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Impact of Supply Chain Transparency on Sustainability under NGO Scrutiny

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Companies are increasingly held accountable for social and environmental sustainability violations committed by their contract suppliers. Since developing codes of conduct and increasing auditing effort from the buyers' side are usually insufficient to ensure supplier compliance, the independent auditing effort by Non-Governmental Organizations (NGOs) plays an important role. In this paper we build an analytical model to examine the impact of such NGO scrutiny on supply chain sustainability. We study the interactions among buyers', NGOs', and suppliers' decisions on optimal auditing effort levels and optimal compliance effort levels given that the buyer has or has not revealed the list of suppliers. We identify conditions under which buyers' auditing effort and NGOs' auditing effort are complements or substitutes. We specifically discuss how the buyer can impact the NGOs' action by revealing her own supplier list and how supply chain transparency and sustainability interacts in various business environments. One major finding is that in many cases they are conflictive goals. Thus, when it's optimal for the buyer to reveal her supplier list, the supply chain sustainability could possibly suffer. We offer conditions and intuitive explanations for such findings.

Key words: Non-Governmental Organizations, Supply Chain Transparency, Social and Environmental Performance, Supplier List

1. Introduction

Today's global companies operate global supply chains. Leading manufacturers' supply chains often span multiple continents. For example, Apple has suppliers from more than 30 countries (McKeefry 2014), and Nike uses about 150 footwear factories located in 14 countries and about 430 apparel factories located in 41 countries (Nike 2014).

The complexity of such global supply chains creates difficulty in managing them, when most of the suppliers are independent contractors (e.g., H&M does not own any production factories; virtually all of Nike's footware and apparel products are manufactured outside of the United States by independent contract manufacturers). Traditional operational issues, such as demand volatility

and poor forecast accuracy, remain atop the list of major concerns (Supply Chain Digest 2010), but social (e.g., working condition, labor practice) and environmental (e.g., resource, environmental impact) sustainability issues have become increasingly more important. They are normally tackled with a multitide of approaches, including government regulation, industry self-regulation, and Non-Governmental Organization (NGO) monitoring.

Government regulation – in the form of minimum wage, working condition, disclosure laws – has been an important tool in enforcing minimum standards in the supply chain. However, as supply chains grow global, many of the suppliers are located in developing countries where the government has limited ability to enforce their own laws. Thus, companies develop company- or industry-specific codes of conduct and use compliance monitoring as the principle way to address poor working conditions (Locke et al. 2007).

Auditing and monitoring is a labor intensive and costly process, especially if a buyer is asked to audit multiple tiers of its supplier network (Wieland and Handfield 2013). Rank a Brand (`rankabrand.org`) reports that only 15% of the apparel brands, including H&M, McGregor, ONLY, Tommy Hilfiger, Zara, WE, Timberland, Nike, and Puma, monitored more than 80% of their suppliers. When companies' private auditing becomes infrequent or predictable, it loses effectiveness. Plambeck and Tylor (2014) report that some suppliers learn to hide their violations, and Locke et al. (2007) use data from Nike during 1998-2005 to show that monitoring alone fails, but may work if it is combined with other interventions focused on tackling some of the root causes of poor working conditions. Critics of the private auditing approach also believe that some companies use these measures not to improve sustainability but to limit legal liability or prevent reputation damage in the case of a scandal (Locke and Romis 2007). In this regard, independent NGOs and media can play an important monitoring role.

When a large-scale negative incident, such as Nike's sweatshop scandal (1990s), Mattel's toy recalls due to lead paint (2007), FoxConn's poor working conditions (2010), or Rana Plaza's building collapse (2013), is reported and publicized, it not only affects the supplier but also reflects poorly on the brand owner. However, these relatively rare headline-grabbing incidents reflect only a subset of NGOs' monitoring work. More commonly, violations of supply chain sustainability are low in profile and don't get reported in mainstream media. Violations are routinely detected by NGOs such as the Business & Human Rights Resource Centre (`business-humanrights.org`), International Labor Organization (`ilo.org`), and China Labor Watch (CLW, `chinalaborwatch.org`), who conduct independent investigations and then publicize violations if any are found.

In general, both the suppliers and their buyers suffer certain financial losses when NGOs detect the suppliers' violations, although the specific amount of loss varies case by case. The suppliers can be urged to take costly remedial measures. The buyers can also suffer reputation damage for

their suppliers' irresponsible activities, so they take countermeasures accordingly. Thus, although the NGOs do not interact with the buyers directly, they could have a significant indirect impact on the buyer through auditing their suppliers.

Many buyers have incorporated NGOs into their monitoring systems. Some opt to become a member of a collective initiative, or use the service of an outside organization that specializes in such activities. For example, Zara (via its owner Inditex) is a member of Ethical Trading Initiative, and Nike uses the service of Fair Labor Association (FLA). These organizations work collaboratively with companies to defray the cost of monitoring and provide creditability via certification, but there could be conflicts of interest. Other truly independent NGOs can sometimes achieve better results. Consider the case of Bratex. When it dismissed 31 workers in 2011 for their unionization effort in Sri Lanka, an investigation by FLA (of which Bratex's buyer Fruit of the Loom is a member) yielded no result. However, Clean Clothes Campaign (CCC, `cleanclothes.org`), an independent NGO, was able to secure a victorious settlement for the workers in 2014. Many NGOs like CCC prefer not to directly collaborate with the companies they monitor. In our study we focus on the NGOs' independent monitoring efforts rather than the certification services some of them provide.

Companies such as Nike and H&M, realizing these NGOs' sheer number and potential power, became more open to the NGOs' independent monitoring effort by publicly revealing their entire supplier lists. Apple also listed its top 200 suppliers that count for more than 97% of its procurement expenditure. These companies took a big step in pushing for supply chain transparency, contrary to the prevailing industry practice to keep a tight grip on such information. At the time of its announcement in 2005, Nike's reason is that transparency would be good for the company because "critics could go out and see for themselves what conditions were like and NGOs could monitor and thereby help address the issues" (Paine et al. 2013).

Indeed, the strategic interaction between buyers and NGOs goes both ways. The NGOs can impact buyers through their strategic auditing of the suppliers and the buyers can leverage the NGOs' scrutiny to prod her suppliers to improve sustainability effort or to reduce her own scrutiny cost. This strategic interaction is an important part of the supply chain sustainability effort that has not been sufficiently studied, but it is a novel, focal feature of our model.

Although many have argued that a transparent supply chain, in which consumers get information about where all the parts in a product come from, can have both marketing and operational benefits (New 2010), there exists no rigorous study on the possible link between supply chain sustainability and transparency. It's not clear whether supply chain transparency would always lead to improved sustainability and economic benefits. Even in the athletic footware and apparel industries, Nike's decision to reveal supplier list has not been followed by any of its competitors. It is another focus

of our study to examine how supply chain transparency and sustainability, as well as the economic incentives of various supply chain parties, interact with each other.

Motivated by industrial practice, our study attempts to investigate the impact of independent NGO scrutiny on supply chain sustainability. Specifically, our research seeks answers to the following questions:

1. Considering the NGOs' strategic role in monitoring and ensuring supply chain sustainability, when would it be optimal for a buyer to reveal her supplier list? What would be the impact of that decision on the buyer's, the NGOs', and the suppliers' auditing and sustainability effort levels?
2. Does supply chain transparency always lead to better supply chain sustainability? If not, then under what conditions do the two objectives agree?
3. Does there exist a situation where the supply chain sustainability, transparency, and the economic objectives of the buyer, the suppliers, and the NGOs can be improved simultaneously?

We build an analytical model to answer these questions. Our major contributions are four-fold. First, we are among the first to formally study the strategic considerations between the buyer and the independent NGOs. While most existing studies model the NGOs' pressure as a fixed external factor, we endogenize the NGOs' decision and find that it's indeed important to do so. For example, when the NGOs' scrutiny on the supply chain increases, a buyer with exogenous NGOs will increase her own auditing level in response. In contrast, a buyer who accounts for the NGOs strategic decisions could, under certain conditions, view the NGOs' effort as a beneficial substitute, and optimally reduce her own auditing effort.

Second, we incorporate revealing supplier list as a new feature into the supply chain sustainability decision models. While past studies usually view supply chain transparency as the public availability of violation information, we study transparency from a different angle by considering the public availability of supply chain structure information. With this modeling feature, we are able to find that whereas in some cases the buyer should reveal her supplier list and this leads to higher supply chain sustainability, in many other cases, the result is the exact opposite: when it's optimal for the buyer not to reveal her supplier list, it could lead to higher supply chain sustainability. Conversely, when the buyer optimally reveals her supplier list, the supply chain sustainability could deteriorate as a result. We offer intuitive explanations.

Third, we identify a few important system parameters as important factors in determining the equilibrium of the game. If a supplier violation is detected, the NGOs gain more utility if they can link the supplier to a renowned buyer. We are able to show that the percentage of suppliers to the renowned buyers among all the unidentified suppliers is a critical factor in deciding whether the buyer reveals her supply list and whether transparency and sustainability agree with each other.

Last but not least, while our model focuses on the interactions within the supply chain of a particular renowned buyer, we offer insights into how our model can be extended to accommodate multiple buyers. In the case of two renowned buyers we show that even if independently both buyers would have taken the same optimal action to reveal her supplier list or not, when jointly considered, they could reach an equilibrium where one reveals while the other doesn't. Again we offer intuitive explanations.

2. Related Literature

This study is closely related to the emerging literature on sustainable and responsible supply chain management including (but not limited to) Chen and Lee (2014), Guo et al. (2015), Kalkanci et al. (2013), Kraft et al. (2013), Kim (2014), Plambeck and Tylor (2014), and Xu et al. (2015).

Some of those studies focus on the impact of financial incentives in supply chain procurement on supplier compliance. For instance, Chen and Lee (2014) investigate the optimal screening mechanism based on the delayed payment procurement contract in order to mitigate supplier responsibility risk. In Guo et al. (2015), a buyer facing socially conscious consumers pays a higher price to a responsible supplier, and pays a lower price to a risky supplier; the buyer may also decide not to purchase from the risky supplier at all. In Xu et al. (2015), a global manufacturer determines the optimal wholesale price to incentivize the suppliers not to employ child labor.

Some of the above-mentioned studies also examine the impact of information transparency on the sustainability performance of a supply chain. For instance, Kalkanci et al. (2013) investigate the effect of mandatory or voluntary disclosure of what a firm knows regarding the social and environmental impact information of its supply chain; the authors show that mandatory disclosure will indeed deter the firm's effort in measuring and improving those impacts. Kim (2014) investigates a production firm's problem regarding when to self-disclose compliance violations; and the author shows that anticipating the firm's opportunistic disclosure behavior, an inspector may need to increase the penalty accompanied by more frequent audits. In Xu et al. (2015), the authors examine the potential effects of a regulation (e.g., California Transparency in Supply Chain Act) that requires firms to disclose their efforts to mitigate supplier responsibility risk of employing child labors; they argue that such kind of information transparency may lead to more employment of child labor, since the buyer firm could commit to no inspections and thus a lower wholesale price. Plambeck and Tylor (2014) study how the buyers can induce their suppliers to exert more compliance efforts if the suppliers can exert effort to pass the buyers' audits through deception and hiding; they suggest that publicizing negative audit reports or a buyer's supplier list can affect the supplier's compliance effort because of the increased damage to the supplier.

