R (2017) Managing social responsibility in multitier supply chains. Working paper, Duke University, Durham, NC.

IACCM (2013) How contracts can make suppliers behave, `www.iaccm.com`.

IISD (2018) The rise and role of NGOs in sustainable development, international Institute for Sustainable Development, `www.iisd.org`.

Iyer A, Schwarz L, Zenios S (2005) A principal-agent model for product specification and production. *Manag. Sci.* 51(1):106–119.

Kalkanci B, Plambeck E (2018) Managing supplier social & environmental impacts with voluntary vs. mandatory disclosure to investors. Working paper, Georgia Institute of Technology, Atlanta, GA.

Karaer O, Kraft T, Khawam J (2017) Buyer and nonprofit levers to improve supplier environmental performance. *Prod. Oper. Manag.* 26(6):1163–1190.

Kim B (2000) Coordinating an innovation in supply chain management. *Eur. J. Oper. Res.* 123(3):568–584.

Kim EH, Lyon T (2015) Greenwash vs. brownwash: Exaggeration and undue modesty in corporate sustainability disclosure. *Organ. Sci.* 26(3):705–723.

Kim S, Netessine S (2013) Collaborative cost reduction and component procurement under information asymmetry. *Manag. Sci.* 59(1):189–206.

KPMG (2017) The road ahead: The KPMG survey of corporate responsibility reporting 2017, `assets.kpmg.com`.

Kraft T, Valdés L, Zheng Y (2018) Supply chain visibility and social responsibility: Investigating consumers' behaviors and motives. *Manuf. Serv. Oper. Manag.* 20(4):617–636.

Letizia P, Hendrikse G (2016) Supply chain structure incentives for corporate social responsibility: An incomplete contracting analysis. *Prod. Oper. Manag.* 25(11):1919–1941.

Lewis T, Liu F, Song J (2016) A dynamic mechanism for achieving sustainable quality supply. Working paper, Duke University, Durham, NC.

Liu S, So K, Zhang F (2010) Effect of supply reliability in a retail setting with joint marketing and inventory decisions. *Manuf. Serv. Oper. Manag.* 12(1):19–32.

Locke R, Qin F, Brause A (2007) Does monitoring improve labor standards? Lessons from Nike. *Ind. Labor Relat. Rev.* 6(1):3–31.

Lyon T, Maxwell J (2011) Greenwash: Corporate environmental disclosure under threat of audit. *J. Econ. Manag. Strategy* 20(1):3–41.

Marufuzzaman M, Ekşioğlu SD, Hernandez R (2014) Environmentally friendly supply chain planning and design for biodiesel production via wastewater sludge. *Transportation Science* 48(4):555–574.

Mendoza A, Clemen R (2013) Outsourcing sustainability: A game-theoretic approach. *Env. Syst. Decis.* 33(2):224–236.

Moorthy K (1988) Product and price competition in a duopoly. *Market. Sci.* 7(2):141–168.

Nagurney A, Nagurney LS (2010) Sustainable supply chain network design: A multicriteria perspective. *International Journal of Sustainable Engineering* 3(3):189–197.

Norman W, MacDonald C (2004) Getting to the bottom of "triple bottom line". *Bus. Ethics Q.* 14(2):243–262.

Nyamadzawo T (2017) 4 ways blockchain is being used in international development, `www.bond.org.uk`.

OECD/WTO (2013) *Aid for Trade at a Glance 2013: Connecting to Value Chains* (OECD Publishing).

Orsdemir A, Hu B, Deshpande V (2018) Ensuring corporate social and environmental responsibility through vertical integration and horizontal sourcing, *Manuf. Serv. Oper. Manag.*, forthcoming.

Plambeck E, Taylor T (2016) Supplier evasion of a buyer's audit: Implications for motivating supplier social and environmental responsibility. *Manuf. Serv. Oper. Manag.* 18(2):184–197.

Porteous A, Rammohan S, Lee H (2015) Carrots or sticks? Improving social and environmental compliance at suppliers through incentives and penalties. *Production & Operations Management* 24(9):1402–1413.

Rangan V, Chase L, Karim S (2015) The truth about CSR. *Harv. Bus. Rev.* 93(1/2):40–49.

Talluri S, Narasimhan R, Chung W (2010) Manufacturer cooperation in supplier development under risk. *European Journal of Operational Research* 207(1):165–173.

The Guardian (2016) The expensive Italian shoes made for a pittance in east European sweatshops, `www.theguardian.com`.

TSC (2016) Greening global supply chains, the Sustainability Consortium 2016 Impact Report, `www.sustainabilityconsortium.org`.

Wang S, Sun P, Véricourt F (2016) Inducing environmental disclosures: A dynamic mechanism design approach. *Oper. Res.* 64(2):371–389.

Wang Y, Gilland W, Tomlin B (2010) Mitigating supply risk: Dual sourcing or process improvement? *Manuf. Serv. Oper. Manag.* 12(3):489–510.

Zhang H, Aydin G, Heese H (2017) Curbing the use of conflict minerals: A supply network perspective. Working paper, Indiana University, Bloomington, IN.

Zhu K, Zhang R, Tsung F (2007) Pushing quality improvement along supply chains. *Manag. Sci.* 53(3):421–436.