Managing Supplier Social & Environmental Impacts with Voluntary vs. Mandatory Disclosure to Investors

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A buying firm might in future incur costs associated with a supplier’s CO2 emissions, safety violations or other social or environmental impacts. Learning about a supplier’s impacts requires costly effort, but is necessary (and sometimes sufficient) to reduce those impacts. The capital market valuation of a buying firm reflects investors’ estimate of future costs associated with a supplier’s impacts, as well as any costs that the buying firm incurs in order to learn about and reduce a supplier’s impacts. This paper analyzes a game theoretic model in which a manager- with the objective of maximizing the capital market valuation of the buying firm- decides whether or not to learn about a supplier’s impacts, how much cost to incur to reduce the supplier’s impacts, and whether or not to disclose the supplier’s impacts to investors; the investors have rational expectations (e.g., that a manager might withhold bad news about the supplier’s impacts) and value the buying firm accordingly. The paper considers a mandate to disclose information learned about a supplier’s impacts. The paper shows that the disclosure mandate deters learning and thus, under plausible conditions, results in higher expected impacts. The disclosure mandate can result in lower expected impacts only if buying firms face moderately high future costs associated with suppliers’ impacts. In contrast, a disclosure mandate always increases a buying firm’s expected discounted profit and capital market valuation. A disclosure mandate can induce cooperation among buying firms with a shared supplier, yet result in higher expected impacts by the supplier. When a buying firm has alternative suppliers, the disclosure mandate favors commitment to a supplier to facilitate learning about that supplier’s impacts (instead of searching for a lower-impact supplier).

“Measurement is the first step that leads to control and eventually to improvement. If you can’t measure something, you can’t understand it. If you can’t understand it, you can’t control it. If you can’t control it, you can’t improve it.” - H. James Harrington

“BlackRock has been undertaking a multi-year effort to integrate environmental, social and governance considerations into our investment processes. We expect companies to have strategies to manage these issues.” - Laurence Fink, CEO BlackRock

“Too many companies are myopically short-term focused on the shareholder.” - Paul Polman, CEO Unilever
1. Introduction

For Unilever, Walmart and many other companies, the negative social and environmental impacts associated with their products (and the opportunities to reduce those impacts) occur primarily in their suppliers’ operations. In the words of a Walmart executive, “If we had focused on just our own operations, we would have limited ourselves to 10 percent of our effect on the environment and, quite frankly, eliminated 90 percent of the opportunity [for impact reduction] that’s out there” (Plambeck and Denend 2007). Suppliers lag behind buyers in tapping opportunities for cost-effective reduction in greenhouse gas (GHG) emissions (Carbon Disclosure Project 2012). Safety, labor and environmental violations occur in suppliers’ operations— and require engagement from buying firms to correct— because regulatory institutions and law enforcement are weak in the developing and emerging economies in which suppliers are concentrated (Locke 2013).

Only a fraction of buying firms (roughly half the firms surveyed by Lee et al. 2012) choose to learn about their suppliers’ social and environmental impacts. Learning about a supplier’s impact is difficult and costly (Securities and Exchange Commission 2012, McKinnon 2010, Guardian 2012). On the other hand, learning is necessary to reduce the supplier’s impact and in many cases is sufficient (Plambeck 2012, WWF and CDP 2013, Xu et al. 2015). Buying firms face possible future costs associated with suppliers’ social or environmental irresponsibility. For example, faulty electrical wiring in a supplier’s factory could in future cause a tragic fire, causing a buying firm to incur costs of reparations, brand damage, supply disruption, etc. Future shortages of natural resources (e.g. water), policies to address climate change, or other environmental policies might cause supply disruption and impose costs associated with environmental impacts. Hence by learning about and reducing a supplier’s impact, a buying firm can potentially achieve higher expected discounted profit— if and only if the initial cost of learning is not too high.

In many buying firms, managers’ focus on the firm’s current capital market price distorts their decisions about supplier impact reduction, according to (Polman 2014). A firm’s current valuation depends on investors’ estimate of the firm’s future costs associated with its suppliers’ impacts. Unless the firm discloses information about those impacts, investors are uncertain about those impacts and recognize that the firm may be withholding bad news, leading to a reduction in valuation (§2.1 provides empirical evidence thereof). Hence this paper examines voluntary disclosure to investors, i.e., a manager’s discretion to choose whether or not to disclose information learned about a supplier’s impact to investors. This paper shows how a manager, seeking to maximize the firm’s current valuation under voluntary disclosure, makes different decisions about learning and reduction of supplier impact than would maximize the firm’s expected discounted profit. Relatedly, (Graham et al. 2005, Asker et al. 2015) provide empirical evidence that in many public firms,
managers commonly make decisions that increase the firm’s current capital market price to the detriment of its discounted profit.

Policy makers have recently introduced disclosure mandates to motivate firms to reduce their suppliers’ impacts. For example, under the Dodd-Frank Act, the U.S. Securities and Exchange Commission (SEC) requires firms with products containing tantalum, tin, tungsten or gold (the so-called “conflict minerals”) to disclose any known use of conflict minerals that originated in the Democratic Republic of the Congo (DRC) or adjoining countries. As a second example, the government of France, with 230 firms, piloted a mandate for disclosure of a product’s supply chain GHG emissions. The literature on disclosure mandates (reviewed in §2.2) provides empirical evidence that requiring a firm to disclose its own, direct impacts motivates a firm to reduce those impacts. In contrast, under the disclosure mandates examined in this paper, a firm must disclose known information about suppliers’ impacts, while learning about the suppliers’ impacts remains voluntary.1 Therefore this paper addresses the questions: Can such a mandate to disclose known information about suppliers’ impacts backfire, i.e., result in higher impacts in expectation? Under what conditions?

Such a disclosure mandate helps investors to correctly value a buying firm, which may increase or decrease the firm’s valuation. More fundamentally, by influencing learning and impact reduction, a disclosure mandate may change the expected discounted profit of a buying firm and hence its valuation. This paper evaluates the overall effect of a disclosure mandate on a buying firm’s expected discounted profit and valuation.

Thus, the paper helps to explain why many buying firms have implemented such a disclosure mandate, in the absence of government policy. For example, hundreds of apparel retailers, as signatories to the Accord on Fire and Building Safety in Bangladesh or the Alliance for Bangladesh Worker Safety, have committed to publicly disclose all safety audit reports for their Bangladeshi suppliers’ factories (Accord on Fire and Building Safety in Bangladesh 2013, the Alliance for Bangladesh Worker Safety 2013).

In deciding whether to undertake costly efforts to learn about and reduce suppliers’ impacts, buying firms are concerned about freeriding by other buyers (Greenhouse 2013). This paper extends the theoretical literature on buyers auditing a common supplier (Caro et al. 2017, Fang and Cho 2015, Chen et al. 2017) by incorporating capital market concerns and a disclosure mandate.

1 Following firms’ objections that the cost of learning about suppliers’ use of conflict minerals from the DRC is prohibitively high (National Association of Manufacturers 2012) the SEC does not prescribe specific actions for learning; in 2014 more than 60% of firms reported that they were “unable to determine” the origins of the conflict minerals in their products (United States Government Accountability Office 2015). Similarly, under the French disclosure mandate for supply chain GHG emissions, a firm may choose to use publicly-available estimates of the emissions associated with its inputs rather than learn about its suppliers’ actual emissions (French Ministry of Ecology, Sust. Dev. and Energy 2012). In short, in both motivating examples, learning about a supplier’s impacts remains voluntary.
In order to more easily learn about suppliers’ social or environmental impacts, some buying firms commit to source from a supplier that cooperates in gathering data, identifying problems, and sharing information with the buying firm (Plambeck et al. 2012, Cummis 2015). Without such a commitment, a supplier is motivated to obstruct rather than cooperate in the effort to learn about its impacts, in order to keep the buyer’s business (Plambeck and Taylor 2016). Jira and Toffel (2013) document how Dell, for example, motivates suppliers to collect and share GHG emissions data by suggesting that failure to do so could result in loss of business, whereas Dell will “work with suppliers on emissions reduction strategies once data is collected.” Therefore this paper addresses the questions: Should a buying firm commit to a supplier or maintain the option to switch to an alternative supplier with lower impacts? How do capital market concerns and a disclosure mandate influence that decision?

Overview

§3 formulates the base model, in which the manager of a buying firm decides whether or not to undertake costly effort to learn about a supplier’s impact. If the manager learns, she then decides how much additional cost to incur to reduce the supplier’s impact, and whether or not to disclose that impact to investors. The buying firm might incur costs associated with the supplier’s impact in future, and the firm’s current valuation reflects investors’ estimate of those future costs. The manager’s objective is to maximize that current valuation.

§4 evaluates the effects of requiring the manager to disclose any information she learns about the supplier’s impact, as in the above examples of disclosure mandates for safety audit reports, conflict minerals, and GHG emissions. A disclosure mandate tends to deter the manager from learning about the supplier’s impact but, if the manager nevertheless chooses to learn, spurs the manager to reduce the supplier’s impacts. A disclosure mandate always increases the firm’s valuation and discounted profit, in expectation. It can result in lower expected impact only if a buying firm faces moderately high costs associated with a supplier’s impact. A disclosure mandate results in higher expected impact by the supplier under specified conditions. §2.3, §4 and §6 provide anecdotal evidence that those conditions are commonplace in reality.

§5 shows that those results hold in model extensions: with two buyers sourcing from a common supplier, alternative suppliers, multiple inputs, an external source of impact information for investors, a generalized objective for the manager, etc. In addition, §5 shows that cooperation by buying firms with a common supplier can result in strictly higher impact by the supplier and strictly lower expected discounted profit and valuation for each buying firm. That buying firms’ cooperation can harm them- due to their strategic interaction with investors- helps address Fang and Cho’s (2015) question: Why is it uncommon to observe cooperation by buying firms in auditing
a common supplier? §5 also shows that a disclosure mandate promotes commitment to a supplier to facilitate learning about the supplier’s impacts.

§6 draws conclusions.

2. Related Literature
2.1 Voluntary Disclosure
In the seminal paper on voluntary disclosure to investors (Verrecchia 1983), a manager decides whether or not to disclose private information about the future value of her firm, with the objective of maximizing investors’ current valuation of the firm. The manager’s disclosure strategy and investors’ current valuation of the firm are co-determined in a rational expectations equilibrium. The manager discloses her private information if and only if the information is sufficiently favorable that disclosure increases investors’ valuation of the firm. Investors expect the manager to use that threshold strategy and, in the event of nondisclosure, value the firm accordingly. Disclosure is costly to the firm; otherwise, the manager would always disclose her private information in equilibrium. Whereas in (Verrecchia 1983) the manager is endowed with the private information, this paper incorporates a manager’s decisions regarding whether or not to learn about a supplier’s impact and how much to reduce that impact.

A survey of the extensive literature on voluntary disclosure to investors is in (Beyer et al. 2010). Beyer et al. observe that “With few exceptions, models of voluntary disclosure focus exclusively on management’s decision to disclose information” and call for researchers to analyze “real” operational decisions jointly with disclosure. This paper is one of the exceptional few to do so. In particular, this paper is the first to study operational decisions about improving a supplier (in §4 and §5) and sourcing strategy (in §5.2) jointly with disclosure to investors.

Among the few that consider other “real” decisions jointly with disclosure, (Pae 1999) has most similarity to this paper. Pae (1999) also builds upon (Verrecchia 1983). In (Pae 1999), the firm’s future value is the sum of the manager’s effort and an independent, exogenous random variable. Investors observe the manager’s effort level. Then the manager decides whether to learn a signal of the random variable, and then whether to disclose the signal. In contrast, in this paper, learning must precede impact reduction effort, and investors cannot directly observe effort. Hence whereas Pae’s result is that the manager exerts too much effort (more than would maximize the firm’s expected profit), in this paper, the manager exerts too little reduction effort when she chooses not to disclose the supplier’s impact.