Although closely related, our paper distinguishes itself in two important aspects. First, we consider the NGOs' objective and thus endogenize the NGOs' optimal auditing effort levels, which

enables us to investigate the effects of the NGOs' decisions on the interactions among a buyer, the buyer's suppliers, and the NGOs. To our best knowledge, the NGOs decisions were overlooked or assumed to be exogenously given in most previous studies of sustainable supply chain management. The only exception is Kraft et al. (2013), which analyzes an NGO's decision on whether to target the industry or the regulatory body in order to compel the firms to replace a potentially hazardous substance. Our paper, however, addresses the NGOs' role in improving the social and environmental impacts of supply chains by inducing the buyers to voluntarily reveal their supplier list, which is different from the problem explored by Kraft et al. (2013). Second, we investigate the buyer's optimal decision regarding whether to reveal her supplier list under the NGO scrutiny pressures and we examine the relationship between supply chain sustainability and transparency. In our paper, supply chain transparency means that the buyer has revealed her supplier list and thus the NGOs are able to associate a supplier's violations to his buyer. This structural transparency is fundamentally different from the informational transparency studied before (e.g., Kim 2014, Kalkanci et al. 2013) where the buyer is mandated to disclose her internal inspections (e.g., Xu et al. 2015) or discloses only supplier violations. In a sense the informational transparency studied in these papers can be viewed as a partial structural transparency when some of the buyers' suppliers are revealed due to violations reported by the buyer.

Our work also relates to the literature on operations management in the NGOs. There is relatively little analytical modeling work involving NGO operations. Also, most studies in this stream of research focus on either the funder-NGO relationship or resource allocation problem within an NGO. For example, McCardle et al. (2009) analyze donor behaviors under a tiered fund-raising structure. Toyasaki and Wakolbinger (2014) examine the conditions under which the NGOs should earmark the donations when fund-raising. Privett and Erhun (2011) investigate how funders can improve the efficiency of funding for the nonprofit sector overall; in particular, they study an auditing contract and show that such contract can not only support the funder but also improve the nonprofit sector. Verheyen (1998) examines a problem of allocating limited internal budget within an NGO. DeVericourt and Lobo (2009) study a resource allocation problem of an NGO who faces the tradeoff between earning profit from the revenue customers in the for-profit sector and serving the mission customers in the non-profit sector. Harrison and Lybecker (2005) focus on the price competition between a for-profit hospital and a non-profit hospital; they show that the non-profit hospital's motive (e.g., serving uninsured patient, quality of service, etc.) has an important impact on the price in equilibrium. We refer the reader to Privett (2010) for a comprehensive literature review of operations management in the nonprofit sector.

Our work, although related, has a different focus on the NGOs' actions compared with the literature on nonprofit operations management. More specifically, we investigate the NGOs' auditing

efforts under different supply chain transparency settings, and show that the NGOs' actions have an important impact on supply chain transparency (i.e., buyer's decision regarding whether to reveal the supplier list) and sustainability levels (i.e., supplier compliance efforts). To our best knowledge, this aspect of NGO operations has not been examined in the previous studies.

Last, this work is partly related to the literature on quality control in supply chain management. In the quality literature, the basic setting is that a supplier can exert costly effort to improve the quality of products (i.e., to reduce the probability of defective products), the buyer can also exert costly inspection effort to detect the defective products, while there is still a probability that a defective product passes the inspection and the customer charges a high penalty cost to the buyer (and/or the supplier). In our setting, the supplier's compliance effort mimics the effort to improve product quality, and the buyer's auditing effort mimics the quality-inspection effort. However, we also consider the NGOs' auditing efforts, as well as the buyer's strategic decision on whether to reveal the supplier list, which is fundamentally different from the quality literature. For a comprehensive discussion about the similarity and difference between the literature on quality control and the literature on sustainable supply chain management, we refer the readers to Plambeck and Tylor (2014), Chen and Lee (2014), and the references therein.

3. Model Setup

We study a simplified two-tier industry with buyers and suppliers. There are two types of buyers: the *renowned buyers* who are industry leaders (e.g. Nike, Apple), and the rest which we call the *ordinary buyers*. Furthermore, we call the suppliers to the renowned buyers *special suppliers*. Each renowned buyer chooses independently to reveal her supplier list or not. We denote this decision by $j = I$ or U (I stands for identified and U stands for unidentified). For the rest of the paper, we will also use superscript $j \in \{I, U\}$ to indicate all the corresponding variables and supplier pools. (For example, supplier pool I includes all the identified suppliers.)

We make a simplifying assumption that the buyers' supplier lists do not overlap. In practice some buyers share common suppliers, which creates another layer of complexity in the supply chain because the buyers' actions interact with each other through the suppliers. We do not model that in this paper in order to focus on the dynamics within each buyer's supply chain and get sharper insights. Our non-overlapping assumption is more reasonable when the suppliers are required to make buyer-specific investments (for example, Foxconn's exclusive factory for Apple, even though it supplies Dell, HP, and other tech firms as well – Kan 2012), so that we can model the supplier's effort for each buyer separately. We plan to use the results in this paper as building blocks for future research on over-lapping supply chains.

There is a pool of NGOs that independently audit and report sustainability issues in this industry. An NGO wants to maximize a narrow set of social objectives for which it is established. Once

an NGO successfully detects and publicizes a supplier's sustainability violation, the NGO gains utility from the positive social and environmental impact that can follow. If the violator is an ordinary supplier, we normalize the NGO's utility to be zero, without loss of generality. If the violator is a special supplier, however, due to the ensuing pressure on, and influence of, his renowned buyer, the NGO can derive a strictly positive utility of v, which comes from the positive social and environmental impact from the publication of a violation. Depending on the natural of the violation and the identity of the special supplier, every time the positive utility gained by an NGO can be different, but we can assume that on average the utility is $v > 0$. We also assume that all the NGOs aim to maximize their net expected payoff which is the expected utility gained by publicizing supplier violations minus the cost of auditing effort. Note that the way we model an NGO's objective is consistent with many of the extant literature such as Kraft et al. (2013) and Harrison and Lybecker (2005).

Since the NGOs are formed with different philosophies, goals, and operational processes, the NGOs' approaches to auditing the suppliers could differ. Some NGOs, especially those who work collaboratively with renowned buyers (e.g., FLA), focus on auditing identified special suppliers; we call them type-I NGOs. Other NGOs, especially who exert pressure on the renowned buyers by confrontation (e.g., CLW), focus on auditing the unidentified suppliers based on the belief that the unidentified suppliers have poor social and environmental performance; we call them type-U NGOs. We do not model the NGOs' decision on which type to become; instead we assume that a fraction of the NGOs become either type. As a result, identified and unidentified suppliers face varying exogenous likelihood of being audited by an NGO. We denote the *likelihood of being audited* for the suppliers in the pool j by γ^j, which is the probability that any supplier in pool j will be audited by one of the type-j NGOs in the planning horizon considered (e.g., one year).

3.1. Timeline

To start, we focus on one renowned buyer, and study the equilibrium behavior in the game played among the buyer (she), her suppliers (he), and the NGOs (it). Section 5 offers an extension to the game between two buyers. Like Chen and Lee (2014) we adopt a Stackelberg framework which implies that the renowned buyer is the dominant player in the industry. The time line is as follows:

Stage 1, Buyer's decision: Any sustainability violation by the suppliers reflect poorly on the buyer. NGOs and presses often put pressure on the buyer when such violations are detected. In the event of a detected and publicized violation, we denote the buyer's cost of brand damage by b. To reduce such a cost, the buyer makes two decisions: 1) She first decides whether to reveal her supplier list (i.e., $j = I$ or U), possibly inviting higher pressure on her suppliers from outside NGOs. 2) Given j, she exerts an auditing effort $e_B^j \in [0, 1]$ which incurs a convex increasing cost *per supplier*. Specifically, we use a quadratic cost function: $k_B(e_B^j)^2$ where k_B is a fixed parameter.

We assume *i.i.d.* suppliers for the same buyer. More importantly, we assume the buyer's effort and penalty costs are additive across all the suppliers. Therefore, the number of her suppliers does not affect the buyer's decision about the auditing effort to exert on each supplier; by doing so, we can analyze each supplier individually in the next stage.

Stage 2, Suppliers' and NGOs' decisions: The buyer's j decision puts all of her suppliers into either the pool of identified suppliers ($j = I$) or the pool of unidentified suppliers ($j = U$). Her suppliers then face public scrutiny from type-j NGOs. The suppliers and the NGOs enter a static game of complete information. That is to say, they know each other's objective function but do not observe each other's action. A type-j NGO adopts its auditing effort level $e_N^j \in [0,1]$ at a convex increasing cost. In particular, we assume it is equal to $k_N(e_N^j)^2$ where k_N is a fixed parameter.

Similarly, a supplier determines his compliance effort level $e_S^j \in [0,1]$ and incurs a convex increasing cost $k_S(e_S^j)^2$. With probability e_S^j, the supplier's performance will comply with the social and environmental standards, while with probability $1 - e_S^j$, there will be a violation of those standards. Note that compliance violation is a random event with probability $1 - e_S^j$. For example, one can interpret the effort level as an investment in pollutant-control technology which is subject to random breakdown (see Kim 2014); the higher the investment, the better the technology, and the lower the probability of violation.

The supplier faces scrutiny from both the buyer and the NGOs. With probability $e_B^j(1 - e_S^j)$ the supplier has a violation and the violation is detected by the buyer. Note that this way we model the various efforts and the associated probabilities follows Plambeck and Tylor (2014). When a violation is detected, the supplier incurs a cost x_B (e.g., a loss of good will or a downgrade on the buyer's scorecard). The pressure from the NGOs, however, depends on the likelihood of auditing and the auditing effort level of the NGOs. Thus, the probability that a type-j supplier will have a violation and it will be detected by an NGO is $\gamma^j e_N^j(1 - e_S^j)$ (for ease of exposition, we refer to $\gamma^j e_N^j$ as the *NGOs' scrutiny* for the rest of the paper). When that happens, the supplier incurs a different cost x_N (e.g., reputation damage, or a loss of potential future buyer). When an NGO detects and reports a violation, the reputation damage is done but the buyer may not be able to confirm the violation allegations when they follow up on the NGO report (for example, see Samsung's response to CLW on allegation of child labor at one of its suppliers, `http://www.chinalaborwatch.org/report/106`). Thus, the buyer may not be able to impose an additional penalty x_B. Some of this could be due to coverup, but often the random nature of the violations makes replication hard. When investigating child labor violations in the apparel industry, CLW discovers that the seasonal nature of the production cycle means a reported violation often cannot be confirmed by the press or the buyer months later (personal communication with Qiang Li, director of CLW). Of course, there is a possibility that a supplier's violation could be detected

by both the buyer and the NGOs. In such a case the supplier will incur a total penalty cost of $x_B + x_N$.

For the reader's convenience, Table 1 summarizes our notations.

Table 1 Notations

b	Brand damage for the buyer if any of her supplier has a violation that's detected and publicized
x_B	Cost to a supplier if a violation is detected by the supplier's buyer
x_N	Cost to a supplier if a violation is detected by the NGOs
v	Gain for an NGO if he detects and publicizes a special supplier's violation
γ^I	Likelihood of auditing (by the NGOs) for identified suppliers
γ^U	Likelihood of auditing (by the NGOs) for unidentified suppliers
p	Proportion of special suppliers in the pool of unidentified suppliers
k_B	Cost factor associated with the buyer's auditing effort
k_N	Cost factor associated with an NGO's auditing effort
k_S	Cost factor associated with a supplier's sustainability effort
e_B^I	Buyer's own auditing effort level if she decides to reveal her supplier list; $e_B^I \in [0,1]$
e_B^U	Buyer's own auditing effort level if she decides not to reveal her supplier list; $e_B^U \in [0,1]$
e_N^I	NGO's effort level when auditing an identified supplier; $e_N^I \in [0,1]$
e_N^U	NGO's effort level when auditing an unidentified supplier; $e_N^U \in [0,1]$
e_S^I	Supplier's sustainability effort level if he is identified; $e_S^I \in [0,1]$
e_S^U	Supplier's sustainability effort level if he is unidentified; $e_S^U \in [0,1]$
C_S^I	An identified supplier's expected total cost
C_S^U	An unidentified supplier's expected total cost
C_B^I	Buyer's expected cost if she reveals her supplier list
C_B^U	Buyer's expected cost if she does not reveal her supplier list
C_B	Buyer's expected optimal cost; $C_B = \min\{C_B^I, C_B^U\}$
Π_N^I	The expected payoff for a type-I NGO
Π_N^U	The expected payoff for a type-U NGO

3.2. Objective functions

As usual, to formulate each player's objective function in the Stackelberg game, we move backwards in time. Once the buyer has decided whether to reveal her supplier list (i.e., $j \in \{I, U\}$) and auditing effort level e_B^j, each of her suppliers will determine his sustainability effort level e_S^j and each of the type-j NGOs will determine its auditing effort accordingly. For given j and e_B^j, each supplier aims to minimize the total of his effort and penalty costs:

$$C_S^j(e_B^j) = \min_{0 \le e_S^j \le 1} \; e_B^j(1-e_S^j)x_B + \gamma^j e_N^j(1-e_S^j)x_N + k_S(e_S^j)^2, \quad j = I \text{ or } U, \tag{1}$$

where e_B^j and $\gamma^j e_N^j$ are probabilities that the supplier's violation will be detected by the buyer and by a type-j NGO respectively.

For a type-U NGO, its target pool of unidentified suppliers contains both special and ordinary suppliers. Therefore, the NGO's potential utility gain from special suppliers must be multiplied by the proportion of special suppliers in this pool (we denote this proportion by p).

$$\Pi_N^U(e_B^U) = \underset{0\le e_N^U\le 1}{max}\ pe_N^U(1-e_S^U)v - k_N(e_N^U)^2. \tag{2U}$$

For a type-I NGO, every supplier in its target pool is identified, so its objective function is similar to the one above, except that p is replaced by one:

$$\Pi_N^I(e_B^I) = \underset{0\le e_N^I\le 1}{max}\ e_N^I(1-e_S^I)v - k_N(e_N^I)^2. \tag{2I}$$

Let $(\widetilde{e}_S^j(e_B^j), \widetilde{e}_N^j(e_B^j))$ denote the Nash equilibrium determined by equations (1)&(2U) or (1)&(2I). Going back in time, the buyer must choose j and e_B^j to minimize the total of its auditing and brand damage costs, knowing the suppliers' and the NGOs' response function, $(\widetilde{e}_S^j(e_B^j), \widetilde{e}_N^j(e_B^j))$. The buyer's cost function is given by:

$$C_B = \underset{j\in\{I,U\}}{min}\left\{ C_B^j = \underset{0\le e_B^j\le 1}{min}\ \gamma^U \widetilde{e}_N^j(e_B^j)(1-\widetilde{e}_S^j(e_B^j))b + k_B(e_B^j)^2 \right\}. \tag{3}$$

It is worth noting that the supply chain's sustainability level is solely determined by the supplier's effort level e_S^j. The buyer and NGOs aim to influence the supplier's action but they do so only indirectly. Therefore, the optimal e_S^j is of particular interest to us. We refer to it as the *supply chain sustainability level*. Moreover, since the supply chain becomes more transparent if the buyer reveals her supplier list, we will refer to her j decision as the *supply chain transparency level*.

4. Analysis

We want to address several issues in this section. First, we derive the equilibrium supply chain sustainability and transparency levels and some comparative statics in §4.1. Since both sustainability and transparency are important measures of a supply chain, we examine how they relate to each other in our model in §4.2. Then in §4.3 we quantify how the expected costs and payoff may change for the buyer, suppliers, and NGOs as a result of the buyer revealing her supplier list.

One novel feature of our model is the incorporation of NGOs' actions in the equilibrium. In §4.4 we compare with a special case with non-strategic NGOs who exert the same auditing effort indiscriminately between identified and unidentified suppliers. In this comparison, we explore the strategic NGOs' impact on the optimal sustainability and auditing efforts, as well as their impact on the buyer's optimal decision on whether to reveal her supplier list.

4.1. Supply chain sustainability and transparency

If the buyer reveals her supplier list (i.e. $j = I$) in the first stage of the Stackelberg game, then the suppliers and NGOs solve (1) and (2I) in the second stage. Likewise, if the buyer chooses not to reveal (i.e. $j = U$), the suppliers and NGOs solve (1) and (2U) instead. The closed-form solutions are summarized in the following lemma. All the proofs in this paper can be found in the Appendix.

LEMMA 1. *(**Suppliers' and NGOs' response functions**) If the buyer reveals her supplier list and chooses e_B^I, then*

$$\widetilde{e}_S^I(e_B^I) = \frac{2e_B^I k_N x_B + \gamma^I v x_N}{4k_N k_S + \gamma^I v x_N},\ \widetilde{e}_N^I(e_B^I) = \frac{pv(2k_S - e_B^I x_B)}{4k_N k_S + \gamma^I v x_N}. \tag{4}$$

If the buyer does not reveal her supplier list and chooses e_B^U, then

$$\widetilde{e}_S^U(e_B^U) = \frac{2e_B^U k_N x_B + \gamma^U p v x_N}{4k_N k_S + \gamma^U p v x_N},\ \widetilde{e}_N^U(e_B^U) = \frac{pv(2k_S - e_B^U x_B)}{4k_N k_S + \gamma^U p v x_N}. \tag{5}$$

Given the suppliers' and the NGOs' response functions in Lemma 1, the buyer solves the optimization problem in (3). The closed-form solutions to her optimal auditing effort are given in (6) below. At this buyer auditing level, the suppliers' optimal effort level and the NGOs' optimal auditing level can be obtained by substituting (6) into (4) and (5). These results are summarized in the following theorem.

THEOREM 1. *(**Optimal equilibrium effort levels**) For given $j = I$ or U, the optimal effort levels by the buyer, the NGOs, and the suppliers in the Stackelberg equilibrium are as follows:*

$$e_B^{I*} = \frac{4k_N k_S b\gamma^I v x_B}{2k_N b\gamma^I v x_B^2 + k_B(4k_N k_S + \gamma^I v x_N)^2},\ e_B^{U*} = \frac{4k_N k_S b\gamma^U p v x_B}{2k_N b\gamma^U p v x_B^2 + k_B(4k_N k_S + \gamma^U p v x_N)^2}, \tag{6}$$

$$e_N^{I*} = \frac{2k_B k_S v(4k_N k_S + \gamma^I v x_N)}{2k_N b\gamma^I v x_B^2 + k_B(4k_N k_S + \gamma^I v x_N)^2},\ e_N^{U*} = \frac{2k_B k_S p v(4k_N k_S + \gamma^U p v x_N)}{2k_N b\gamma^U p v x_B^2 + k_B(4k_N k_S + \gamma^U p v x_N)^2}, \tag{7}$$

$$e_S^{I*} = \frac{\gamma^I v[k_B(4k_N k_S + \gamma^I v x_N)x_N + 2k_N b x_B^2]}{2k_N b\gamma^I v x_B^2 + k_B(4k_N k_S + \gamma^I v x_N)^2},\ e_S^{U*} = \frac{p\gamma^U v[k_B(4k_N k_S + \gamma^U p v x_N)x_N + 2k_N b x_B^2]}{2k_N b\gamma^U p v x_B^2 + k_B(4k_N k_S + \gamma^U p v x_N)^2} \tag{8}$$

Before we use the optimal effort levels in (6)-(8) to find the buyer's optimal decision about supply chain transparency (i.e., choosing j), we first examine how these effort levels, especially the supply chain sustainability level e_S^{j*} is influenced by the configuration of the industry – in particular, the likelihood of being audited by type-j NGOs γ^j, and the proportion of special suppliers among all unidentified suppliers p.

PROPOSITION 1. *(**Comparative statics of the optimal effort levels**)*

a. For $j = I$ or U, supply chain sustainability level e_S^{j*} is increasing in γ^j. Moreover, as γ^j increases, e_N^{j*} decreases and $\gamma^j e_N^{j*}$ increases; but e_B^{j*} decreases if and only if $4k_N k_S < \gamma^I v x_N$ (for $j = I$) or $4k_N k_S < \gamma^U p v x_N$ (for $j = U$).

b. Supply chain sustainability level e_S^{U*} is increasing in p. Moreover, as p increases, both e_N^{U*} and $\gamma^U e_N^{U*}$ increase; but e_B^{U*} decreases if and only if $4k_N k_S < \gamma^U pvx_N$.

When there are more type-j NGOs, a type-j supplier's likelihood of being audited γ^j goes up. Proposition 1a indicates that although each NGO will spend less effort in auditing, the overall NGO scrutiny $\gamma^j e_N^{j*}$ still increases. Accordingly, each supplier will increase his compliance effort level. This is desirable as the supply chain sustainability level will increase.

The buyer's reaction could go either way, however. On the one hand, higher scrutiny by the NGOs increases the risk of the buyer's reputation damage, so the buyer should put on more auditing effort herself. On the other hand, now that the NGOs are putting more scrutiny on the suppliers, the suppliers will respond with higher effort so the buyer should be able to reduce her own costly auditing effort. The outcome of this tradeoff depends on the last condition in Proposition 1a. Mathematically it's easy to see this condition follows from (6). Intuitively, as γ^j increases, we already know the NGO scrutiny $\gamma^j e_N^j$ increases and the probability of a violation $(1-e_S^j)$ decreases. It's the product of the two, $\gamma^j e_N^j(1-e_S^j)$, that matters to the buyer, however, from her objective function (3). The buyer's decision depends on which probability changes more quickly. This also explains why the condition involves only the cost and benefit parameters of the NGOs and the suppliers: k_N, k_S, v, and x_N. Practical implication: the buyer can save auditing effort if the NGOs' audit is effective (the suppliers will take the threats seriously); conversely, if the suppliers ignore the NGOs' threats, then the buyer has to exert more auditing efforts.