Motivating the model in this paper, empirical literature shows that the valuation of a buying firm reflects an estimate of the firm’s future costs associated with its suppliers’ social and environmental impacts. Sell side analysts generate a more optimistic assessment of future financial
performance for a firm with a better social responsibility rating, based partly on its suppliers’ labor conditions and other supply chain metrics (Ioannou and Serafeim 2015). Data use by sell side analysts indicates their particular interest in a firm’s indirect, supply chain GHG emissions (Eccles et al. 2011). Among firms that disclose their supply chain GHG emissions, emissions reduction is associated with lower immediate profit (presumably because a firm incurs immediate cost to learn about and reduce suppliers’ emissions) but increased capital market valuation (Delmas and Nairn-Birch 2011). Firms with higher levels of GHG emissions, whether direct or in the supply chain, have higher costs for debt as well as equity (Chava 2014). When a firm chooses not to disclose GHG emissions information, investors nevertheless value the firm based on estimated emissions (Griffin et al. 2012) and interpret non-disclosure as a signal that emissions are relatively high (Matsumura et al. 2014). Voluntary disclosure of emissions— including supply chain emissions—is associated with increased capital market valuation, presumably because managers voluntarily disclose only favorable information; investors have a correspondingly high estimate of the emissions and associated future costs for non-disclosing firms (Griffin and Sun 2013, Matsumura et al. 2014). Relatedly, Matsumura et al. (2014) observe that a firm is more likely to disclose its emissions when a larger proportion of other firms in its industry disclose emissions, and posit that as more firms disclose, investors’ estimate of the emissions and associated future costs for a non-disclosing firm increases, which spurs disclosure. More generally, firms that voluntarily disclose more social and environmental impact information have better access to capital (Cheng et al. 2014). In contrast, firms’ disclosures of their suppliers’ use of conflict minerals—when facing a new disclosure mandate—are associated with reductions in capital market price (Griffin et al. 2014).

Consistent with (Verrecchia 1983, Pae 1999) and most of the other literature on disclosure to investors surveyed in (Beyer et al. 2010), this paper rules out fraudulent disclosure. That is motivated by the fact that in many countries, managers are subject to criminal prosecution for providing fraudulent information to investors (Sarbanes-Oxley Act 2002, Zacharias 2010). In modeling voluntary disclosure, this paper also is consistent with the theoretical literature on “greenwashing” in which a manager can selectively withhold information, but cannot disclose false information (e.g., Lyon and Maxwell 2011). The theoretical literature on mandatory disclosure surveyed below also rules out fraudulent disclosure.

2.2 Mandatory Disclosure
Extensive empirical literature, surveyed in Doshi et al. (2013), shows that requiring a firm to disclose its own, direct impacts promotes impact reduction. Doshi et al. (2013) observe that that reduction is greater among private than public firms, and highlight a public firm’s concern about its current valuation as one possible explanation. It remains an open question whether requiring
a firm to disclose information learned about a supplier’s impact (while learning remains optional) leads to impact reduction.

In the theoretical literature on disclosure to consumers about a product’s quality or safety, (Shavell 1994) and (Polinsky and Shavell 2012) consider a mandate for a firm to disclose information learned, while learning remains optional. In those papers, the mandate tends to deter the firm from learning, which also occurs in the base model in this paper, as established in (16) within Proposition 1. In contrast, Proposition 6b shows an opposite result- a disclosure mandate can spur learning, by causing a buying firm to commit to its supplier. The other results in this paper have no analogs in (Shavell 1994, Polinsky and Shavell 2012).

That this paper focuses on disclosure to investors- not disclosure to consumers- is important in that consumers’ response to disclosure about suppliers’ impacts is qualitatively different from that of investors. Behavioral experiments suggest that by voluntarily disclosing negative information about suppliers’ social or environmental impacts to consumers (and not under a disclosure mandate), a firm can win trust, market share and higher profit (Kalkanci et al. 2016). In contrast, disclosure of negative information to investors (that suppliers’ impacts are higher than the investors expected) lowers a firm’s valuation, which drives the results in this paper.

Xu et al. (2015) consider a mandate for a buyer to disclose its policy regarding auditing for child labor. They show that the mandate can backfire by enabling the buyer to pay a low price and never audit, so the supplier chooses to employ child labor. In contrast, this paper considers a different sort of mandate for a buying firm (to disclose what it learns about a supplier’s impact, if it learns about the supplier’s impact) that can backfire in a different manner.

2.3 Socially & Environmentally Responsible Operations Management

Empirical literature shows that many suppliers’ GHG emissions could be reduced through immediately-profitable improvements in energy efficiency (see (Blass et al. 2014, Wu et al. 2014) and the literature surveyed therein). Why haven’t suppliers tapped those immediately-profitable energy efficiency opportunities? One explanation is that suppliers lack the expertise to identify those opportunities. After a government-sponsored auditor identifies energy-savings opportunities for them, manufacturing firms pursue ones that pay back immediately, in less than one or two years (Anderson and Newell 2004). Similarly, when buying firms help suppliers identify and implement energy-efficiency improvements, they commonly pursue only projects that are immediately profitable; the buying firms choose not to incur additional cost to further reduce suppliers’ GHG emissions (Wu et al. 2014, Cummis 2015, Plambeck 2012). This paper shows that a disclosure mandate results in higher expected impact by the supplier under such conditions.

Whereas a large theoretical literature focuses on a supplier’s choice of responsibility effort (Babich and Tang 2012, Bondareva and Pinker 2015, Caro et al. 2017, Chen et al. 2015, Fang and Cho
2015, Plambeck and Taylor 2016, Chen and Lee 2017, Chen et al. 2017), this paper instead focuses on a buying firm’s investment and costly effort to improve its supplier’s responsibility and, in §5.2, selection of a supplier based on social or environmental impact considerations. Lewis et al. (2013) also consider buyer investment to help a supplier produce in a responsible manner, in a more complex dynamic setting with asymmetric information. Huang et al. (2015) consider effort by a buyer or tier-1 supplier to improve a tier-2 supplier’s responsibility. Guo et al. (2016) examine a buyer’s selection of a responsible supplier versus a cheaper supplier with risk of a violation causing the buyer to lose customers. Aral et al. (2014) consider supplier selection through responsibility auditing and a procurement auction informed by audit scores.

The most important differentiation of this paper from other literature on socially and environmentally responsible OM (including all the papers cited in this subsection) is that this paper addresses the issue of disclosure to investors.

3. Model Formulation

Investors’ valuation of a firm decreases with their expectation of the firm’s future costs associated with a supplier’s impact and also decreases with any current cost the firm incurs to learn about and reduce the supplier’s impact. With the objective of maximizing that valuation, a manager in the firm decides whether to learn about a supplier’s impact, how much to reduce the supplier’s impact, and whether to disclose the supplier’s impact to investors.

Initially, investors and the manager are uncertain about the supplier’s impact $G$ (mnemonic for GHG emissions), the cost $C$ for the firm to learn about its supplier’s impact, and the potential for the firm to reduce its supplier’s impact $R$. Investors and the manager have common information represented by the joint probability distribution for the random variables $(C, G, R)$. Whereas the learning cost $C$ and impact $G$ are real-valued random variables, the reduction potential $R$ is a function-valued random variable. By learning about its supplier’s impact and then incurring an additional cost $k \in [0, \infty)$, the firm will reduce the supplier’s impact by $R(k)$, which must be a non-negative, increasing, right-continuous function of $k$.

**Illustrative Example:** In an illustrative example used throughout the paper, the supplier’s impact $G$ is the sum of a uniform random variable on $[0, 1]$ and an independent binary random variable that takes value 3 with probability 0.5 and 0 otherwise. The uniform represents the GHG emissions from an efficient production process. The binary represents incremental emissions from a faulty piece of equipment, if any. In the event that the binary random variable takes value 3, $R(k) = 1 + 2 \times I\{k \geq 10\}$, meaning that learning about the faulty equipment reduces the incremental emissions by a third at no additional cost to the buying firm (e.g., by tuning the equipment$^2$), whereas the buying

$^2$ Rajaram and Corbett (2002) document a 30% reduction in GHG emissions from tuning a starch manufacturing process, with no capital expenditure.
firm must incur cost $k = 10$ to eliminate the incremental emissions (e.g., by enabling the supplier to replace the faulty equipment). In the event that the binary random variable takes value 0, $R(k) = 0$ because the supplier’s process is already efficient, with no faulty equipment.

The sequence of events, in which the manager seeks to maximize the buying firm’s current valuation, is depicted in Figure 1. In the current period, the manager observes the learning cost $C = c$ and decides whether or not to incur cost $c$ to learn about the supplier’s impact. If the manager learns, the manager observes the impact $G = g$ and reduction potential $R = r$, then chooses how much additional cost $k$ to incur to reduce the supplier’s impact, so the supplier’s impact is reduced to $g - r(k)$ and the firm’s current period profit is reduced by $c + k$. The manager discloses the current period profit to investors. If the manager learned, the manager may disclose the supplier’s impact $g - r(k)$ to investors. The firm’s current valuation is set accordingly.

In future periods, the firm may incur cost associated with its supplier’s impact. The expected discounted value of any such cost is proportional to the magnitude of the supplier’s impact; $\tau > 0$ denotes the discounted expected cost to the firm per unit impact by the supplier. The parameter $\tau$ incorporates the likelihood that the firm will incur cost associated with its supplier’s impact, the probability distribution of the magnitude and timing of any such cost, and the discount factor.

Following (Stein 1989, pp. 657 and 660)\(^3\), we assume that investors cannot observe the manager’s decisions about learning and impact reduction and do not update their beliefs about those decisions upon observing the current period profit. The motivation is that, in reality, the profit of a buying firm is stochastic and has many elements other than costs of learning about and reducing a supplier’s impact. In financial reporting to investors, a manager is not required to break out costs of learning about or reducing a supplier’s impact and indeed cannot report opportunity costs of managerial effort to learn about and reduce the supplier’s impact (profit that could have been generated had the manager allocated effort elsewhere).

\(^3\) That seminal paper assumes investors cannot observe a manager’s actions to inefficiently inflate a firm’s current profit at the expense of future profit, and do not update their beliefs about those actions upon observing the firm’s current profit.
We focus on rational expectations equilibria, in which investors’ beliefs are consistent with the manager’s strategy for learning, impact reduction and disclosure. We represent investors’ beliefs regarding the manager’s decision of whether or not to learn by \( \hat{l}(C) \), where \( \hat{l}(c) = 1 \) if investors believe that the manager learns upon observing that \( C = c \), otherwise \( \hat{l}(c) = 0 \). Similarly, \( \hat{k}(G, R) \) represents investors’ beliefs about impact reduction, i.e., that the manager chooses to incur cost \( \hat{k}(g, r) \) to reduce the supplier’s impact upon learning that \( (G, R) = (g, r) \). Also, \( \hat{d}(C, G, R) \) represents investors’ beliefs about disclosure, that \( \hat{d}(c, g, r) = \emptyset \) if the manager chooses not to disclose the supplier’s impact upon learning that \( (C, G, R) = (c, g, r) \), and \( \hat{d}(c, g, r) = 1 \) otherwise. Therefore, in the event that the manager does not disclose the supplier’s impact, investors’ expectation of the supplier’s impact is

\[
M_\emptyset \equiv E[(1 - \hat{l}(C))G + \hat{l}(C)(G - R(\hat{k}(G, R))) \mid \hat{d}(C, G, R) = \emptyset]. \tag{1}
\]

The conditional expectation in (1) is taken with respect to the joint distribution of \( (C, G, R) \), using Bayes’ rule and investors’ beliefs \( (\hat{l}, \hat{k}, \hat{d}) \) about the manager’s decisions about learning, impact reduction and disclosure. Hence the firm’s valuation at the end of the current period is

\[
V = \begin{cases} 
\tau M_\emptyset & \text{if the manager does not learn} \\
C + k + \tau M_\emptyset & \text{if she learns, incurs impact-reduction cost } k \text{ and doesn’t disclose} \\
C + k + \tau(G - R(k)) & \text{if she learns, incurs impact-reduction cost } k \text{ and discloses the impact} 
\end{cases}, \tag{2}
\]

where \( V \) is investors’ current period valuation of the firm excluding cost associated with the supplier’s impact and any cost of learning about and reducing that impact. (In the remainder of the paper, “valuation” refers to that valuation at the end of the current period.) In choosing a strategy for learning, reduction and disclosure of the supplier’s impact to maximize the firm’s expected valuation, the manager’s problem simplifies to

\[
\min \left( \tau M_\emptyset , C + E[k \min_{k \in [0, \infty), d \in \{1, \emptyset\}} \{k + \tau M_d\}] \right) \text{ wherein } M_1 \equiv G - R(k). \tag{3}
\]