When the proportion of special suppliers increases in the unidentified pool, the type-U NGOs recognize the higher marginal return on its effort in detecting a violation by an unidentified supplier, so they are more motivated to increase their auditing efforts. At the same time, the suppliers will respond with higher effort, dampening the NGOs' motivation. Proposition 1b shows that in aggregate both suppliers and NGOs will increase their effort. This also results in a desirable increase in the supply chain sustainability. A similar tradeoff – hence a similar condition – applies to the buyer's decision. Practical implication: If the NGOs could narrow down to a list where most are likely to be special suppliers, then the supply chain sustainability level can be increased. Method: hot lines, protection of whistle blowers, etc.

Recall that we consider the supply chain to be more transparent if the buyer reveals her supplier list, and e_S^{j*} represents the supply chain sustainability level under buyer decision j. The following proposition shows that more supply chain transparency does not always lead to higher supply chain sustainability, and gives condition under which the two metrics agree.

PROPOSITION 2. *(**Transparency vs sustainability**) The following conditions are equivalent: (i) $e_S^{U*} \le e_S^{I*}$, (ii) $\gamma^U e_N^{U*} \le \gamma^I e_N^{I*}$, and (iii) $p \le \gamma^I/\gamma^U$.*

Condition (i) represents the situation where the supply chain sustainability improves after the buyer reveals her supplier list (doing so optimally). In such a case, transparency and sustainability agree with each other. Condition (ii) means the NGO scrutiny is higher on the identified suppliers than on the unidentified ones. The equivalency between (i) and (ii) shows that the NGOs' scrutiny level is essential in determining how the supply chain performs. Higher scrutiny on a supplier pool helps to increase their sustainability effort. So for an industry where NGOs scrutinize the unidentified suppliers more closely, supply chain transparency (revealing supplier list) may actually lead to lower sustainability effort, an undesirable outcome.

Because the NGOs' auditing efforts are endogenized in our model, condition (ii) is not easy to check directly. Condition (iii) is simpler and directly verifiable, because it only depends on the fixed parameters. When condition (iii) holds, the type-U NGOs are less likely to detect violations by a special supplier than the type-I NGOs. Given the same cost function, type-U NGOs would optimally put less scrutiny than the type-I NGOs. Thus it's equivalent to condition (ii). The reasoning is stated rigorously in the proofs in the Appendix.

4.2. Buyer's optimal transparency decision and relationship to sustainability

So far we have only characterized the equilibrium behaviors for $j = I$ and $j = U$ separately. It is quite straightforward to plug (6)-(8) into the buyer's objective function (3) to see whether the buyer should optimally reveal her supplier list. Without loss of generality, we will assume that if the buyer is indifferent between revealing the supplier list and not revealing it, she will not reveal.

THEOREM 2. *(**Optimal transparency decision**) It is optimal for the buyer to reveal her supplier list if and only if*

$$\min\left\{\frac{16k_N^2k_S^2}{\gamma^I\gamma^U v^2 x_N^2}, \frac{\gamma^I}{\gamma^U}\right\} < p < \max\left\{\frac{16k_N^2k_S^2}{\gamma^I\gamma^U v^2 x_N^2}, \frac{\gamma^I}{\gamma^U}\right\}. \tag{9}$$

The buyer's corresponding optimal auditing effort is given by (6) *in Theorem 1. Moreover,* $e_B^{U*} > e_B^{I*}$ *if and only if the optimal decision is to reveal her supplier list.*

Together, Theorems 1 and 2 characterize the optimal decisions for the supply chain. Moreover, Theorem 2 states that a buyer will reduce her own auditing effort if and only if it's optimal for her to reveal her supplier list. This implies that when the buyer chooses to reveal her supplier list, she will substitute the NGOs' auditing effort for her own auditing effort. Thus, supply chain transparency becomes a strategic tool that the buyer can use to reduce her own auditing effort.

The major result of Theorem 2 is that the buyer optimally reveals her supplier list when p is within the interval stated in (9). Depending on the parameters, there are two possible scenarios.

COROLLARY 1.

a. *(Scenario 1) When* $4k_Nk_S < \gamma^I v x_N$*, it is optimal to reveal the supplier list if and only if* $\frac{16k_N^2k_S^2}{\gamma^I\gamma^U v^2 x_N^2} < p < \frac{\gamma^I}{\gamma^U}$.
b. *(Scenario 2) When* $4k_Nk_S \geq \gamma^I v x_N$*, it is optimal to reveal the supplier list if and only if* $\frac{\gamma^I}{\gamma^U} < p < \frac{16k_N^2k_S^2}{\gamma^I\gamma^U v^2 x_N^2}$.

Scenario 1, when $4k_Nk_S < \gamma^I v x_N$, is more likely to happen if γ^I, v, and x_N are larger, or if k_N and k_S are smaller; that is, if the auditing likelihood by NGOs for the identified suppliers is larger (e.g., there are more NGOs focusing on the identified pool), or the NGO's utility gain from publicizing violations is higher, or the penalty cost of the supplier whose violation is publicized by an NGO is higher, or the cost factors of the NGOs and the suppliers are smaller.

Note that when $4k_Nk_S = \gamma^I v x_N$, the buyer prefers not to reveal her supplier list for all p values except $p = \frac{\gamma^I}{\gamma^U} = \frac{16k_N^2k_S^2}{\gamma^I\gamma^U v^2 x_N^2}$, where the buyer is indifferent between revealing and not revealing. Therefore, by our assumption, the buyer will never reveal when $4k_Nk_S = \gamma^I v x_N$.

To understand the rationale for the buyer's behavior, we summarize how the various optimal effort levels change based on the buyer's decision on whether to reveal the supplier list in Tables 2 and 3, for scenarios 1 and 2 respectively.

Table 2 Scenario 1. Impact of buyer's decision on j

Interval	Buyer's Decision	e_S	e_B	γe_N
(1-i) $p < \frac{16k_N^2k_S^2}{\gamma^I\gamma^U v^2 x_N^2}$	Not to reveal	$e_S^{U*} < e_S^{I*}$	$e_B^{U*} < e_B^{I*}$	$\gamma^U e_N^{U*} < \gamma^I e_N^{I*}$
(1-ii) $\frac{16k_N^2k_S^2}{\gamma^I\gamma^U v^2 x_N^2} < p < \frac{\gamma^I}{\gamma^U}$	Reveal	$e_S^{U*} < e_S^{I*}$	$e_B^{U*} > e_B^{I*}$	$\gamma^U e_N^{U*} < \gamma^I e_N^{I*}$
(1-iii) $p > \frac{\gamma^I}{\gamma^U}$	Not to reveal	$e_S^{U*} > e_S^{I*}$	$e_B^{U*} < e_B^{I*}$	$\gamma^U e_N^{U*} > \gamma^I e_N^{I*}$

Analysis of scenario 1 In scenario 1, when p is in interval (1-i), there is only a small portion of special suppliers in the unidentified pool, and as a result, there is less NGO scrutiny on the suppliers in the unidentified pool. If the buyer reveals her supplier list, her suppliers will face higher NGO scrutiny, and both the buyer and her suppliers will need to increase their effort levels. While this is a socially desirable outcome – both supply chain transparency and sustainability are increased – the buyer chooses not to do it because she finds the increased costs to herself too high. She would rather hide her suppliers in the unidentified pool.

When p is in interval (1-iii), there is a high proportion of special suppliers in the unidentified pool. The buyer still prefers not to reveal her supplier list, but for a different reason. When $p\gamma^U > \gamma^I$, there is actually more NGO scrutiny on the unidentified suppliers ($\gamma^U e_N^{U*} > \gamma^I e_N^{I*}$). By not revealing her suppliers, the buyer puts more pressure on her suppliers and they respond by improving their sustainability effort. A secondary benefit to the buyer is that she can reduce her own effort cost.

Therefore, for very high p values, the buyer again chooses not to reveal. Contrary to the low p value case, while the supply chain transparency suffers, its sustainability is better off.

In (1-i) the supply chain achieves lower sustainability and no transparency. In (1-iii) the supply chain achieves higher sustainability but no transparency. It's in the middle range of p value – interval (1-ii) – where the supply chain achieves both higher sustainability and transparency, a most desirable outcome. The intuition is that by revealing her supplier list, the buyer "invites" more NGO scrutiny on her suppliers, which pressures the suppliers to exert more sustainability effort. Moreover, the buyer is able to reduce her own auditing effort and cost. This reasoning seems to be behind Nike's decision to reveal its entire supplier list (Paine et al. 2013).

It's worth noting that when p is very high or low, the makeup of the unidentified supplier pool becomes very clear: it consists of mostly special suppliers or mostly ordinary suppliers. The intermediate values of p gives less information of the pool makeup. Therefore, we can also loosely view p as a proxy for the transparency of the whole industry (in a non-monotonic fashion). This is a different concept than the transparency of the particular supply chain which is represented by the buyer's j decision. The results in Theorem 2 indicate that higher supply chain sustainability and transparency are optimal when the whole industry is not very transparent. When the industry is transparent, the buyer tends not to reveal her own supplier list; the supply chain sustainability level may suffer or improve.

A special case happens when $\gamma^I \geq \gamma^U$, i.e. when the NGOs focus more on the identified suppliers so the auditing likelihood is higher for identified suppliers. In such a case, interval (1-iii) disappears and the buyer's optimal reveal strategy is of a threshold type. The most desirable outcome is achieved for higher p – suppliers are revealed and they put in more sustainability effort. Another special case happens when $4k_N k_S = \gamma^I v x_N$. The buyer is indifferent at $p = 4k_N k_S = \gamma^I v x_N$. Everywhere else she prefers not to reveal her supplier list.

Table 3 Scenario 2. Impact of buyer's decision on j

Interval	Buyer's Decision	e_S	e_B	γe_N
(2-i) $p < \frac{\gamma^I}{\gamma^U}$	Not to reveal	$e_S^{U*} < e_S^{I*}$	$e_B^{U*} < e_B^{I*}$	$\gamma^U e_N^{U*} < \gamma^I e_N^{I*}$
(2-ii) $\frac{\gamma^I}{\gamma^U} < p < \frac{16k_N^2 k_S^2}{\gamma^I \gamma^U v^2 x_N^2}$	Reveal	$e_S^{U*} > e_S^{I*}$	$e_B^{U*} > e_B^{I*}$	$\gamma^U e_N^{U*} > \gamma^I e_N^{I*}$
(2-iii) $p > \frac{16k_N^2 k_S^2}{\gamma^I \gamma^U v^2 x_N^2}$	Not to reveal	$e_S^{U*} > e_S^{I*}$	$e_B^{U*} < e_B^{I*}$	$\gamma^U e_N^{U*} > \gamma^I e_N^{I*}$

Analysis of scenario 2 The results for scenario 1 does not carry over to scenario 2 entirely. For low and high values of p in intervals (2-i) and (2-iii), the buyer chooses not to reveal her suppliers for the same reasons as those for (1-i) and (1-iii) in scenario 1. Furthermore, for intermediate levels of p in (2-ii), the buyer reveals her supplier list, as in (1-ii), but for a different reason. Specifically,

in (2-ii) the NGO scrutiny is *lower* for the identified suppliers. The buyer reveals her suppliers in order to hide them in the lower scrutiny pool. With less pressure, both the buyer and her suppliers now exert less effort to reduce their cost. While this is good for their own objectives, the supply chain sustainability suffers after the buyer reveals her supplier list. This is a unique case of where the buyer optimally chooses to be transparent but the supply chain sustainability indeed suffers.