Having observed the cost of learning \( C = c \), the manager chooses to learn if and only if the second term in (3) achieves the minimum. After learning \( (G, R) = (g, r) \), the manager chooses the cost \( k \) to incur to reduce the supplier’s impact and whether to disclose \( d = 1 \) or not disclose \( d = \emptyset \) the resulting impact to minimize that second term in (3). By assumption, the manager “breaks ties” in favor of learning and disclosing, when that yields the same objective value as not doing so, and, similarly, chooses the largest optimal cost to reduce the supplier’s impact. In a rational expectations equilibrium, the manager’s strategy for learning, impact reduction and disclosure \((l^*, k^*, d^*)\) must be a solution to (3) consistent with the investors’ beliefs

\[
(l^*, k^*, d^*) = (\hat{l}, \hat{k}, \hat{d}). \tag{4}
\]
We will also consider a mandatory disclosure scenario in which, if the manager learns the supplier’s impact then the manager must disclose the supplier’s impact to investors. In that scenario, if the manager does not disclose the supplier’s impact, investors know that the manager did not learn, so the supplier’s impact remains at \( G \). Hence investors’ valuation of the firm is

\[
V = \begin{cases} 
\tau E[G] & \text{if the manager does not learn} \\
C + k + \tau(G - R(k)) & \text{if she learns and incurs impact-reduction cost } k
\end{cases}.
\]

Therefore, having observed the cost of learning \( C = c \), the manager chooses to learn if and only if the second term in (6) achieves the minimum

\[
\min \left( \tau E[G] \right. , \ \left. C + E[ \min_{k \in [0, \infty)} \{ k + \tau(G - R(k)) \} \right).
\]

After learning \((G, R) = (g, r)\), the manager chooses the expenditure \( k \) to minimize the second term in (6). Let \( \kappa^*(R) \) denote that optimal expenditure \( k \) conditional on the impact reduction function \( R = r \) and observe that

\[
\kappa^*(R) \in \arg \min_{k \in [0, \infty)} \{ k - \tau R(k) \}
\]

and by the aforementioned “tie-breaking” rule, \( \kappa^*(R) \) is the maximum element of the set of \( k \) that achieve the minimum in (7) and in (6). Hence \( R(\kappa^*(R)) \) is the corresponding amount of impact reduction that (after learning) minimizes the buying firm’s expected discounted cost. (That optimal expenditure \( \kappa^*(R) \) and impact reduction \( R(\kappa^*(R)) \) feature prominently in subsequent analysis, so the reader might wish to see these in the illustrative example. In the event that no equipment is faulty, which occurs with probability 0.5, \( \kappa^*(R) = 0 \) and \( R(\kappa^*(R)) = 0 \) for all \( \tau > 0 \). Otherwise, in the event that equipment is faulty, \( \kappa^*(R) \) and \( R(\kappa^*(R)) \) depend on \( \tau \). For \( \tau \in (0, 5) \), \( \kappa^*(R) = 0 \) and \( R(\kappa^*(R)) = 1 \). For \( \tau \geq 5 \), \( \kappa^*(R) = 10 \) and \( R(\kappa^*(R)) = 3 \).)

Finally, we state a few technical assumptions about the joint distribution of the random variables \((C, G, R)\). The learning cost \( C \) has a continuous distribution with support \((0, \infty)\). By assumption, the support of the impact reduction function \( R \) is a finite set, and each element in the support of \( R \) is a nonnegative, increasing function on the domain \([0, \infty)\), so (7) is well defined. Conditional on \( R \), the distribution of \( G \) is continuous\(^4\) and has support on a finite, nonnegative interval. Whereas the supplier’s impact \( G \) and the potential to reduce that impact \( R \) may be dependent random variables, the learning cost \( C \) is independent of \((G, R)\). Furthermore, we assume that

\[
\text{with nonzero probability } \kappa^*(R) + \tau(G - R(\kappa^*(R))) > \tau E[G],
\]

\(^4\) Assuming that \( G \) has a continuous distribution and the buying firm’s expected discounted cost is linear in the supplier’s impact is natural when “impact” is the supplier’s level of GHG emissions. However, when “impact” is a specific set of fire safety violations, a discrete distribution for \( G \) might be more appropriate. The EC provides an illustrative example. Appropriate choice of a discrete distribution for \( G \) and the scaling parameter \( \tau \) could represent any level of expected discounted cost for the buying firm associated with a list of various types of discrete social or environmental violation. Our main results (Propositions 1, 2 and 3) hold with a discrete distribution for \( G \).
meaning that a manager might learn that the discounted cost associated with the supplier’s impact (even with optimal impact reduction) is higher than expected without learning. (Proposition 4 shows that with voluntary disclosure, (8) is necessary and sufficient for the manager to withhold impact information from investors with nonzero probability in equilibrium. In other words, if (8) did not hold, the manager would always choose to disclose the supplier’s impact after learning, so a disclosure mandate would have no effect.) We also assume that \( E[R(0)] > 0 \) as in our illustrative example, which is necessary for Proposition 2 to hold in the strict sense, so is explicitly imposed in the statement of Proposition 2 and motivated in that context. Without the two assumptions stated in this paragraph, our main results, Propositions 1, 2 and 3, hold in the weak sense.

Importantly, recall from \S 1 and \S 2.3 that in the context of GHG emission reduction, a buying firm can expect to, by learning about a supplier’s impact, find immediately-profitable ways to reduce that impact. Such expected profit could be captured in our model and analysis by generalizing \( C \) to represent the expected net cost of learning, i.e., the cost of learning less any expected profit for the buying firm associated with the minimum impact reduction \( R(0) \), whereas additional impact reduction would be costly.

4. Results
Characterization of Equilibria: We begin with preliminary analysis of the base case with voluntary disclosure, to establish that an equilibrium exists and has properties consistent with the empirical observations in (Delmas and Nairn-Birch 2011, Griffin and Sun 2013, Matsumura et al. 2014). In (3), the first term \( \tau M_\emptyset \) is the manager’s objective value without learning. The second term is the manager’s objective value with learning, which simplifies to

\[
C + E[\min(\tau M_\emptyset, \kappa^*(R) + \tau(G - R(\kappa^*(R)))]],
\]

The term \( \kappa^*(R) + \tau(G - R(\kappa^*(R))) \) in (9) is the manager’s objective value if the manager discloses the impact to investors \( (d = 1) \) in which case the manager optimally pursues the impact reduction \( R(\kappa^*(R)) \) that minimizes the expected discounted cost for the buying firm. (Recall that the same impact reduction \( R(\kappa^*(R)) \) occurs after learning under a disclosure mandate and was characterized through (7).) In contrast, if the manager chooses not to disclose the supplier’s impact to investors \( (d = \emptyset) \) the manager optimally chooses not to incur additional cost to further reduce the supplier’s impact, so the manager’s optimal objective is \( \tau M_\emptyset \); observe in (2) and (3) that to incur cost \( k > 0 \) to further reduce the supplier’s impact would reduce the firm’s valuation, given the choice \( d = \emptyset \) not to disclose the supplier’s impact to investors. Therefore the manager’s jointly optimal disclosure decision and expenditure to reduce the supplier’s impact are

\[
(d^*(G,R), k^*(G,R)) = \begin{cases} 
(1, \kappa^*(R)), & \text{if } \tau M_\emptyset \geq \kappa^*(R) + \tau(G - R(\kappa^*(R))) \\
(\emptyset, 0), & \text{otherwise.}
\end{cases}
\]
The condition for disclosure $\tau M_0 \geq \kappa^*(R) + \tau(G - R(\kappa^*(R)))$ is equivalent to $G \leq \hat{g}(R, M_0)$ with the disclosure threshold $\hat{g}(R, M_0)$ defined in (13) in Lemma 1, below. The manager chooses to learn if and only if $\tau M_0$ is greater than (9), i.e.,

$$l^*(C) = \begin{cases} 1 & \text{if } \tau M_0 \geq C + E[\min(\tau M_0, \kappa^*(R) + \tau(G - R(\kappa^*(R))))] \\ 0 & \text{otherwise.} \end{cases}$$  \tag{11}

Equivalently, the manager chooses to learn if and only if the learning cost $C \leq c_v$, with the learning cost threshold $c_v$ defined in (12) in Lemma 1. In a rational expectations equilibrium (4), investors’ expectation of the supplier’s impact in the event of nondisclosure $M_\emptyset$ is consistent with the manager’s optimal strategy, which with Bayes’ rule and $F$ denoting the distribution function for $C$ gives (14) in Lemma 1.

In addition to summarizing the equilibrium conditions, Lemma 1 establishes existence of an equilibrium, and reports properties of the equilibrium. Proofs of all Lemmas and Propositions are in the Electronic Companion (EC).

**Lemma 1.** (Voluntary Disclosure) (a.) In an equilibrium, the manager learns if and only if $C \leq c_v$. After learning, the manager chooses to reduce the supplier’s impact according to $\kappa^*(R)$ and disclose it if and only if $G \leq \hat{g}(R, M_\emptyset)$; otherwise, the manager does not disclose and pursues only the immediately-profitable impact reduction $R(0)$. Together, $c_v$, $\hat{g}(R, M_\emptyset)$ and $M_\emptyset$ satisfy:

$$\overline{c}_v = \tau M_\emptyset - E[\min(\tau M_\emptyset, \kappa^*(R) + \tau(G - R(\kappa^*(R))))]$$  \tag{12}

$$\hat{g}(R, M_\emptyset) = M_\emptyset + \left(\tau R(\kappa^*(R)) - \kappa^*(R)\right)/\tau$$  \tag{13}

$$M_\emptyset = \frac{F(\overline{c}_v)E[(G - R(0))1\{G > \hat{g}(R, M_\emptyset)]}{F(\overline{c}_v)Pr(G > \hat{g}(R, M_\emptyset)) + (1 - F(\overline{c}_v))E[G]}$$  \tag{14}

(b.) An equilibrium exists.

(c.) In any equilibrium, investors’ expectation of the impact in the event of nondisclosure $M_\emptyset$ is strictly greater than the expected impact without learning $E[G]$, i.e., $M_\emptyset > E[G]$.

(d.) If the equilibrium is unique, decreasing the learning cost $C$ (in first order stochastic dominance) strictly increases the learning cost threshold $\overline{c}_v$.

The equilibrium properties summarized in Lemma 1 are consistent with the empirical observations in (Delmas and Nairn-Birch 2011, Griffin and Sun 2013, Matsumura et al. 2014): Observing nondisclosure causes investors to increase their impact-estimate (Lemma 1c). Furthermore, the expected discounted cost is lower for a disclosing firm than for a non-disclosing firm (Lemma 1a), so disclosure is associated with an increase in valuation. A shift in investors’ priors- such that investors think that a buying firm is more likely to learn and disclose- tends to motivate a manager to actually do so (Lemma 1d).
The rationale for Lemma 1c is that, observing nondisclosure, investors know that either the manager didn’t learn or the manager learned and is withholding bad news that the supplier’s impact is high. Hence investors’ expectation of the supplier’s impact is higher than if investors knew that the manager didn’t learn.

The rationale for Lemma 1d is that in the event of nondisclosure, to the extent that investors’ prior distribution for the learning cost is low, investors assign a higher probability that the manager learned and is withholding bad news, so their expectation of the supplier’s impact $M_\emptyset$ is correspondingly higher. That increase in $M_\emptyset$ motivates the manager to incur higher levels of the learning cost in the hope of getting good news to disclose.