It's notable that in scenario 2, the supply chain will never achieve both transparency and higher sustainability. Either they are in conflict with each other or both suffer. As before, in the special case of $\gamma^I \geq \gamma^U$, interval (2-iii) no longer exists, and the supply chain sustainability and transparency is always in conflict with each other.

In summary, we have found the relationship between supply chain sustainability and supply chain transparency to be complex. In many cases the buyer will choose not to be transparent, but even in cases when supply chain transparency is optimal for the buyer, it could lead to higher or lower supply chain sustainability. Only in the case of (1-ii) are they in agreement.

4.3. Expected costs and payoffs in the supply chain

In the previous sections we have examined how the supply chain transparency decision by the buyer can change equilibrium effort levels of the various parties, and how that impacts supply chain sustainability. In this section we further explore how the buyer's decision to reveal supplier list can affect the costs of the buyer and her suppliers and the payoff of the NGOs, which will help us to determine whether there are any incentive conflicts between different parties. The next lemma is useful to answer this question.

LEMMA 2. *C_S^U is increasing in p and γ^U; while Π_N^U is increasing in p but is decreasing in γ^U.*

Lemma 2 says that the type-U NGOs will benefit while the unidentified suppliers will suffer from an increase in p. Furthermore, if the likelihood of being audited for the unidentified supplier pool is increased, the suppliers will respond with higher sustainability effort (Proposition 1), making it harder for the NGOs to find violations. Consequently, the suppliers will incur a higher cost and the NGOs should expect a lower payoff.

PROPOSITION 3. *(**The expected NGO payoff and supplier cost**) When the buyer optimally reveals her supplier list,*

a. *Under scenario 1 (i.e., in interval (1-ii)), the suppliers incur a higher cost after the revelation ($C_S^U < C_S^I$). For the NGOs, if $\gamma^I \leq \gamma^U$, then $\Pi_N^U \leq \Pi_N^I$, but if $\gamma^I > \gamma^U$, then Π_N^U can be either greater or smaller than Π_N^I.*
b. *Under scenario 2 (i.e., in interval (2-ii)), the suppliers incur a lower cost after the revelation ($C_S^U > C_S^I$). The type-I NGOs expect a higher payoff than the type-U NGOs ($\Pi_N^U \leq \Pi_N^I$) if and only if $\gamma^I \leq \gamma^U$.*

For the reader's convenience, the results of Proposition 3 are summarized in Table 4. A rigorous proof can be found in the Appendix.

In scenario (1-ii), the buyer reveals her supplier list because she wants to expose the suppliers to higher NGO scrutiny, as we discovered in Theorem 2. It makes sense that the suppliers' costs increase after the revelation. The impact on the NGOs is more complicated. Since the NGO's expected payoff decreases in γ^U, per Proposition 1, revealing the supplier list is roughly equivalent to changing the suppliers' γ^U to γ^I. If $\gamma^I \le \gamma^U$, the NGO receives a higher payoff after the revelation, $\Pi_N^U < \Pi_N^I$, but if $\gamma^I > \gamma^U$, there is no definite answer. We are able to show that there exists a threshold $\overline{p}$ such that $\Pi_N^U > \Pi_N^I$ if and only if $p > \overline{p}$.

In scenario (2-ii), however, the suppliers are always better off if the buyer's optimal decision is to reveal her supplier list. As we have explained under Theorem 2, under such scenario, the buyer's reason for revealing her supplier list is to take advantage of the reduced NGO scrutiny (since $\gamma^I e_N^{I*} < \gamma^U e_N^{U*}$). Consequently, the suppliers reduces their sustainability effort and saves cost after the buyer chooses to reveal the supplier list.

Table 4 The impact of revealing the supplier list, when it's optimal for the buyer to reveal

Scenario	on buyer	on supplier	on NGO	on sustainability
(1-ii) and $\gamma^I \le \gamma^U$	beneficial	harmful	beneficial	beneficial
(1-ii) and $\gamma^I > \gamma^U$	beneficial	harmful	Depends	beneficial
(2-ii) and $\gamma^I \le \gamma^U$	beneficial	beneficial	beneficial	harmful
(2-ii) and $\gamma^I > \gamma^U$	beneficial	beneficial	harmful	harmful

The key observation is that there is no win-win-win-win situation across the supply chain when the buyer reveals her supplier list. Because the buyer makes the first decision on transparency and everyone else follows, we should only consider the cases that are beneficial to the buyer. The most notable scenarios are (1-ii) plus $\gamma^I \le \gamma^U$, and (2-ii) plus $\gamma^I \le \gamma^U$. In the former, supply chain transparency is beneficial to the buyer, NGO, and supply chain sustainability, but all these benefits come at the expense of the suppliers. In the latter, supply chain transparency is beneficial to the buyer, suppliers, and the NGO, but the this leads to a worse sustainability performance. The table also reiterate the result that scenario (1-ii) is the most desirable as far as just supply chain sustainability and transparency are considered.

Table 5 summarizes the results when the buyer *does not* want to reveal her supplier list. Together, Tables 4 and 5 provide a complete picture of the tradeoffs in the supply chain. More importantly, they also provide a contrast between voluntary revealing and involuntary revealing of the suppliers.

In all the situations in Table 4, the buyer willingly reveals her supplier list because it's in her interest to do so, even if such a revelation can hurt the supplier or the supply chain sustainability.

Table 5 The impact of revealing the supplier list, when it's optimal for the buyer not to reveal

Scenario	on buyer	on supplier	on NGO	on sustainability
(1-i) and $\gamma^I \le \gamma^U$	harmful	harmful	beneficial	beneficial
(1-i) and $\gamma^I > \gamma^U$	harmful	harmful	depends	beneficial
(1-iii) and $\gamma^I \le \gamma^U$	harmful	beneficial	beneficial	harmful
(1-iii) and $\gamma^I > \gamma^U$	harmful	beneficial	interval does not exist	harmful
(2-i) and $\gamma^I \le \gamma^U$	harmful	harmful	beneficial	beneficial
(2-i) and $\gamma^I > \gamma^U$	harmful	harmful	depends	beneficial
(2-iii) and $\gamma^I \le \gamma^U$	harmful	beneficial	beneficial	harmful
(2-iii) and $\gamma^I > \gamma^U$	harmful	beneficial	interval does not exist	harmful

In all the situations in Table 5, the buyer prefers not to reveal her suppliers. However, if the government mandates disclosure of violation incidents, then the reported suppliers are, in effect, revealed. Once revealed, the buyer suffers, but the supply chain sustainability could either improve or deteriorate depending on the scenario (last column). It must be noted that Scenarios (1-iii) and (3-iii) are where there is less NGO scrutiny for the identified suppliers, a rather unlikely assumption in practice. Hence, in the more likely Scenarios (1-i) and (2-i), when the buyer does not want to reveal her supplier list, forcing her to do so would lead to higher sustainability. Such a mandate for information revelation, clearly not in the best interest of the buyer and the revealed suppliers (both "harmful"), does achieve the desired goal of improving supply chain sustainability.

Note that the comparison between voluntary and mandated revelation above mirrors our earlier discussion of structural transparency and informational transparency. With structural transparency, the buyer willingly reveals her suppliers, whereas with informational transparency, the buyer is forced to reveal only some of her suppliers (when violation is detected). The results in Table 5 clearly indicate that both transparency could lead to better supply chain sustainability.

Although these results are derived in a stylized model, we believe the tradeoffs incorporated in our model and the insights from it are real. They can prove useful to policy makers in this field.

4.4. Impact of Non-Strategic NGO

Most if not all studies in the existing literature model the auditing effort from the NGOs as being fixed and exogenously given (the exception being Kraft et al. 2013). In our modeling framework, we can impose an additional constraint that $e_N^U = e_N^I$ and call such NGOs non-strategic because they do not adjust auditing effort based on supplier type and supplier's sustainability effort. Since the explicit modeling of strategic NGOs' actions is one of our major contributions, in this section we study how these non-strategic NGOs can change the supply chain dynamics.

Suppose that the non-strategic NGOs exert a constant auditing effort, i.e., $e_N^I = e_N^U = e_N \in (0,1)$. Then, a type-$j$ supplier solves the following cost-minimization problem:

$$C_S^j(e_B^j, e_N) = \min_{0 \le e_S^j \le 1} \; e_B^j(1-e_S^j)x_B + \gamma^j e_N(1-e_S^j)x_N + k_S(e_S^j)^2.$$

The buyer can infer the supplier's best response function $\widetilde{e}_S^j(e_B^j, e_N)$ and use that, together with the constant e_N, in (3) to find her own optimal auditing level. The resulting equilibrium behavior of both the buyer and her suppliers are given in the next proposition. We use the $\circ$ superscript notation in this section for the results based on non-strategic NGOs.

PROPOSITION 4. ***(Optimal equilibrium effort levels when NGOs are non-strategic)*** *Suppose that the NGOs' auditing effort is a constant e_N.*

$$e_B^{I\circ} = \tfrac{be_N\gamma^I x_B}{4k_Bk_S}, \qquad e_B^{U\circ} = \tfrac{be_N\gamma^U x_B}{4k_Bk_S}.$$
$$e_S^{I\circ} = \tfrac{\gamma^I e_N(4k_Bk_Sx_N+bx_B^2)}{8k_Bk_S^2}, \qquad e_S^{U\circ} = \tfrac{\gamma^U e_N(4k_Bk_Sx_N+bx_B^2)}{8k_Bk_S^2}.$$

In parallel to Proposition 1, the following proposition contains the comparative statics of the optimal effort levels when NGOs are non-strategic.

PROPOSITION 5. ***(Comparative statics when the NGOs are non-strategic)*** *Suppose that the NGOs' auditing effort is a constant e_N. For both $j = I$ and U, if γ^j increases, then $\gamma^j e_N$ increases, $e_S^{j\circ}$ increases, and $e_B^{j\circ}$ increases.*

Note that p is not part of the study because the NGOs' effort level does not respond to the p value anymore. Therefore, p does not affect the suppliers' or the buyer's decision.

As the likelihood of being audited by NGOs increases for either supplier pool, both the suppliers and the buyer react in a straightforward way by increasing their own effort levels. While the suppliers' response is in the same direction as in the strategic-NGO case, the buyer's decision is different. When the NGOs are strategic, increase in γ^j induces the NGOs to strategically reduce their own effort, so while the suppliers all increase their effort, the total $\gamma^j e_N^j(1-e_S^j)$ could either increase or decrease. This causes the buyer to adjust her own effort up or down. When the NGOs are non-strategic, however, as more NGOs are present, each NGO continues to exert the same auditing effort, increasing the total possibility of a violation detection. Therefore, the buyer must increase her own effort.

Proposition 5 states that, if NGOs are considered non-strategic, the buyer and suppliers both increase their effort level if and only if the NGO scrutiny for their pool increases. The next proposition explores when supply chain sustainability and transparency are in agreement with each other.

PROPOSITION 6. ***(Sustainability vs transparency when the NGOs are non-strategic)*** *Suppose that the NGOs' auditing effort is a constant e_N. $e_S^{U\circ} < e_S^{I\circ}$ if and only if $\gamma^U < \gamma^I$; and $e_B^{U\circ} < e_B^{I\circ}$ if and only if $\gamma^U < \gamma^I$.*

If the identified pool faces higher NGO scrutiny ($\gamma^U < \gamma^I$, or equivalently, $\gamma^U e_N < \gamma^I e_N$), the suppliers will increase effort level after the buyer reveals her list; hence the supply chain sustainability and transparency are in agreement. However, if the unidentified pool faces higher NGO scrutiny, the supply chain sustainability and transparency are in conflict. Higher supplier sustainability effort comes as a result of the buyer not revealing her supplier list.

Since the non-strategic NGOs' objective function ignores the p parameter, it can be treated as if $p = 1$. Letting $p = 1$ in Propositions 2, we see that when NGOs are considered strategic, the suppliers always increase their sustainability effort when switched into the higher-scrutiny pool. This is in agreement with the results under non-strategic NGOs in Propositions 6.

It's a different story for the buyer, however: when she overlooks the NGOs' strategic actions, her effort change will always go in the same direction as the supplier scrutiny change (Proposition 6). When she considers the NGOs to be strategic, however, her effort level change could go in the same *or* the opposite direction (Tables 2 and 3) – that is, once the buyer starts to consider the NGOs as strategic, revealing her supplier list could allow her to decrease auditing effort and save cost. Thus, it is important for the buyer to consider the strategic actions of the NGOs.

The next proposition parallels Theorem 2:

PROPOSITION 7. ***(Optimal transparency decision when the NGOs are non-strategic)*** *Suppose that the NGOs' auditing effort is a constant e_N. It is optimal for the buyer to reveal her supplier list if and only if*

$$\min\left\{\gamma^I e_N^I, \frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} - \gamma^I e_N^I\right\} < \gamma^U e_N^U < \max\left\{\gamma^I e_N^I, \frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} - \gamma^I e_N^I\right\}.$$

Moreover, under Scenario 1 (2), the interval within which the buyer will reveal the supplier list is larger (smaller) than that in Theorem 2 under the strategic NGOs.

In Theorem 2, the optimal revelation interval is stated in terms of p, but by Proposition 1, varying p is equivalent to varying $\gamma^U e_N^{U*}$, so the optimal revelation intervals in Theorem 2 and Proposition 7 share the same structure. However, we show that under Scenario 1 – which happens, for example, when the supplier's sustainability effort cost coefficient (k_S) is not too high – the buyer is more likely to reveal her supplier list if she takes the NGOs' strategic actions into consideration. The reason is that, by revealing her suppliers, the buyer can expect strategic NGOs to exert more effort (as opposed to the fixed effort by non-strategic NGOs), and the suppliers to respond by increasing their effort. In aggregate, these reduces the reputation cost to the buyer, and allows the buyer to reduce her own auditing effort. Thus, the buyer is more willing to reveal the list. This sequence of actions echoes Nike's logic when making the decision to reveal its supplier list. In

contrast, under scenario 2, the buyer is less likely to reveal her supplier list if the NGOs strategic actions are considered.

Together, Propositions 5-7 demonstrate that the while the suppliers' action stays qualitatively the same, the buyer's decisions could be very different depending on how she views the NGOs. When she considers the NGO's strategic actions, she does not always have to increase her own effort if the NGOs' scrutiny intensifies, and she can actually reduce her own auditing effort by revealing her supplier list even if this subjects her suppliers to higher NGO scrutiny. Finally, the buyer can be more likely to reveal her supplier list when she considers the NGO's strategic actions. Through these results, we see that the NGOs play a important strategic role in affecting both the supply chain sustainability and the supply chain transparency. Since the NGOs' strategic actions most significantly affect the buyer who is the Stackelberg leader in the supplier chain, it is utterly important for the buyer to account for the NGOs' strategic actions properly in her decision.

5. Extension to Two Buyers

In the previous section, we examine each buyer's decision in isolation. When the number of buyers is large and even renowned buyers account for only a small fraction of the industry, this is a reasonable approach. We can assume each buyer's decision has minimal impact on the overall supplier pool configurations, and then study each of them in isolation. In this section we study an extension with two renowned buyers, both with a sizable supplier base. They are both aware that their own decision now may have a significant impact on the other buyer, and vice versa, as the value of p depends on both of their decisions. We demonstrate the impact such a game can have on the buyers' optimal decisions on whether to reveal their supplier lists, in the presence of the NGOs' strategic auditing pressure.

Consider two renowned buyers in the same industry. Each has a sizable supplier base so that her decision on whether to reveal her supplier list will have a material impact on the other buyer's calculation. We will keep the non-overlapping assumption about the two supplier lists, for tractability. The case of overlapping suppliers is very important but beyond the scope of this paper.

In the beginning, neither buyer has revealed her supplier list, but they both regard revealing the supplier list as an option. Let $\lambda_i, i = 1, 2$ denote the ratio of the number of buyer i's suppliers to the number of all suppliers in the unidentified pool where, without loss of generality, $\lambda_1 \leq \lambda_2$. Let p denote the proportion of special suppliers in the unidentified pool, then $\lambda_1 + \lambda_2 \leq p$. Furthermore, define p_{jk} as the proportion of remaining special suppliers in the unidentified pool if buyer 1 chooses action j and buyer 2 chooses action k, where $j, k \in \{I, U\}$. In particular, we should have

$$p_{II} = \frac{p - \lambda_1 - \lambda_2}{1 - \lambda_1 - \lambda_2} \quad < \quad p_{UI} = \frac{p - \lambda_2}{1 - \lambda_2} \quad \leq \quad p_{IU} = \frac{p - \lambda_1}{1 - \lambda_1} \quad < \quad p_{UU} = p.$$

Suppose that the two buyers enter a static game of complete information; that is, they make decisions simultaneously.

THEOREM 3. *The Nash equilibriums of the two-buyer game depend on the initial value of p and which scenario of Corollary 1 is present:*

a. *If p is in interval (1-i) or (2-i), then (U,U) is the unique equilibrium.*
b. *If p is in interval (1-iii) or (2-iii), then (U,U) is definitely an equilibrium and what is more, (I,I) can also be an equilibrium under certain condition.*
c. *If p is in interval (1-ii) or (2-ii), then either (I,I) is an equilibrium, or (I,U) and/or (U,I) are equilibriums.*

From Theorem 2 we know that a renowned buyer making an isolated decision will not reveal her supplier list when p has a small value in interval (1-i) or (2-i). When each buyer has the option to reveal supplier list, p_{IU} or p_{UI} can only be lower than p_{UU}; so each buyer will continue to not reveal her supplier list. Therefore, Theorem 3a is straightforward to verify.

When p has a large value (in interval 1-iii or 2-iii), each player in isolation would have chosen not to reveal her supplier list. When they consider the possible action of the other buyer, however, they may reach an equilibrium where both will reveal the supplier list, according to Theorem 3b. The rationale is that when both buyers reveal the supplier list, the p_{II} value may drop to the intermediate range (interval 1-ii or 2-ii) which will support the (I,I) equilibrium. To understand this result, we note that in interval (1-iii) or (2-iii) the buyer hopes to keep her suppliers under *higher* NGO scrutiny. If the other buyer could reveal her list – thus moving her suppliers to the identified pool – the NGO scrutiny may reduce as a result. Thus, this buyer should possibly move her supplier to the identified pool as well. Thus, under conditions for (1-iii) or (2-iii), the buyers want more NGO scrutiny so they will stay together in the unidentified pool or move together to the identified pool. The game consideration clearly can alter the buyers' decision.

Theorem 3c can be explained similarly. The two buyers start in an intermediate value p_{UU} in interval (1-ii) or (2-ii), where each buyer in isolation would choose to reveal her supplier list. Therefore (U,U) cannot be an equilibrium. The other three combinations are all possible equilibriums. When one buyer reveals her supplier list, all her suppliers leave the unidentified pool, dropping the p value to p_{IU} or p_{UI}. This may be low enough (i.e. in interval1-iii or 2-iii) for the other buyer so (U,I) or (I,U) becomes the equilibrium. If the p value does not drop low enough then both buyers could choose to reveal their lists, making (I,I) an equilibrium. Thus, in 3c, the game consideration makes the buyers to change their actions. The difference from 3b is that in 3c, the consideration the other buyer may lead each buyer to reveal, instead of hide, her supplier list.

6. Future Research

In this paper we model the strategic interactions among a buyer, her suppliers, and outside NGOs in monitoring and enforcing supply chain sustainability efforts. We are able to characterize the Stackelberg equilibrium and study the relationship between supply chain sustainability and transparency, and the important role played by the NGOs. We view our work as a first, and important, step in this fruitful direction of research. To facilitate the analytical study, we make a few simplifying assumptions in this paper. We see a few promising venues for additional research in the future.

First, we narrow our analysis to buyers with non-overlapping suppliers. It'd be interesting to find out what happens when buyers have common suppliers. The auditing effort will affect the supplier's sustainability effort which carries over to his dealings with other buyers. Free-riding is a possibility but it is equally common that there exists synergy between different buyer's auditing effort. Moreover, the revelation by one buyer of her supplier list will have impact on how the other buyers choose, certify, and audit their suppliers. How such interactions affect supply chain transparency and sustainability is well worth studying.

Another direction for future research is to incorporate consumer choice into the decision process. Many consumers want to make responsible purchase decisions using product provenance information (New (2010)). Bregman et al. (2015) use data from a large-scale U.S. consumer survey to show that there is a strong relationship between consumers' ethical judgement of a firm's global sourcing practices and their intention to alter consumption of its products. If making the supply chain transparency and sustainability effort can have an impact on consumer demand, then that's important to consider. Wieland and Handfield (2013) suggest that it may be difficult for consumers to distinguish between companies that do not report compliance due to poor performance and others due to lack of transparency. Proactively revealing supplier list and compliance effort before any incident happens could have impact on consumer in that regard as well.

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Appendix. Mathematical Proofs for Main Results

Proof of Lemma 1 If the buyer has revealed the supplier list, then the NGO and the supplier solve (1)-(2I) simultaneously. That is, we solve the following first-order conditions simultaneously:

$$\begin{cases} -e_B^I x_B - \gamma^I e_N^I x_N + 2k_S e_S^I = 0 \\ (1-e_S^I)v - 2k_N e_N^I = 0 \end{cases}$$

If instead the buyer has not revealed the supplier list, then the NGO and the supplier solve (1)-(2I) simultaneously. That is, we solve the following first-order conditions simultaneously:

$$\begin{cases} -e_B^U x_B - \gamma^U e_N^U x_N + 2k_S e_S^U = 0 \\ p(1-e_S^U)v - 2k_N e_N^U = 0 \end{cases}$$

Solving the two sets of equations gives out the results stated in this lemma.

□

Proof of Theorem 1. To obtain the optimal auditing effort of the buyer, we substitute the suppliers' and NGOs' response functions into the buyer's cost function (3). Then we have

$$C_B^U = \min_{0\le e_B^U\le 1} (e_B^U)^2 k_B + \frac{2b\gamma^U k_N pv(2k_S - e_B^U x_B)^2}{(4k_N k_S + \gamma^U pvx_N)^2},$$

$$C_B^I = \min_{0\le e_B^I\le 1} (e_B^I)^2 k_B + \frac{2b\gamma^I k_N v(2k_S - e_B^I x_B)^2}{(4k_N k_S + \gamma^I vx_N)^2}.$$

Then, we derive the first-order-derivative of C_B^j with respect to e_B^j ($j\in\{I,U\}$) in order to obtain the optimal auditing effort of the buyer, i.e., e_B^{j*}. Last, substitute e_B^{j*} into the suppliers' and NGOs' response functions to obtain their optimal efforts.