Let us return to the illustrative example introduced in §3 to see how, in equilibrium, the manager’s decisions and objective value depend on investors’ prior distribution for the learning cost $C$ and the manager’s observation of $C$ and (if she learns) of $G$ and $R$. Recall that the manager makes her learning, impact-reduction and disclosure decisions with the objective of minimizing the reduction in investors’ valuation of the buying firm due to any current costs of learning and impact-reduction and investors’ expectation of future discounted costs associated with the supplier’s impact. We focus on $\tau = 3$, which is sufficiently low that (as discussed on page 11) the manager will never choose to incur additional cost $k > 0$ to reduce the supplier’s impact. Figure 2 depicts the manager’s equilibrium learning and disclosure decisions and objective value, as a function of the observed learning cost and initial impact. Consider the left panel, wherein investors’ prior for the learning cost $C$ is exponential with rate 0.1. In that case, the manager learns if and only if the realized learning cost $C \leq \bar{c}_v = 2.3$. Hence for $C > \bar{c}_v$ the objective value is the constant $\tau M_\emptyset = 6.2$, investors’ estimate of the buying firm’s expected discounted cost associated with the supplier’s impact in the event of nondisclosure, which is represented by the dotted horizontal line. In the event that the manager learns, she chooses not to disclose the supplier’s impact if and only if $G > 3.1$. Hence the objective value, in the event $C \leq 2.3$ and $G > 3.1$, is $C + \tau M_\emptyset = C + 6.2$: the learning cost plus investors’ estimate of the buying firm’s expected discounted cost associated with the supplier’s impact in the event of nondisclosure. That objective value increases linearly with the learning cost $C$ as is evident in the upper dashed line. In the “good news” event $C \leq 2.3$ and $G \leq 3.1$ that the manager learns and discloses the supplier’s impact, the objective value is $C + \tau G$; the specific, representative case $G = 0.5$ is depicted by the lower, solid line.

For comparison with the left panel of Figure 2, consider the right panel of Figure 2 in which investors’ prior for the learning cost $C$ is exponential with rate 0.6. As predicted by Lemma 1, the decrease in investors’ prior for the learning cost (in first order stochastic dominance) increases the learning cost threshold to $\bar{c}_v$, increases investors’ estimate of the supplier’s impact in the event of nondisclosure $M_\emptyset$, and increases the threshold on the supplier’s impact $G$ below which the manager
Learning cost is likely to be large \( (\mathcal{C} \sim \text{exp}(0.1)) \)

Learning cost is likely to be small \( (\mathcal{C} \sim \text{exp}(0.6)) \)

**Figure 2** Manager’s equilibrium learning and disclosure decisions and objective value (the reduction in investors’ valuation of the buying firm)

discloses the impact. In short, due to the decrease in investors’ prior for the learning cost, the manager faces a higher penalty for nondisclosure, which favors learning and disclosure.

Lemma 2 characterizes the equilibrium under a disclosure mandate.

**Lemma 2.** (Mandatory Disclosure) A unique equilibrium exists. The manager learns if and only if \( C \leq \tau_m \) with

\[
\tau_m \equiv \tau E[R(\kappa^*(R))] - E[\kappa^*(R)],
\]

and, after learning, incurs cost \( \kappa^*(R) \) in (7) to reduce the supplier’s impact.

**Voluntary vs. Mandatory Disclosure:** Subsequent propositions show the effects of imposing a disclosure mandate. For a policy maker that aims to reduce impacts, Proposition 1 indicates a trade-off.

**Proposition 1.** A mandate for disclosure strictly reduces the probability that the manager learns:

\[
\tau_m < \tau_v
\]

with \( \tau_v \) representing the learning cost threshold in any equilibrium under voluntary disclosure. However, if \( C \leq \tau_m \) so that the manager nevertheless learns, the mandate for disclosure results in weakly greater impact reduction.

Why does a disclosure mandate deter learning? Under voluntary disclosure, the manager is motivated to incur a higher cost to learn in the hope of obtaining good news to disclose to investors because, in the event of nondisclosure, investors infer that the manager may be withholding bad news and lower the firm’s valuation accordingly. In contrast, under mandatory disclosure, investors infer from nondisclosure that the manager did not learn, so the firm’s valuation in the event of nondisclosure is higher under mandatory than voluntary disclosure.
Together, Lemma 1d, Lemma 2 and Proposition 1 imply that the loss of learning due to a disclosure mandate is exacerbated (the region $[\tau_m, \tau_v]$ is expanded) by a decrease in the learning cost $C$. Recall that that decrease, in the base case with voluntary disclosure, makes the manager more likely to learn and hence more likely to withhold bad news, so the valuation for a non-disclosing firm is relatively lower, which spurs the manager to incur a higher cost to learn, increasing $\tau_v$. In contrast, with mandatory disclosure, the learning cost threshold $\tau_m$ is invariant with respect to the distribution of the learning cost.

Why does a disclosure mandate result in weakly greater impact reduction after learning? Any cost of reducing the supplier’s impact reduces the buying firm’s current profit and hence its valuation. Reducing the supplier’s impact reduces the associated expected discounted cost for the buying firm $\tau(G - R(k))$ but, unless the manager discloses the supplier’s impact, does not reduce investors’ expectation of that cost so does not increase the buying firm’s valuation. Hence the manager, when withholding impact information, chooses not to incur additional cost to reduce the supplier’s impact, in order to increase the buying firm’s valuation. Mandating disclosure ensures that the valuation reflects the reduction in the supplier’s impact, which incentivizes the manager to reduce the supplier’s impact (though if $\kappa^*(R)$ defined in (7) is 0, the manager still chooses not to incur additional cost to reduce the supplier’s impact, so the disclosure mandate yields only weakly greater impact reduction after learning).

Proposition 2 identifies a sufficient condition for a disclosure mandate to increase the supplier’s impact. In Propositions 2 and 3 expectations are taken with respect to the joint distribution of $(C, G, R)$ and in equilibrium. For comparison in Proposition 2, the supplier’s expected impact with voluntary disclosure and under a disclosure mandate are, respectively,

$$
F(\tau_v) \left( E[(G - R(k^*(G, R)))1\{G \leq \hat{g}(R, M_\emptyset)\}] + E[(G - R(0))1\{G > \hat{g}(R, M_\emptyset)\}] \right) + (1 - F(\tau_v)) E[G]
$$

$$
F(\tau_m) E[G - R(k^*(G, R))] + (1 - F(\tau_m)) E[G].
$$

**Proposition 2.** A disclosure mandate results in strictly higher impact in expectation if $E[R(0)] > 0$ and w.p. 1 $k^*(G, R) = 0$.

The increase in expected impact by the supplier under the disclosure mandate is due to the reduced likelihood that the manager chooses to learn about the supplier’s impact.

The sufficient condition in Proposition 2 commonly holds in the settings that motivate this paper. In many cases, a buying firm, upon learning of a supplier’s safety, labor or environmental problems, can require the supplier to take corrective actions and bear the cost of those corrective actions, so $E[R(0)] > 0$ and $k^*(G, R) = 0$ (Accord 2013, Apple Supplier Responsibility 2015 Progress Report, Xu et al. 2015, Chen and Lee 2017). In particular, garment suppliers in Bangladesh can well afford to bear the cost of corrective actions, according to (Jacobs and Singhal 2017) and as discussed in
§6. Commonly, as documented in §2.3, buying firms that learn about suppliers’ GHG emissions find immediately-profitable ways for suppliers to reduce those emissions and choose not to pay for additional, costly reduction in suppliers’ GHG emissions, so \( E[R(0)] > 0 \) and \( k^*(G, R) = 0 \). (Recall that any immediate expected profit for the buyer from learning about the supplier’s impact is captured in \( C \), as explained in the last paragraph of §3.)

In summary, Propositions 1 and 2 show that under commonplace conditions, a disclosure mandate can harm society or the environment by deterring the manager of a buying firm from learning about and thereby reducing a supplier’s negative social or environmental impact.

In contrast, a disclosure mandate benefits the buying firm and its manager.

**Proposition 3.** A disclosure mandate strictly increases the buying firm’s valuation and discounted profit, in expectation.

A disclosure mandate strictly increases the buying firm’s expected discounted profit by motivating the manager to pursue the learning and impact reduction strategies that minimize the buying firm’s expected discounted cost, whereas with voluntary disclosure the expected learning cost would be strictly larger and the expected impact after learning also would be larger. A disclosure mandate strictly increases the buying firm’s valuation in two ways. First, the increase in expected discounted profit translates to an increase in expected valuation for the firm, because investors have rational expectations about the manager’s strategy. Second, a disclosure mandate strictly decreases investors’ expectation of the supplier’s impact in the event of nondisclosure (to \( E[G] \) because investors infer that the manager did not learn).

Proposition 4 shows the importance of \( \tau \), the buying firm’s expected discounted cost associated with the supplier’s impact. In short, a disclosure mandate can strictly reduce the supplier’s impact only if \( \tau \) is moderately large (\( \tau \in (\underline{\tau}, \overline{\tau}) \)). A disclosure mandate is ineffective (because the manager would never choose to withhold impact information from investors) if and only if \( \tau \geq \overline{\tau} \). Increasing \( \tau \) spurs learning and reduces the supplier’s impact under a disclosure mandate (whereas the opposite can occur with voluntary disclosure, if \( \tau < \overline{\tau} \)).

**Proposition 4.** (a.) A disclosure mandate can strictly reduce the supplier’s impact only if \( \tau > \overline{\tau} \). (b.) With voluntary disclosure, the manager withholds information from investors with nonzero probability if and only if (8), which is equivalent to \( \tau < \overline{\tau} \). (c.) Under a disclosure mandate, as \( \tau \) increases, the learning cost threshold \( c_\text{m} \) strictly increases and the supplier’s impact decreases.

\(^5\) The safety audit reports published at [http://accord.fairfactories.org/ffcweb/Web/ManageSuppliers/InspectionReportsEnglish.aspx](http://accord.fairfactories.org/ffcweb/Web/ManageSuppliers/InspectionReportsEnglish.aspx) show that garment suppliers have corrected some of the violations detected by buying firms’ safety audits \( (R(0) > 0) \) whereas other violations persist \( (G - R(0) > 0) \). That \( G - R(0) > 0 \) occurs with nonzero probability is necessary for (8) to hold.
Expressions for the thresholds \( \tau \) and \( \overline{\tau} \) are in the proof of Proposition 4. Assuming \( R \) is differentiable and strictly concave \( \overline{\tau} \equiv \min \{ 1/R'(0) \} \) with the min taken over the finite support of \( R \).

The rationale for Proposition 4a is that when \( \tau \) is low \( (\tau \leq \overline{\tau}) \), the manager chooses not to incur any additional cost to reduce the supplier’s impact, so a disclosure mandate has only its less-learning effect and (weakly) increases the supplier’s impact.

The low \( \tau \) condition in Proposition 4a is commonplace in settings that motivate this paper. The parameter \( \tau \) is low when a buying firm faces little immediate risk of costly regulation or brand damage associated with a supplier’s impact; §6 provides evidence that that is currently the case regarding a supplier’s GHG emissions and safety violations. Moreover, the parameter \( \tau \) could be low because a buying firm has short, transactional engagements with suppliers; a buying firm has little expected discounted cost \( \tau \) associated with a supplier’s impact insofar as the buying firm is unlikely to be sourcing from the supplier in future.

The rationale for Proposition 4b is that when \( \tau \) is very large \( (\tau \geq \overline{\tau}) \), after learning, the manager is always motivated to reduce the supplier’s impact to the extent that the impact is lower than expected prior to learning and disclose that good news to investors. Because the manager always wants to disclose the supplier’s impact after learning, a disclosure mandate has no effect. Otherwise, for lower \( \tau < \overline{\tau} \), the manager is less motivated to reduce the supplier’s impact and hence with nonzero probability chooses not to disclose the supplier’s impact to investors. It is straightforward to verify that \( \overline{\tau} = \infty \) (equivalently, (8) holds for all \( \tau > 0 \)) if and only if with nonzero probability \( G - R(\infty) > E[G] \), meaning that the manager cannot generate good news for investors- cannot lower the supplier’s impact below the expected level prior to learning- no matter how much cost and effort the manager exerts to do so.

To better understand Proposition 4a-b, let us return to the illustrative example introduced in §3. In the left panel in Figure 3, a disclosure mandate strictly increases the supplier’s expected impact at low levels of \( \tau \), strictly decreases the supplier’s expected impact at moderately high levels of \( \tau \), and has no effect at very high levels of \( \tau \). The rational is that for \( \tau < \overline{\tau} = 5 \), the manager never chooses to incur additional cost to reduce the supplier’s impact, but learning about the supplier’s impact can yield some impact reduction without additional cost to the buying firm (through the tuning of faulty equipment, as described above Figure 2) and a disclosure mandate increases the supplier’s impact in expectation by deterring the manager from learning. The maximum learning cost at which the manager chooses to learn falls from the \( c_v = 2.3 \) with voluntary disclosure shown in the left panel of Figure 2 to \( c_m = 1.5 \) under a disclosure mandate. In contrast, at a higher expected discounted cost per unit impact by the supplier \( \tau \geq \overline{\tau} \), under a disclosure mandate, in the event that the manager learns that the supplier has faulty equipment with high emissions \( (G \geq 3) \), the manager chooses to incur the cost \( k = 10 \) required to replace that faulty equipment. In contrast,
with voluntary disclosure, the manager chooses not to incur additional cost to reduce the supplier’s impact when the manager chooses not to disclose the supplier’s impact, so the supplier’s impact can be higher in expectation under voluntary disclosure. However, as $\tau$ increases, the manager faces a larger reduction in the current valuation from nondisclosure, so the manager becomes more likely to reduce and voluntarily disclose the supplier’s impact, so a disclosure mandate has weaker effect. For sufficiently large $\tau \geq \overline{\tau} = 10$, the manager always discloses impact information after learning, so a disclosure mandate has no effect. In contrast to the left panel, in the right panel of Figure 3, a disclosure mandate never reduces the supplier’s expected impact. The rationale is that with voluntary disclosure, as explained above Figure 2, decreasing investors’ prior for the learning cost causes the manager to face a higher penalty for nondisclosure, which favors learning and disclosure. Thus, decreasing investors’ prior for the learning cost amplifies the less-learning effect of a disclosure mandate and reduces the likelihood that a disclosure mandate results in strictly greater impact reduction, such that a disclosure mandate always increases the supplier’s impact in expectation.

Under a disclosure mandate, the probability that the manager chooses to learn about the supplier’s impact strictly increases with the buying firm’s expected discounted cost per unit impact $\tau$ and the supplier’s impact decreases with $\tau$ (Proposition 4c). Moreover, due to our assumption $E[R(0) > 0]$, the supplier’s expected impact strictly decreases with $\tau$, as illustrated in Figure 3.

With voluntary disclosure, one can construct numerical examples in which the opposite of Proposition 4c occurs: the probability that the manager chooses to learn about the supplier’s impact strictly decreases with $\tau$ and, with positive probability, the supplier’s impact strictly increases with $\tau$. The mechanism is evident from (14) and (12) in Lemma 1. As $\tau$ increases, the manager is motivated to more greatly reduce the supplier’s impact if she learns and discloses the supplier’s impact and, due to that greater impact reduction, is more inclined to disclose the supplier’s impact, resulting in a higher $\hat{g}$. Investors’ estimate of the supplier’s impact in the event of nondisclosure $M_\emptyset$ decreases with $\hat{g}$, i.e., decreases with the probability that, after learning, the manager chooses...
to disclose the supplier’s impact. Decreasing $M_0$ reduces the manager’s incentive to learn, thereby strictly reducing the learning cost threshold $\bar{c}_v$ in (12). In the event that the manager does not learn (but would have learned and strictly reduced the supplier’s impact at the lower level of $\tau$) the supplier has strictly higher impact due to the increase in $\tau$. In numerical studies, we observed that in most such examples, the increase in impact reduction when the manager learns outweighs the reduced probability of learning, such that (as in Figure 3) the supplier’s expected impact strictly decreases with $\tau$.

5. Extensions
5.1 Shared Supplier
Now suppose that a second firm buys from the supplier. The second buying firm has lower expected cost per unit impact by the supplier $\tau_2 \in (0, \tau)$. That may represent a situation in which the second buying firm purchases less of the supplier’s output (particularly in the context of supply chain GHG emission accounting, wherein a supplier’s emissions are allocated in proportion to buyers’ quantities purchased) or in which the second buying firm faces less scrutiny, less potential brand damage or less policy risk associated with the supplier’s impact. The manager of the second buying firm maximizes its valuation, analogous to (6) and (3), but with $\tau_2$ substituted for $\tau$.

Whether or not the managers cooperate, all of the propositions in §4 hold for both buying firms. The sole exception is that, without cooperation, a disclosure mandate decreases the second buying firm’s valuation and discounted profit in expectation if and only if the disclosure mandate results in greater expected impact by the shared supplier. Proofs are provided in the EC.

We will state the mechanics of a noncooperative equilibrium, followed by those of a cooperative equilibrium, then identify surprising implications of cooperation.

Noncooperation
Each manager decides whether or not to incur the cost $c$ to learn about the supplier. If a manager learns, she observes the initial magnitude of the supplier’s impact $G = g$, the reduction potential $R = r$ and whether or not the other manager learned. Then, each manager that learned decides how much cost to incur to reduce the supplier’s impact. If neither manager learned, the supplier’s impact persists at $G$. If one or both of the managers learned, the supplier’s impact becomes $G - R(k + k_2)$ wherein $k$ and $k_2$ denote the costs that the focal and second buying firm incur to reduce the supplier’s impact, respectively, which must be zero unless that firm learned. Finally, each manager that learned decides whether or not to disclose the supplier’s impact $G - R(k + k_2)$. If either does so, investors set the valuations of both buying firms accordingly. We consider noncooperative rational expectations equilibria in which each manager maximizes its firm’s valuation and investors’ beliefs are consistent with both managers’ strategies for learning, impact reduction and disclosure. The
EC provides proof of existence of such an equilibrium, in which only the focal buying firm (the one with higher \( \tau \)) learns, and we focus on that equilibrium.\(^6\)

**Cooperation**

The managers decide whether or not to learn together, i.e., share the cost \( c \) and both observe the supplier’s initial impact \( G = g \) and reduction potential \( R = r \). Subsequently, if they learned, the managers decide how much cost to incur together to reduce the impact, and then decide whether to disclose the impact to investors. We consider cooperative rational expectations equilibria in which, in each successive decision, the managers maximize the expected sum of their firms’ valuations\(^7\) and share the costs of learning and then impact reduction such that each firm achieves a higher expected valuation than if its manager were to behave noncooperatively. In the cooperative rational expectations equilibria, investors’ beliefs are consistent with the managers’ cooperative strategies for learning, impact reduction and disclosure.

Proposition 5 shows that due to voluntary disclosure- cooperation can prevent the buying firms from learning about and reducing the supplier’s impact. Cooperation also can decrease the buying firms’ valuations and discounted profits (assuming investors are aware of the cooperation). Moreover, even if a disclosure mandate motivates cooperation (by ensuring that both managers and buying firms benefit from the cooperation), a disclosure mandate can increase the supplier’s impact in expectation.

**Proposition 5.** (a.) With voluntary disclosure (and not under a disclosure mandate), cooperation can strictly reduce the learning cost threshold and result in higher impact.

(b.) With voluntary disclosure (and not under a disclosure mandate), cooperation can strictly reduce the expected values of both buying firms’ valuations and discounted profits.

(c.) The supplier’s expected impact can be strictly higher with a disclosure mandate and cooperation than with voluntary disclosure and noncooperation.

Cooperation overcomes the problem that the second buying firm (having lower \( \tau \)) freerides, choosing not to incur cost to learn about or reduce the shared supplier’s impact. Hence one would

\(^6\)As shown in the EC, in equilibrium, at most one of the buying firms learns. The equilibrium in which only the focal firm learns is not always the unique equilibrium. For some parameter values, complex equilibria exist in which, for some intermediate levels of the learning cost \( c \), the second buying firm learns, whereas the focal buying firm learns in intervals of lower and higher learning cost. In any equilibrium, the focal buying firm learns with positive probability. The paper focuses on the equilibrium in which only the focal buying firm learns because that is the most plausible equilibrium, due to its relative simplicity and because the focal firm has the higher expected cost per unit impact by the supplier \( \tau > \tau_2 \), and correspondingly higher incentive to learn about and reduce the supplier’s impact.

\(^7\)Maximizing the expected sum of the buying firms’ valuations is Pareto optimal for the managers because each manager seeks to maximize her firm’s expected valuation and utility is transferrable through the sharing of the learning and impact reduction costs. Moreover, the managers’ individual objectives are aligned in the final decision regarding whether or not to disclose the impact information to investors. Disclosure increases a buying firm’s valuation if and only if it also increases the other buying firm’s valuation. The EC provides a detailed formulation and analysis of the cooperative game that rigorously establishes these claims.
naturally expect for cooperation to spur the buying firms to learn about and more greatly reduce the supplier’s impact. The proof of Proposition 5a shows that indeed, under a disclosure mandate, cooperation increases the learning cost threshold and reduces the supplier’s impact.

More surprisingly, Proposition 5a shows that, with voluntary disclosure, cooperation can deter the firms from learning about and reducing the supplier’s impact. That occurs for the same reason, explained in the last paragraph of §4, that increasing expected discounted cost associated with the supplier’s impact \( \tau \) can strictly reduce the probability that the focal buying firm learns about and thereby reduces the supplier’s impact. Cooperation causes the buying firms to consider their total expected discounted cost \( \tau + \tau_2 \) associated with the supplier’s impact, which is similar to an increase in \( \tau \).

Proposition 5b shows a paradox that, with voluntary disclosure, cooperation can harm both of the buying firms and their managers. That occurs when cooperation increases the likelihood of learning so, in the event of nondisclosure, investors think that the managers are more likely to be withholding bad news, investors’ expectation of the supplier’s impact is higher and each firm’s valuation is correspondingly lower. That makes both managers worse off in the event of nondisclosure, causing them to incur higher costs to learn in the hope of disclosing good news about the supplier’s impact. Thus, cooperation reduces the expected profit of both buying firms by motivating their managers to over-invest in learning. The paradox arises from investors having rational expectations regarding the managers’ strategies in the setting with cooperation and in the setting without cooperation. If the managers could cooperate unbeknownst to investors, cooperation would not harm them. In reality, cooperation by buying firms is publicized in at least some cases, e.g. the Accord on Fire and Building Safety in Bangladesh and Alliance for Bangladesh Worker Safety. Fang and Cho (2015) raise the question: Why is it uncommon to observe such cooperation by buying firms? Proposition 5b helps to address that question by identifying conditions under which buying firms should not cooperate (or should try to hide their cooperation).

Relatedly, Proposition 5b suggests that a disclosure mandate might facilitate cooperation because, unlike with voluntary disclosure, under a disclosure mandate both buying firms and their managers benefit from cooperation.

Proposition 5c shows the robustness of our main result that a disclosure mandate can result in strictly higher expected impact. Even if a disclosure mandate leads to cooperation (by ensuring that both managers and buying firms benefit from the cooperation), a disclosure mandate can strictly increase the supplier’s expected impact. The rationale is that, in such cases, the disclosure mandate reduces the probability that the buying firms learn about the supplier’s impact, even though the cooperation caused by the disclosure mandate partially mitigates that loss of learning.
5.2 Alternative Suppliers

Now suppose that the buying firm has alternative suppliers. The impact and potential for impact reduction for each supplier is drawn independently from the same joint prior distribution as for \((G, R)\) in the base model with a single supplier. With alternative suppliers, the buying firm’s cost to learn about a supplier’s impact is \(\gamma C\), where \(\gamma\) is a strictly positive constant and \(C\) is the learning cost random variable in the base model. (The motivation for introducing \(\gamma\) is that to avoid losing business, a supplier may obstruct a buying firm’s learning about its impacts (Plambeck and Taylor 2016), making learning about a supplier’s impacts more costly for a buying firm.)

The sequence of events is that, first, the manager decides whether to commit to source from a supplier. If the manager does so, the game proceeds exactly as in the base model formulated in §3 (with learning cost \(C\)). Otherwise, having alternative suppliers, the manager observes the cost \(\gamma C = \gamma c\) to learn about a supplier’s impact and decides whether to do so. If manager chooses not to learn, she sources from a supplier and achieves the same expected profit as in the base model with no learning. If the manager learns, she observes the realization of a supplier’s impact \(G = g\) and reduction potential \(R = r\), and chooses whether to source from that supplier, or incur the cost \(\gamma c\) again to learn about an alternative supplier’s impact and reduction potential. That process repeats until the manager chooses to source from a supplier, and then the manager chooses the cost \(k \geq 0\) to incur to reduce that supplier’s impact, and whether or not to disclose the resulting impact to investors. To break ties, we assume that the manager chooses to commit to a supplier if and only if the buying firm’s expected valuation with commitment (in the base model) is strictly greater than with the flexibility to switch to an alternative supplier.