□

Proof of Proposition 1. For Proposition 1 (a), we show the proof for the effort levels of the unidentified supplier pool, since the proof for the identified supplier pool is similar.

First, we have

$$\frac{de_N^{U*}}{d\gamma^U} = -\frac{2k_B k_S p^2 v^2 (8bk_N^2 k_S x_B^2 + k_B x_N (4k_N k_S + \gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2 + k_B(4k_N k_S + \gamma^U pvx_N)^2)^2} < 0,$$

and

$$\frac{d(\gamma^U e_N^{U*})}{d\gamma^U} = \frac{4k_B k_N k_S pv(b(\gamma^U)^2 p^2 v^2 x_B^2 x_N + 2k_B k_S(4k_N k_S + \gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2 + k_B(4k_N k_S + \gamma^U pvx_N)^2)^2} > 0.$$

Second, with regards to the supplier's optimal compliance effort, we have

$$\frac{de_S^{U*}}{d\gamma^U} = \frac{4k_B k_N k_S pv(8bk_N^2 k_S x_B^2 + k_B x_N (4k_N k_S + \gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2 + k_B(4k_N k_S + \gamma^U pvx_N)^2)^2} > 0.$$

Next, consider the buyer's optimal auditing effort, we obtain

$$\frac{de_B^{U*}}{d\gamma^U} = \frac{4bk_B k_N k_S pvx_B(16k_N^2 k_S^2 - (\gamma^U)^2 p^2 v^2 x_N^2)}{(2b\gamma^U k_N pvx_B^2 + k_B(4k_N k_S + \gamma^U pvx_N)^2)^2},$$

which is larger than zero (implying that e_B^{U*} is increasing in γ^U) if and only if $4k_N k_S > \gamma^U pvx_N$.

For Proposition 1 (b), we obtain

$$\frac{de_N^{U*}}{dp} = \frac{4k_B k_N k_S v(b(\gamma^U)^2 p^2 v^2 x_B^2 x_N + 2k_B k_S(4k_N k_S + \gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2 + k_B(4k_N k_S + \gamma^U pvx_N)^2)^2} > 0,$$

and thus $\gamma^U e_N^{U*}$ is also increasing in p.

Moreover, we also have

$$\frac{de_S^{U*}}{dp} = \frac{4\gamma^U k_B k_N k_S v(8bk_N^2 k_S x_B^2 + k_B x_N(4k_N k_S + \gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2 + k_B(4k_N k_S + \gamma^U pvx_N)^2)^2} > 0.$$

Last, we obtain

$$\frac{de_B^{U*}}{dp} = \frac{4b\gamma^U k_B k_N k_S v x_B(16k_N^2 k_S^2 - (\gamma^U)^2 p^2 v^2 x_N^2)}{(2b\gamma^U k_N pvx_B^2 + k_B(4k_N k_S + \gamma^U pvx_N)^2)^2},$$

which is larger than zero if and only if $4k_N k_S > \gamma^U pvx_N$.

□

Proof of Proposition 2. Note that by Proposition 1, e_S^{U*} is increasing in p. But solving the equation $e_S^{U*} = e_S^{I*}$, we have $p = \gamma^I/\gamma^U$. Therefore, we can conclude that $e_S^{U*} \le e_S^{I*}$ if and only if $p \le \gamma^I/\gamma^U$.

Moreover, by Proposition 1, we also know that $\gamma^U e_N^{U*}$ is increasing in p. But solving the equation $\gamma^U e_N^{U*} = \gamma^I e_N^{I*}$, we obtain $p = \gamma^I/\gamma^U$. Therefore, we can also conclude that $\gamma^U e_N^{U*} \le \gamma^I e_N^{I*}$ if and only if $p \le \gamma^I/\gamma^U$.

Therefore, those statements are equivalent: $e_S^{U*} \le e_S^{I*}$, $\gamma^U e_N^{U*} \le \gamma^I e_N^{I*}$, and $p \le \gamma^I/\gamma^U$.

□

Proof of Theorem 2 and Corollary 1. To understand the buyer's optimal strategy, we need to compare the buyer's expected cost if she reveals the supplier list to her expected cost if she does not reveal the list. Let C_B^{U*} denote the buyer's minimal expected cost if she decides not to reveal the list, and let C_B^{I*} denote the buyer's minimal cost if she reveals the supplier list. We obtain

$$C_B^I = \frac{8b\gamma^I k_B k_N k_S^2 v}{2b\gamma^I k_N v x_B^2 + k_B(4k_N k_S + \gamma^I v x_N)^2},$$
$$C_B^U = \frac{8b\gamma^U k_B k_N k_S^2 pv}{2b\gamma^U k_N pv x_B^2 + k_B(4k_N k_S + \gamma^U pv x_N)^2}.$$

Solving the equation $C_B^I = C_B^U$ with respect to p, we obtain

$$p_1 = \frac{\gamma^I}{\gamma^U}, \text{ or } p_2 = \frac{16k_N^2 k_S^2}{\gamma^I \gamma^U v^2 x_N^2}. \tag{10}$$

And note that $p_1 > p_2$ if and only if $4k_N k_S < \gamma^I v x_N$.

What is more, note that

$$\frac{dC_B^U}{dp} = \frac{8b\gamma^U k_B^2 k_N k_S^2 v(16k_N^2 k_S^2 - (\gamma^U)^2 p^2 v^2 x_N^2)}{(2b\gamma^U k_N pv x_B^2 + k_B(4k_N k_S + \gamma^U pv x_N)^2)^2}.$$

Define $\hat{p} = 4k_N k_S/(\gamma^U v x_N)$. Then C_B^U is a quasi-concave function of p; that is, it is increasing in p when $p < \hat{p}$ and is decreasing in p when $p > \hat{p}$. Thus, $C_N^U > C_B^I$ if and only if $\min(p_1, p_2) < p < \max(p_1, p_2)$. In other words,

- (Scenario 1) If $4k_N k_S < \gamma^I v x_N$, then $C_B^U > C_B^I$ if and only if $p_2 < p < p_1$.
- (Scenario 2) If $4k_N k_S > \gamma^I v x_N$, then $C_B^U > C_B^I$ if and only if $p_1 < p < p_2$.

Next, we want to compare the buyer's optimal auditing effort if she reveals the list, e_B^{I*}, to that if she does not reveal the list, e_B^{U*}. Solving $e_B^{U*} = e_B^{I*}$ with respect to p, we obtain the same threshold values: p_1 and p_2 as above. Also note that

$$\frac{de_B^{U*}}{dp} = \frac{4b\gamma^U k_B k_N k_S v x_B(16k_N^2 k_S^2 - (\gamma^U)^2 p^2 v^2 x_N^2)}{(2b\gamma^U k_N pv x_B^2 + k_B(4k_N k_S - \gamma^U pv x_N)^2)^2}.$$

Thus, e_B^{U*} is a quasi-concave function of p; it is increasing in p when $p < \hat{p}$ and is decreasing in p when $p > \hat{p}$. Therefore, $e_B^{U*} > e_B^{I*}$ if and only if $\min(p_1, p_2) < p < \max(p_1, p_2)$. In other words,

- (Scenario 1) If $4k_Nk_S < \gamma^I v x_N$, then $e_B^{U*} > e_B^{I*}$ if and only if $p_2 < p < p_1$.
- (Scenario 2) If $4k_Nk_S > \gamma^I v x_N$, then $e_B^{U*} > e_B^{I*}$ if and only if $p_1 < p < p_2$.

Therefore, $e_B^{U*} > e_B^{I*}$ if and only if the buyer's optimal decision is to reveal her supplier list. That is, if the buyer decides to reveal her supplier list, she will exert less auditing effort than what she would do if she decided not to reveal the list.

□

Proof of Lemma 2. First, consider C_S^{U*} as a function of p and γ^U.

$$\frac{dC_S^U}{dp} = \frac{32\gamma^U k_B^2 k_N^2 k_S^3 v(4k_Nk_S+\gamma^U pvx_N)(8bk_N^2k_Sx_B^2+k_Bx_N(4k_Nk_S+\gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2+k_B(4k_Nk_S+\gamma^U pvx_N)^2)^3} > 0.$$

Also,

$$\frac{dC_S^U}{d\gamma^U} = \frac{32k_B^2 k_N^2 k_S^3 pv(4k_Nk_S+\gamma^U pvx_N)(8bk_N^2k_Sx_B^2+k_Bx_N(4k_Nk_S+\gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2+k_B(4k_Nk_S+\gamma^U pvx_N)^2)^3} > 0.$$

Next, consider Π_N^{U*} as a function of p and γ^U.

$$\frac{d\Pi_N^U}{dp} = \frac{16k_B^2 k_N^2 k_S^2 pv^2(4k_Nk_S+\gamma^U pvx_N)(b(\gamma^U)^2p^2v^2x_B^2x_N+2k_Bk_S(4k_Nk_S+\gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2+k_B(4k_Nk_S+\gamma^U pvx_N)^2)^3} > 0.$$

Also,

$$\frac{d\Pi_N^U}{d\gamma^U} = -\frac{8k_B^2 k_N k_S^2 p^3 v^3(4k_Nk_S+\gamma^U pvx_N)(8bk_N^2k_Sx_B^2+k_Bx_N(4k_Nk_S+\gamma^U pvx_N)^2)}{(2b\gamma^U k_N pvx_B^2+k_B(4k_Nk_S+\gamma^U pvx_N)^2)^3} < 0.$$

□

Proof of Proposition 3. We provide only the proof of Proposition 3 (a) here because the proof of Proposition 3 (b) is similar. Under Scenario 1 (i.e., $4k_Nk_S < \gamma^I v x_N$), the interval of p such that the buyer's optimal decision is to reveal her supplier list is $p_2 < p < p_1$, where p_1 and p_2 are defined by equation (10).

First, consider the supplier's cost C_S^j $(j \in \{I,U\})$. Note that $C_S^U = C_S^I$ if and only if $p = \gamma^I/\gamma^U = p_1$, and C_S^{U*} is increasing in p by Lemma 2. Thus, in the interval such that $p_2 < p < p_1$, we must have $C_S^U < C_S^I$.