Proposition 6a shows that a manager commits to a supplier before learning about the supplier’s impact if and only if the resulting reduction in learning cost is sufficiently high. In other words, commitment occurs when the learning-cost-multiplier \(\gamma\) from having the option to switch suppliers is high. A disclosure mandate favors commitment, i.e., lowers the \(\gamma\)-threshold above which the manager commits. Proposition 6b shows that when the manager retains the option to switch suppliers (which occurs for \(\gamma \leq \hat{\gamma}_m\)) a disclosure mandate has no effect on learning, supplier selection, impact reduction, or the buying firm’s profit or valuation. When a disclosure mandate causes the manager to commit to a supplier (which occurs for \(\gamma \in (\hat{\gamma}_m, \hat{\gamma}_v]\)) a disclosure mandate increases learning. Otherwise (for \(\gamma > \hat{\gamma}_v\)), all the propositions in §4 hold.

**Proposition 6.** (a.) With voluntary disclosure, the manager commits to a supplier if and only if \(\gamma > \hat{\gamma}_v\) where \(1 < \hat{\gamma}_v\). Under a disclosure mandate, the manager commits to a supplier if and only if \(\gamma > \hat{\gamma}_m\) where \(1 < \hat{\gamma}_m < \hat{\gamma}_v\). (b.) For \(\gamma \leq \hat{\gamma}_m\), a disclosure mandate is ineffective. For \(\gamma \in (\hat{\gamma}_m, \hat{\gamma}_v]\), a disclosure mandate strictly increases the probability that the manager learns. For \(\gamma > \hat{\gamma}_v\), Propositions 1, 2, 3, and 4 hold.
Why does a disclosure mandate favor commitment to a supplier \( (\hat{\gamma}_m < \hat{\gamma}_v) \)? Recall from Proposition 3 that when committed to a supplier, the manager and buying firm benefit from a disclosure mandate. In contrast, when the manager has the option to switch to an alternative supplier, a disclosure mandate is ineffective, because the manager would never choose to withhold information from investors about his chosen supplier’s impact. The rationale is that with voluntary disclosure, if the learning cost is sufficiently low that the manager chooses to learn, then the manager continues to evaluate alternative suppliers until finding one with lower impact (after optimal impact reduction) than the expected impact of an alternative supplier. Disclosing the impact of that chosen supplier increases the valuation of the buying firm, so the manager does so. Because the manager would never choose to withhold impact information from investors about its chosen supplier, a disclosure mandate has no effect on the equilibrium learning, supplier selection, impact reduction or disclosure by the manager, and hence has no impact on the expected profit or investors’ valuation of the buying firm.

When a disclosure mandate causes the manager to commit to a supplier, why does the manager become more inclined to learn? The proof is subtle because commitment to a supplier decreases the value of learning, by sacrificing the option (after learning that the supplier has high impact and low potential for impact reduction) to switch to an alternative supplier. However, in the parameter region \( \gamma \in (\hat{\gamma}_m, \hat{\gamma}_v) \) wherein a disclosure mandate causes commitment, the reduction in the cost of learning from \( \gamma_c \) to \( c \) outweighs that loss in the value of learning.

5.3 Manager’s Objective/Information for Investors

All the propositions in this paper hold for the extension in this section; the proofs are provided in the EC. We state the extension (and its two alternative interpretations) then present new insights.

Suppose that the manager’s objective is a weighted sum of the firm’s expected discounted profit and its valuation, as in (Lai et al. 2012, Schmidt et al. 2015). Let \( \theta \in [0,1) \) be the weight assigned to expected discounted profit and \( 1 - \theta \) the weight assigned to the valuation (2). The manager’s optimization problem under voluntary disclosure generalizes from (3) to

\[
\min \left( \theta \tau E[G] + (1 - \theta) \tau M_\emptyset, C + E \left[ \min_{k \in [0, \infty), d \in \{1, \emptyset\}} \{ k + \theta \tau M_1 + (1 - \theta) \tau M_d \} \right] \right)
\]

(17)

with \( M_\emptyset \) denoting (1) and \( M_1 \equiv G - R(k) \).

The manager learns if and only if the second term in (17) achieves the minimum. After learning the supplier’s impact and the potential for reduction \( (G, R) = (g, r) \), the manager chooses the cost

---

8 Propositions 1-6 hold. In addition, all statements in extensions sections §5.1 and §5.2 regarding the robustness of the propositions in §4 hold, with this subsection’s extension combined with that of §5.1 and §5.2, respectively. The proof for Proposition 4b, Proposition 5, and the robustness statements in §5.1 assume that \( R \) is differentiable and strictly concave.
$k$ to incur to reduce the supplier’s impact and whether to disclose ($d = 1$) or not disclose ($d = \emptyset$) the resulting impact to minimize that second term in (17).

Alternatively, suppose the manager knows that investors will observe the supplier’s impact with probability $\theta$, independently of $C, G, R$ and the manager’s own decisions. In the event that investors observe the supplier’s impact, the buying firm’s valuation will become

$$V = \begin{cases} \tau G \\ C + k + \tau(G - R(k)) \end{cases}$$

if the manager did not learn or the manager learned and incurred impact-reduction cost $k$; otherwise, it will be (2) as in the base model. The manager’s objective is to maximize the expected valuation of the buying firm, which under voluntary disclosure is (17). 9

Proposition 7 shows that imposing a disclosure mandate is equivalent to motivating the manager to maximize the firm’s expected discounted profit (without regard for its valuation) and that imposing a disclosure mandate is equivalent to eliminating investors’ uncertainty about the supplier’s impact.

**Proposition 7.** A disclosure mandate has the same effect on learning, impact reduction, the firm’s expected discounted profit and its valuation as increasing $\theta$ to 1.

Whereas under a disclosure mandate the manager’s decisions do not depend on $\theta$, Proposition 8 shows that with voluntary disclosure, as $\theta$ increases (investors are more likely to learn about the supplier’s impact from an alternative source or the manager places increasingly more weight on expected discounted profit than valuation) the manager becomes less inclined to learn about the supplier’s impact. Recall that $\tau_v$ denotes the maximum realization of the learning cost $C$ such that the manager chooses to learn, in equilibrium.

**Proposition 8.** With voluntary disclosure, if the equilibrium is unique, the learning cost threshold $\tau_v$ strictly decreases with $\theta$.

The rationale is that when investors observe the supplier’s impact, they cease to draw negative inference from nondisclosure by the manager, so the manager has less motivation to learn.

---

9 This note provides a more detailed explanation of this alternative interpretation of (17). For the case that the manager decides not to learn, the term $\theta \mathbb{E}[G] + (1 - \theta) \tau M_0$ is the manager’s expectation of investors’ rational expectation of the buying firm’s expected discounted cost associated with the supplier’s impact. Therein, the term $(1 - \theta) \tau M_0$ reflects the probability $(1 - \theta)$ that investors do not observe the supplier’s impact and $\tau M_0$ is investors’ rational expectation of the buying firm’s expected discounted cost associated with the supplier’s impact, in the event that investors do not observe the supplier’s impact and the manager does not disclose the supplier’s impact. For the case that the manager decides to learn, $C + \mathbb{E} \left[ \min_{k \in [0, \infty), d \in \{1, \emptyset\}} \{k + \theta \tau M_1 + (1 - \theta) \tau M_d\} \right]$ is the expected reduction in the valuation due to the costs of learning $C$ and impact reduction $k$ and investors’ expectation of the buying firm’s expected discounted cost associated with the supplier’s impact. Therein, $M_1 \equiv G - R(k)$ is the supplier’s impact, which is observed by investors with probability $\theta$ or may be disclosed by the manager, as represented by $d = 1$. 
5.4 Multiple Inputs and Impact Categories

All propositions in the paper generalize to a setting in which the buying firm sources multiple inputs, under two assumptions: First, the random variables \((C_i, G_i, R_i)\) representing the learning cost, impact and impact reduction potential for an input \(i\) supplier are independent of those for suppliers of other inputs. Second, the manager can selectively learn about and disclose impact information for a subset of its suppliers. Under those two assumptions, the manager’s optimization problem is separable into a optimization problem (of the sort analyzed above) for each input. Providing empirical support for the second assumption, Blanco et al. (2016) found that firms that disclosed information about their “Scope 3” supply chain emissions disclosed only a small fraction of their actual Scope 3 emissions, and Kim and Lyon (2011) found that firms selectively disclosed successful GHG emission reduction projects, without disclosing their growing overall carbon footprints.

The propositions generalize in a similar manner with multiple independent categories of impacts (e.g., GHG emissions, unsafe factory conditions, use of conflict minerals).

6. Concluding Remarks

Famed corporate sustainability leader and Unilever CEO Paul Polman argues that too many companies are myopically short-term focused on shareholders. With the goal of improving Unilever’s supply chain sustainability and long run profitability, Polman made changes at Unilever that incentivize managers to maximize expected discounted profit over the long run, rather than focus on the firm’s current valuation (Polman 2014). Within the scope of this paper, that change in a manager’s objective is equivalent to a disclosure mandate. In other words, all the results in this paper regarding effects of a disclosure mandate can alternatively be interpreted as effects of a change in the manager’s objective to maximize the buying firm’s expected discounted profit rather than its current market valuation.

Most fundamentally, a disclosure mandate (or the aforementioned change in the manager’s objective) tends to deter the manager from learning about a supplier’s impact but, if the manager nevertheless chooses to learn, incentivizes impact reduction.

Furthermore, this paper has shown that a disclosure mandate increases a buying firm’s expected discounted profit and its current market valuation, by three mechanisms. First, a buying firm is deterred from learning about a supplier’s social and environmental impacts when the learning cost exceeds the expected improvement in future discounted profit from learning. (Concern about investors’ valuation of the buying firm motivates a manager to incur a higher learning cost, in the hope of getting good news to disclose to investors.) Second, after learning, the buying firm will optimally reduce the supplier’s impact, rather than withhold impact information from investors and
hence not reduce that impact. Third, investors are no longer concerned that a buying firm may be withholding bad news about a supplier’s impacts, which increases their valuation of the buying firm.

However, a disclosure mandate results higher impact by the supplier in expectation, under a condition that apparently holds in settings that motivate this paper. The condition is that by learning about a supplier’s impacts, a buying firm can expect to reduce those impacts and will not bear additional cost to do so. For example, as documented in §2.3, that condition is commonplace among buying firms that learn about suppliers’ GHG emissions. Hence this paper’s results suggest that a mandate for disclosure of supply chain (Scope 3) GHG emissions, of the sort piloted in France, will result in higher GHG emissions. The condition also holds in settings where, upon observing labor, safety, or environmental problems, the buyer can require the supplier to take corrective actions and bear the cost. For example, under the Accord on Fire and Building Safety in Bangladesh (2013), suppliers are required to take corrective actions for observed safety problems. Although buyers are responsible to ensure “financial feasibility” for suppliers to do so, Jacobs and Singhal (2017) document that large garment suppliers in Bangladesh are profitable (have higher median return on assets than the retailers that source from them) and conclude that those suppliers can indeed bear cost to improve safety. Hence this paper’s results suggest that the mandate to disclose all safety audit reports for Bangladeshi suppliers’ facilities (adopted by apparel retailers as signatories to the Accord) might be a deterrent to thorough safety auditing, and thereby result in more safety violations in expectation.

This paper also shows the importance of a buying firm’s expected discounted cost associated with a supplier’s impact (denoted \( \tau \) in this paper). A disclosure mandate can reduce a supplier’s impact only if \( \tau \) is moderately high. If \( \tau \) is very high, a buying firm voluntarily reduces and discloses the supplier’s impact, so a disclosure mandate is useless. If \( \tau \) is low, a buying firm will not choose to bear additional cost to reduce a supplier’s impact, so a disclosure mandate (at least weakly) increases the supplier’s impact, through the decrease in learning discussed above. In settings that motivate this paper, \( \tau \) is indeed low and has recently become lower. Delay in government action to address climate change (President Trump withdrawing the U.S. from the Paris Accord) reduces a firm’s expected discounted cost associated with a supplier’s GHG emissions. In the context of the Bangladesh garment industry, Jacobs and Singhal (2017) provide empirical evidence that \( \tau \) is low; buyers suffered little brand damage or other costs from even the notorious Rana Plaza factory collapse. A recent U.S. Supreme Court ruling curbs liability for buying firms to pay reparations to victims of such incidents in suppliers’ factories (Greenhouse 2013), which lowers \( \tau \). However, NGOs are now mobilizing to pressure buying firms into paying reparations and shame ones that fail to do so (Clean Clothes Campaign 2017), which will increase \( \tau \). This paper has shown that,
under a disclosure mandate, increasing \( \tau \) spurs a buying firm to learn and more greatly reduce a supplier’s impact. The implication for the Bangladesh garment industry is that, under the mandate to disclose safety audit results for buying firms in the Accord and Alliance, the aforementioned NGO actions will spur safety improvements in suppliers’ facilities.

How else could government or NGOs compel buying firms to mitigate their suppliers’ social and environmental impacts? One way would be to reduce buying firms’ costs of learning about their suppliers’ impacts. For example, the U.S. Dodd-Frank Act requires the Department of Commerce to provide a listing of all known conflict minerals-processing facilities worldwide and to recommend best practices for auditing to learn about the origins of those conflict minerals. This paper shows that reduction in a buyer’s cost of learning would be more effective in stimulating learning and impact reduction with voluntary disclosure than under a disclosure mandate.

**Acknowledgments**

The authors thank Serguei Netessine (Department Editor), the Associate Editor, the anonymous review team, Erjie Ang, Beril Toktay, Feryal Erhun, and Cynthia Cummis for their insights and suggestions that helped to improve the paper substantially.

**References**


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Electronic Companion

Fire Safety Illustrative Example: As an illustrative example, suppose that the supplier could have \( N \) different types of fire safety violations. For \( n = 1, \ldots, N \), let \( 1_n \) be the indicator random variable with value 1 in the event that the supplier has a type \( n \) violation, and 0 otherwise. Define constants \( g_n \) such that \( \tau g_n \) is the expected discounted cost to the buying firm associated with the supplier having a fire safety violation of type \( n \). Let the constant \( k_n \) denote the cost to the buying firm to correct a fire safety violation of type \( n \) after learning about it. The supplier’s ”impact” \( G \) and the potential to reduce that impact \( R \) are the dependent random variables

\[
G = \sum_{n=1}^{N} g_n 1_n \\
R(k) = \sum_{n=1}^{F(k)} g_n 1_n
\]

wherein \( F(k) \) is the subset of \( \{1, \ldots, n\} \) representing the optimal set of violations to correct when spending \( k \)

\[
F(k) = \max_{F \subseteq \{1, \ldots, n\}} \sum_{n \in F} g_n 1_n \text{ subject to } \sum_{n \in F} k_n \leq k.
\]

Proof of Lemma 1: (a.) Solving for \( G \) that satisfies the condition \( \tau M_\emptyset \geq \kappa^*(R) + \tau(G - R(\kappa^*(R))) \) in the top line of (10) as an equality, we find the disclosure threshold \( \hat{g}(R, M_\emptyset) \) in (13). Solving for \( C \) that satisfies the condition in the top line of (11) as an equality, we find the learning threshold \( \tau_\emptyset \) defined in (12). The manager’s strategy for learning, impact reduction and disclosure is consistent with the investors’ beliefs in a rational expectations equilibrium, \( (l^*, k^*, d^*) = (\hat{l}, \hat{k}, \hat{d}) \). Investors’ expectation of the impact (1) then equals

\[
M_\emptyset = E[(1 - l^*(C))G + l^*(C)(G - R(k^*(G, R)))]|d = \emptyset \] \hfill (18)

\[
= (Pr\{l^*(C) = 0\}E[G] + Pr\{l^*(C) = 1\}E[G - R(k^*(G, R))]|d = \emptyset, l^*(C) = 1]/(Pr\{l^*(C) = 0\} + Pr\{d = \emptyset, l^*(C) = 1\})
\]

where the second equality follows from the independence of \( C \) and \( (G, R) \) and Bayes’ Rule. By (10) and (11), expression (18) becomes (14).

(b.) We characterize an equilibrium under voluntary disclosure by characterizing a solution to the equilibrium conditions (12)-(14). We first solve for an equilibrium \( M_\emptyset \) by using (12) to express \( \tau_\emptyset \) in terms of \( M_\emptyset \), and substituting that expression into (14). With an abuse of notation, we use \( \tau_\emptyset (M_\emptyset) \) to denote the \( \tau_\emptyset \) that corresponds to a given \( M_\emptyset \) in (12), so (14) can be written as

\[
P = F(\tau_\emptyset (M_\emptyset))E[(G - R(0)) - M_\emptyset]1\{G > \hat{g}(R, M_\emptyset)\} + (1 - F(\tau_\emptyset (M_\emptyset)))(E[G] - M_\emptyset) = 0 \] \hfill (19)

An equilibrium \( M_\emptyset \) is a solution to (19). Let \( \underline{g} \) and \( \bar{g} \) denote the minimum and maximum possible realizations of \( G \), which by assumption satisfies \( 0 \leq \underline{g} < \bar{g} < \infty \). We will show that \( P > 0 \) at \( M_\emptyset = E[G], P < 0 \) at \( g = \bar{g} > E[G] \) and that \( P \) is continuous so by the Intermediate Value Theorem, a
solution to (19) exists in \((E[G], \bar{g})\) at which \(P\) is decreasing with respect to \(M_0\). First, we evaluate \(P\) at \(M_0 = E[G]\). Suppose \(c_\ast(E[G]) \geq \tau \) satisfies \(\tau E[G] - E[\tau (G - R(\kappa^\ast (R))) + \kappa^\ast (R)] \geq \tau E[R(0)] > 0\) where the first inequality is by (12), the second inequality is by the optimality of \(\kappa^\ast (R)\), and the last inequality is by \(\tau > 0\) and \(E[R(0)] > 0\). Therefore, \(F(c_\ast(E[G])) > 0\) (because \(C\) has support on \((0, \infty)\)). The first term on the RHS of (19) is positive at \(M_0 = E[G]\) because with positive probability we have \(\tau (G - R(0)) \geq \tau (G - R(\kappa^\ast (R))) + \kappa^\ast (R) > \tau E[G]\) (where the first inequality is by the optimality of \(\kappa^\ast (R)\) and the second inequality is by our initial assumption) and \(\tau > 0\). The second term is zero, leading to \(P > 0\). Now we evaluate \(P\) at \(M_0 = \bar{g}\). \(\hat{g}(R, \bar{g}) \geq \bar{g}\) because \(\hat{g}(R, \bar{g}) \geq \bar{g} + R(0)\) (due to (13) and the optimality of \(\kappa^\ast (R)\)) and \(R \geq 0\). \(\tau (\bar{g}) = \tau \bar{g} - E[\kappa^\ast (R) + \tau (G - R(\kappa^\ast (R)))] \geq \tau E[R(0)] + \tau (\bar{g} - E[G]) > 0\) where the equality is by (12) and \(\hat{g}(R, \bar{g}) \geq \bar{g}\), the first inequality is by the optimality of \(\kappa^\ast (R)\), and the last inequality is by \(\tau > 0\) and \(E[R(0)] > 0\). \(0 < F(\tau c_\ast(\bar{g})) < 1\) because \(\tau c_\ast(\bar{g})\) is positive and finite. At \(M_0 = \bar{g}\), \(\Pr(G > \hat{g}(R, \bar{g})) = 0\) and the second term on the RHS of (19) is negative, implying

\[
P|_{M_0 = \bar{g}} < 0. \tag{20}
\]

Finally, we note that \(\tau c_\ast(M_0)\) and and \(E[(G - R(0) - M_0)1\{G > \hat{g}(R, M_0)\}]\) are continuous in the region \(M_0 \in [E[G], \bar{g}]\) because \(\hat{g}(R, M_0)\) is continuous in \(M_0\), \(G\) follows a continuous distribution conditional on \(R\), and the support of \(R\) is a finite set of functions. Therefore, \(P\) is continuous in \(M_0 \in [E[G], \bar{g}]\).

c.) Consider the investors’ expectation of the impact in the event of nondisclosure given by (18). Suppose \(\Pr\{l^\ast (C) = 1\} > 0\) and \(M_0 \leq E[G]\). In the event that the manager learns and \(\kappa^\ast (R) + \tau (G - R(\kappa^\ast (R))) \leq M_0\), then according to (10) the manager discloses the impact. In the event that the manager learns and \(\kappa^\ast (R) + \tau (G - R(\kappa^\ast (R))) > \tau M_0\) (which occurs with strictly positive probability by our initial assumption), the manager does not disclose, according to (10). For such \((G, R)\), \(\kappa^\ast (G, R) = 0\) and \((G - R(0)) > M_0\) because \(\tau (G - R(0)) \geq \kappa^\ast (R) + \tau (G - R(\kappa^\ast (R))) > \tau M_0\) (where the first inequality is by the optimality of \(\kappa^\ast (R)\) and the second inequality is by our initial assumption) and \(\tau > 0\). Therefore \(E[G - R(\kappa^\ast (G, R))] = 0\) and \(\Pr\{l^\ast (C) = 1\} > 0\), the RHS of (18) is strictly greater than \(M_0\), a contradiction. It remains to show that in any equilibrium under voluntary disclosure, the manager learns with positive probability: \(\Pr\{l^\ast (C) = 1\} > 0\). Suppose \(\Pr\{l^\ast (C) = 1\} = 0\), leading to \(M_0 = E[G]\) according to (18). The manager’s objective without learning is \(\tau E[G]\) (by (3)). The expected value of the manager’s objective after learning (ignoring the learning cost) satisfies \(E[\min(\tau M_0, \kappa^\ast (R) + \tau (G - R(\kappa^\ast (R))))] \leq E[\tau (G - R(\kappa^\ast (R)) + \kappa^\ast (R))] \leq \tau E[G - R(0)] < \tau E[G]\), where the first two inequalities are due to (9) and the optimality of \(\kappa^\ast (R)\), respectively, and the last inequality is due to \(\tau > 0\) and \(E[R(0)] > 0\). Therefore, a manager
with \( c \leq \tau E[R(0)] \) would choose to learn and \( \Pr\{l^*(C) = 1\} > \Pr\{c \leq \tau E[R(0)]\} > 0 \), contradicting \( \Pr\{l^*(C) = 1\} = 0 \).

(d.) Suppose \( F_b(\cdot) \) is a learning cost distribution dominated by \( F(\cdot) \) in the first order and \( M_0 \) satisfies (19) when the learning cost follows \( F \). If \( F_b(\tau_v(M_0)) = F(\tau_v(M_0)) \), \( P \) in (19) evaluated at the distribution \( F_b(\cdot) \) and \( M_0 \) is zero. Otherwise, \( F_b(\tau_v(M_0)) > F(\tau_v(M_0)) \) and \( P \) evaluates to a positive value at \( M_0 \), which, by (20) and Intermediate Value Theorem, establishes the existence of a solution that satisfies \( M_{\theta b} > M_0 \). Note that \( \kappa^*(R) + \tau(G - R(\kappa^*(R))) \leq \tau M_{\theta b} \) with positive probability because \( \kappa^*(R) + \tau(G - R(\kappa^*(R))) \leq \tau(\tau - R(0)) \leq \tau G \) with positive probability (where the first and second inequalities are by the optimality of \( \kappa^*(R) \) and \( R(0) \geq 0 \) respectively), \( \tau > 0 \), \( \tau G \leq \tau E[G] \) with positive probability, and \( E[G] < M_{\theta b} \) by part (c.). As a result, \( E[\min(\tau M_{\theta b}, \kappa^*(R) + \tau(G - R(\kappa^*(R))))] - E[\min(\tau M_{\theta b}, \kappa^*(R) + \tau(G - R(\kappa^*(R))))] < (\tau M_{\theta b} - M_0) \) and \( \tau_v(M_{\theta b}) - \tau_v(M_0) > 0 \) follows from this inequality and (12).