Next, consider the NGOs' expected payoffs Π_N^j $(j \in \{I,U\})$. The closed-form solutions of the NGOs' expected payoffs are

$$\Pi_N^I = \frac{4k_B^2 k_N k_S^2 v^2(4k_Nk_S+\gamma^I vx_N)^2}{(2b\gamma^I k_N vx_B^2+k_B(4k_Nk_S+\gamma^I vx_N)^2)^2},$$
$$\Pi_N^U = \frac{4k_B^2 k_N k_S^2 p^2 v^2(4k_Nk_S+\gamma^U pvx_N)^2}{(2b\gamma^U k_N pvx_B^2+k_B(4k_Nk_S+\gamma^U pvx_N)^2)^2}.$$

At $p = p_1 = \gamma^I/\gamma^U$, we obtain

$$\Pi_N^U(p=\frac{\gamma^I}{\gamma^U}) = (\frac{\gamma^I}{\gamma^U})^2 \cdot \Pi_N^I.$$

Thus, if $\gamma^I < \gamma^U$, then $\Pi_N^U(p=p_1) < \Pi_N^I$. Furthermore, since Π_N^U is increasing in p by Lemma 2, we must have $\Pi_N^U < \Pi_N^I$ for any p within the interval such that the buyer's optimal decision is to reveal the supplier list (i.e., $p_2 < p < p_1$).

If instead, $\gamma^I > \gamma^U$, then $\Pi_N^U(p=p_1) > \Pi_N^I$. But at $p = p_2$, Π_N^U can be greater or smaller than Π_N^I, because

$$\Pi_N^U(p=p_2) - \Pi_N^I = \frac{4k_B^2 k_N(4k_Nk_S+\gamma^I vx_N)^2(16k_N^2k_S^4-(\gamma^U)^2k_S^2v^2x_N^2)}{(\gamma^U)^2x_N^2(2b\gamma^I k_N vx_B^2+k_B(4k_Nk_S+\gamma^I vx_N)^2)^2},$$

which is greater than zero if and only if $4k_Nk_S > \gamma^U vx_N$. Therefore, if $\gamma^I > \gamma^U$, then Π_N^U can be either greater or smaller than Π_N^I depending on the model parameters.

□

Proof of Proposition 4. Note that now the NGOs' auditing effort is a constant e_N. Then for any e_B^j ($j \in \{I,U\}$), the supplier's best response function is given by

$$-e_B^j x_B - \gamma^j e_N x_N + 2k_S e_S^j = 0.$$

That is,

$$\widetilde{e}_S^j(e_B^j) = \frac{e_B^j x_B + \gamma^j e_N x_N}{2k_S}.$$

Thus, the buyer's optimization problem becomes

$$C_B^j(e_N) = \min_{0 \le e_B \le 1} \ \gamma^j e_N(1 - \widetilde{e}_S^j(e_B^j)) + k_B(e_B^j)^2.$$

Solving the buyer's problem yields the optimal auditing effort $e_B^{j\circ}$ as stated in this proposition. Finally, substituting $e_B^{j\circ}$ into the supplier's best response function yields the supplier's optimal compliance effort as stated in this proposition.

□

Proof of Proposition 5. The results stated in this proposition is straightforward based on the closed-form solution of the optimal effort levels. That is,

$$e_B^{j\circ} = \frac{be_N\gamma^j x_B}{4k_B k_S}, \text{and } e_S^{j\circ} = \frac{\gamma^j e_N(4k_B k_S x_N + bx_B^2)}{8k_B k_S^2}, \text{ where } j \in \{I,U\}.$$

It is obvious that both the buyer's optimal auditing effort and the supplier's optimal compliance effort are proportional to γ^j.

□

Proof of Proposition 6. Based on the closed-form solution of the optimal effort levels (e.g., see also the proof of Proposition 5). It is obvious that $e_B^{U\circ} < e_B^{I\circ}$ and $e_S^{U\circ} < e_S^{I\circ}$ if and only if $\gamma^U < \gamma^I$.

□

Proof of Proposition 7. Note that under the assumption of facing non-strategic NGOs, the buyer's minimal expected cost is given as follows

$$C_B^{j\circ} = \gamma^j e_N^j(1 - e_S^{j\circ}) + k_B(e_B^{j\circ})^2 = \frac{be_N^j\gamma^j(8k_B k_S(2k_S - e_N^j\gamma^j x_N) - be_N^j\gamma^j x_B^2)}{16k_B k_S^2}, \text{ where } j \in \{I,U\},$$

which is a quadratic function of $\gamma^j e_N^j$. Solving $C_B^{I\circ} = C_B^{U\circ}$, we find that this equation holds if and only if

$$\gamma^U e_N^U = \gamma^I e_N^I, \text{ or } \gamma^U e_N^U = \frac{16k_B k_S^2}{8k_B k_S x_N + bx_B^2} - \gamma^I e_N^I.$$

Furthermore, we also find that

$$\gamma^I e_N^I > \frac{16k_B k_S^2}{8k_B k_S x_N + bx_B^2} - \gamma^I e_N^I \text{ if and only if } \gamma^I e_N^I > \frac{8k_B k_S^2}{bx_B^2 + 8k_B k_S x_N} \tag{11}$$

Therefore, if the condition stated in equation (11) is satisfied, then $C_B^{U\circ} > C_B^{I\circ}$ if and only if

$$\frac{16k_B k_S^2}{8k_B k_S x_N + bx_B^2} - \gamma^I e_N^I < \gamma^U e_N^U < \gamma^I e_N^I,$$

which is the result stated in Proposition 7 (a). In the same vein, Proposition 7 (b) can also be proved.

Next, we compare the model under the assumption of non-strategic NGOs to that under the assumption of strategic NGOs. It is important to note that by Theorem 2 and Proposition 7, the structure of the

buyer's optimal decision on whether to reveal the supplier list is similar, because in the model with strategic NGOs, varying p is equivalent to varying $\gamma^U e_N^{U*}$ (by Proposition 1). And interestingly, we find that those two conditions are equivalent:

$$4k_N k_S < \gamma^I v x_N, \text{ and } \gamma^I e_N^{I*} > \frac{8k_B k_S^2}{8k_B k_S x_N + b x_B^2},$$

Thus, Theorem 2 and Corollary 1 can be re-stated as follows:

- (Scenario 1) When $\gamma^I e_N^{I*} > \frac{8k_B k_S^2}{8k_B k_S x_N + b x_B^2}$, then it is optimal to reveal the supplier list if and only if $\frac{16k_N^2 k_S^2}{\gamma^I \gamma^U v^2 x_N^2} < p < \frac{\gamma^I}{\gamma^U}$.
- (Scenario 2) When $\gamma^I e_N^{I*} < \frac{8k_B k_S^2}{8k_B k_S x_N + b x_B^2}$, then it is optimal to reveal the supplier list if and only if $\frac{\gamma^I}{\gamma^U} < p < \frac{16k_N^2 k_S^2}{\gamma^I \gamma^U v^2 x_N^2}$.

Furthermore, it is easy to verify that $\gamma^I e_N^{I*} = \gamma^U e_N^{U*}$ if and only if $p = \gamma^I/\gamma^U$. And at $p = \frac{16k_N^2 k_S^2}{\gamma^I \gamma^U v^2 x_N^2}$,

$$\begin{aligned} &\gamma^I e_N^{I*} + \gamma^U e_N^{U*} - \frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} \\ =\ &\frac{2bk_B k_S x_B^2 (4k_N k_S - \gamma^I v x_N)^2}{x_N (8k_B k_S x_N + b x_B^2)(2bv\gamma^I k_N x_B^2 + k_B (4k_N k_S + \gamma^I v x_N)^2)} > 0. \end{aligned}$$

Define

$$\frac{2bk_B k_S x_B^2 (4k_N k_S - \gamma^I v x_N)^2}{x_N (8k_B k_S x_N + b x_B^2)(2bv\gamma^I k_N x_B^2 + k_B (4k_N k_S + \gamma^I v x_N)^2)} = \Delta.$$

Then at $p = \frac{16k_N^2 k_S^2}{\gamma^I \gamma^U v^2 x_N^2}$,

$$\gamma^I e_N^{I*} + \gamma^U e_N^{U*} = \frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} + \Delta.$$

Thus, Theorem 2 and Corollary 1 can be re-stated as follows:

- (Scenario 1) When $\gamma^I e_N^{I*} > \frac{8k_B k_S^2}{8k_B k_S x_N + b x_B^2}$, then it is optimal to reveal the supplier list if and only if $\frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} - \gamma^I e_N^{I*} + \Delta < \gamma^U e_N^{U*} < \gamma^I e_N^{I*}$.
- (Scenario 2) When $\gamma^I e_N^{I*} < \frac{8k_B k_S^2}{8k_B k_S x_N + b x_B^2}$, then it is optimal to reveal the supplier list if and only if $\gamma^I e_N^{I*} < \gamma^U e_N^{U*} < \frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} - \gamma^I e_N^{I*} + \Delta$.

However, Proposition 7 implies that

- (Scenario 1) When $\gamma^I e_N^{I} > \frac{8k_B k_S^2}{8k_B k_S x_N + b x_B^2}$, then it is optimal to reveal the supplier list if and only if $\frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} - \gamma^I e_N^{I} < \gamma^U e_N^{U} < \gamma^I e_N^{I}$.
- (Scenario 2) When $\gamma^I e_N^{I} < \frac{8k_B k_S^2}{8k_B k_S x_N + b x_B^2}$, then it is optimal to reveal the supplier list if and only if $\gamma^I e_N^{I} < \gamma^U e_N^{U} < \frac{16k_B k_S^2}{8k_B k_S x_N + b x_B^2} - \gamma^I e_N^{I}$.

Therefore, under scenario 1, the interval within which the buyer is willing to reveal her supplier list is smaller with strategic NGOs than that with non-strategic NGOs; whereas under scenario 2, the interval within which the buyer is willing to reveal her supplier list is larger with strategic NGOs than that with non-strategic NGOs.

□

Proof of Theorem 3. The key to the proof is that $p_{II} < \min(p_{IU}, p_{UI}) \leq \max(p_{IU}, p_{UI}) < p_{UU}$. Without loss of generality, the following proof is based on scenario 1 such that a single buyer's optimal decision is to reveal her supplier list if and only if $p_2 < p < p_1$, where p_1 and p_2 are defined by equation (10).

Consider Theorem 3 (a). If one firm has not revealed her supplier list, the other firm faces an unidentified supplier pool with $p = p_{UU} < p_2$ and thus decides not to reveal her supplier list as well; that is, no firm has a reason to deviate from the equilibrium (U, U). In the same vein, (U, I) and (I, I) are not equilibrium.

Consider Theorem 3 (b). Note that (U, U) is not an equilibrium. The reason is as follows. Suppose that one firm has decided not to reveal her supplier list and if the other firm chooses not to reveal her own supplier list, then the latter faces an unidentified supplier pool with $p = p_{UU} \in (p_2, p_1)$ and by Theorem 2, this firm incurs a higher expected cost than what she would have incurred if this firm revealed her supplier list. Furthermore, (I, I) can be an equilibrium if and only if p_{IU} and p_{UI} are within the interval (p_2, p_1); that is, if and only if no firm has a good reason to deviate from I to U. Last, (I, U) (or (U, I) respectively) is an equilibrium if and only if p_{IU} (or p_{UI}) is within the interval $(0, p_2)$.

Consider Theorem 3 (c). When $p_{UU} \in (p_1, 1)$, it is obvious that if one firm decides not to reveal her supplier list, the other firm has no good reason to deviate from U to I, so (U, U) is an equilibrium. Furthermore, (I, I) can also be an equilibrium if and only if p_{IU} and p_{UI} are within the interval (p_2, p_1), because if that happens, then given that one firm has revealed her supplier list, the other firm should also decide to reveal her supplier list.

□