**Proof of Lemma 2:** Under a disclosure mandate, the manager’s objective without learning (first term in (6)) is \( \tau E[G] \) and the manager’s objective with learning (second term in (6)) is \( c + E[\kappa^*(R) + \tau(G - R(\kappa^*(R)))] \) with \( \kappa^*(R) \) defined in (7). In equilibrium, the manager learns if and only if the second term is less than or equal to the first, or equivalently \( c \leq \tau_m \), with \( \tau_m \) as defined in (15). From (6) and (7), the manager’s optimal additional cost to reduce the impact after learning equals \( k^*(G, R) = \kappa^*(R) \). If the manager learns, she discloses the impact, and if the manager does not learn, she does not disclose the impact, so investors know that the manager did not learn. Therefore investors’ valuation of the buying firm equals the expected profit of the buying firm, and the equilibrium is unique.

**Proof of Proposition 1:** That \( \tau_v > \tau_m \) follows from (12), (15), Lemma 1c and the fact that the manager’s objective after learning (and ignoring the learning cost) is greater under mandatory than voluntary disclosure, \( \min(\tau M_{\theta b}, \kappa^*(R) + \tau(G - R(\kappa^*(R)))) \leq \kappa^*(R) + \tau(G - R(\kappa^*(R))) \), because under voluntary disclosure the manager has the flexibility to choose not to disclose the impact.

The manager’s optimal cost to reduce the supplier’s impact equals either \( \kappa^*(R) \) or 0 under voluntary disclosure (Lemma 1a), and equals \( \kappa^*(R) \) under a mandate (Lemma 2). Hence a mandate increases \( R(k^*(G, R)) \).

**Proof of Proposition 2:** Lemma 1a and Lemma 2 imply that in equilibrium under voluntary disclosure, the manager learns and thereby reduces the supplier’s impact by \( R(0) \) for \( c \leq \tau_v \), whereas the manager does so in equilibrium under mandatory disclosure for \( c \leq \tau_m \) where \( \tau_m < \tau_v \). By assumption, the learning cost \( C \) has a continuous distribution and is independent of \( R(0) \), so under the conditions \( k^*(G, R) = 0 \) and \( E[R(0)] > 0 \), a disclosure mandate increases the supplier’s expected impact by \( (F(\tau_v) - F(\tau_m))E[R(0)] > 0 \).
Proof of Proposition 3: We refer to the buying firm’s discounted cost associated with the supplier’s impact and the cost of learning about and reducing that impact as the buying firm’s discounted impact-related cost in the remainder of the proof. We prove that a mandate strictly decreases the expected value of the buying firm’s discounted impact-related cost and investors’ valuation of that cost, which is equivalent to the statement of the proposition. In equilibrium under voluntary or mandatory disclosure, the expected values (with respect to \( C, G, R \)) of the buying firm’s discounted impact-related cost and investors’ valuation of that cost are equal. We provide the proof under voluntary disclosure only, because the proof under mandatory disclosure is similar.

In equilibrium under voluntary disclosure, the expected value of investors’ valuation of the buying firm’s discounted impact-related cost is:

\[
\int_0^{\tau_v} \left[ c + E[(\kappa^*(R) + \tau(G - R(\kappa^*(R))))1\{G \leq \hat{g}(R, M_\theta)\}] + E[\tau M_\theta 1\{G > \hat{g}(R, M_\theta)\}] \right] f(c) dc + \int_{\tau_v}^{\infty} (\tau M_\theta) f(c) dc, (21)
\]

with \( \tau_v, M_\theta, \) and \( \hat{g}(R, M_\theta) \) as characterized in Lemma 1a. Observe that (21) is equal to

\[
\int_0^{\tau_m} \left[ c + E[(\kappa^*(R) + \tau(G - R(\kappa^*(R))))1\{G \leq \hat{g}(R, M_\theta)\}] + E[\tau(G - R(0))1\{G > \hat{g}(R, M_\theta)\}] \right] f(c) dc + \tau E[G](1 - F(\tau_v))
\]

\[
+ \tau \left( M_\theta (F(\tau_v) Pr(G > \hat{g}(R, M_\theta)) + (1 - F(\tau_v))) - F(\tau_v) E[(G - R(0))1\{G > \hat{g}(R, M_\theta)\}] - E[G](1 - F(\tau_v)) \right),
\]

wherein the quantity in the first line is the expected discounted impact-related cost of the buying firm, and the quantity in the last line is equal to zero due to the value of \( M_\theta \) in (14) in Lemma 1a.

It remains to show that a mandate for disclosure strictly reduces the buying firm’s expected discounted impact-related cost in equilibrium. The firm’s expected discounted impact-related cost under a disclosure mandate is

\[
t_{man} = \int_0^{\tau_m} \left[ c + E[(\kappa^*(R) + \tau(G - R(\kappa^*(R))))1\{G \leq \hat{g}(R, M_\theta)\}] + E[\tau(G - R(0))1\{G > \hat{g}(R, M_\theta)\}] \right] f(c) dc + \tau E[G](1 - F(\tau_m)), (22)
\]

with \( \tau_m \) as characterized in Lemma 2. The firm’s expected discounted impact-related cost with voluntary disclosure \( t_{vol} \) can be defined similarly to \( t_{man} \), by replacing \( \tau_m \) with \( \tau_v \) (which is characterized in Lemma 1) in the expression above. We will show that \( t_{man} \leq \omega(\tau_m) < t_{vol} \), with \( \omega \) defined as

\[
\omega(\hat{c}) = \int_0^{\hat{c}} \left[ c + E[(\kappa^*(R) + \tau(G - R(\kappa^*(R))))1\{G \leq \hat{g}(R, M_\theta)\}] + E[\tau(G - R(0))1\{G > \hat{g}(R, M_\theta)\}] \right] f(c) dc + \tau E[G](1 - F(\hat{c})).
\]

From the optimality of \( \kappa^*(R), \tau(G - R(0)) \geq \kappa^*(R) + \tau(G - R(\kappa^*(R))), \) and as a result, \( t_{man} \leq \omega(\tau_m) \). The second inequality, \( \omega(\tau_m) < t_{vol} \), holds if \( \omega \) is increasing with \( \hat{c} \) for all \( \tau_m, \leq \hat{c} \leq \tau_v \) (and strictly increasing for some \( \hat{c} \) values in this region), because \( t_{vol} = \omega(\tau_v) \).

\[
\frac{d\omega}{d\hat{c}} = f(\hat{c}) \left( \hat{c} + E[(\kappa^*(R) + \tau(G - R(\kappa^*(R))))1\{G \leq \hat{g}(R, M_\theta)\}] + E[\tau(G - R(0))1\{G > \hat{g}(R, M_\theta)\}] - \tau E[G] \right). (23)
\]
By the expression of \( c_m \) in (15), \( \frac{d\omega}{dc} \geq 0 \) for \( \hat{c} = c_m \) and \( \frac{d\omega}{dc} > 0 \) for \( \hat{c} > c_m \). By Proposition 1, \( c_v > c_m \), which establishes \( \omega(c_m) < t_{vol} \).

**Proof of Proposition 4:** (a.) We refer to the impact reduction cost that satisfies (7) for a given \( \tau \) as \( \kappa^*(R, \tau) \) without loss of generality. By (7), the fact that \( -k + \tau R(k) \) has increasing differences with respect to \( (k, \tau) \), and Topkis’ Theorem, \( \kappa^*(R, \tau) \) increases with \( \tau \). Furthermore, \( \kappa^*(R, \tau) = 0 \) at \( \tau = 0 \) because the manager’s objective in (7) at \( \tau = 0 \) is strictly decreasing with \( k \). Therefore, there exists a \( \tau \) defined as

\[
\tau \equiv \sup\{\tau : \kappa^*(R, \tau) = 0 \text{ with probability 1, } \tau \in [0, \infty)\},
\]

such that \( \kappa^*(R, \tau) = 0 \) for all \( \tau \leq \tau \), which by Proposition 2 implies that a disclosure mandate results in strictly higher expected impact. Therefore, for a disclosure mandate to strictly reduce the supplier’s expected impact, it must be that \( \tau > \tau \).

(b.) We first show that with voluntary disclosure the manager withholds information from investors with positive probability if and only if (8). If (8) holds, we can show by contradiction that full disclosure cannot be observed in equilibrium. Suppose there exists an equilibrium with full disclosure. By observing nondisclosure, investors expect that the manager did not learn and that the supplier’s expected impact is \( E[G] \). Hence, the valuation is reduced by \( \tau E[G] \) after observing nondisclosure. However, for \( (G, R) \) such that \( \kappa^*(R) + \tau (G - R(\kappa^*(R))) > \tau E[G] \) (which occurs with positive probability by (8)) the manager is strictly better off by not disclosing the impact, contradicting the existence of a full disclosure equilibrium.

Now we show that if the manager withholds information with positive probability, (8) holds. Note that in a rational expectations equilibrium, investors’ expectation of the impact (1) equals

\[
M_\emptyset = E[(1 - l^*(C))G + l^*(C)(G - R(\kappa^*(G, R)))] | d = \emptyset = (Pr\{l^*(C) = 0\}E[G] + Pr\{l^*(C) = 1\}E[G - R(0)|d = \emptyset, l^*(C) = 1])/ (Pr\{l^*(C) = 0\} + Pr\{d = \emptyset, l^*(C) = 1\})
\]

where the second equality follows from the independence of \( C \) and \( (G, R) \), Bayes’ Rule and \( k^*(G, R) = 0 \) by (10). Suppose that the manager withholds information with positive probability but (8) does not hold; i.e., \( \tau (G - R(\kappa^*(R))) + \kappa^*(R) \leq \tau E[G] \) with probability 1. Then, \( M_\emptyset \) must be strictly less than \( E[G] \) because otherwise disclosing weakly dominates not disclosing for all \( (G, R) \). \( M_\emptyset < E[G] \) implies that \( Pr\{l^*(C) = 1\} > 0 \) (because \( Pr\{l^*(C) = 1\} = 0 \) would lead to \( M_\emptyset = E[G] \) by (25)). Consequently,

\[
E[G - R(0)|d = \emptyset, l^*(C) = 1] < E[G] < M_\emptyset.
\]
Let \((\hat{g}, \hat{r})\) belong to the set of \((G, R)\) for which not disclosing is optimal and satisfy \(\hat{g} - \hat{r}(0) = \inf\{G - R(0) : \kappa^*(R) + \tau(G - R(\kappa^*(R))) > \tau M_\theta\}\). By the definition of \((\hat{g}, \hat{r})\) and (26), \(\hat{g} - \hat{r}(0) < M_\theta\). However, by \(\tau > 0\) and by the optimality of \(\kappa^*(\hat{r})\),

\[
\tau(\hat{g} - \hat{r}(\kappa^*(\hat{r}))) + \kappa^*(\hat{r}) \leq \tau(\hat{g} - \hat{r}(0)) < \tau M_\theta,
\]

which contradicts the assertion that the manager would not reduce and disclose the impact for \(G = \hat{g}\) and \(R = \hat{r}\).

We now show that (8) does not hold if and only if \(\tau \geq \overline{\tau}\). For this part, we refer to the impact reduction cost that satisfies (7) for a given \(\tau\) as \(\kappa^*(R, \tau)\) without loss of generality. Moreover, let \(\overline{\tau}\) satisfy

\[
\overline{\tau} = \max\{\inf\{\tau > 0 : \tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau E[G] \text{ with probability } 1\}\}.
\]

Here, the max is taken over the finite support of \(R\) and \(\inf\) is taken over all possible \(\tau\) for a given realization of \(R\). We prove the result for \(\overline{\tau} = 0\) and \(\overline{\tau} > 0\) separately. First, we show that

\[
\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau E[G] \text{ with probability } 1 \text{ for all } \tau > 0 \text{ if and only if } \overline{\tau} = 0.
\]

If \(\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau E[G] \text{ with probability } 1 \text{ for all } \tau > 0, \text{ then by the definition of } \overline{\tau}\) in (28) \(\overline{\tau} = 0\). If \(\overline{\tau} = 0, \text{ then there exists } \tau_1 = \epsilon > 0 \text{ (i.e., arbitrarily close to } 0 \text{ and positive) such that } \tau_1(G - R(\kappa^*(R, \tau_1))) + \kappa^*(R, \tau_1) \leq \tau_1 E[G] \text{ with probability } 1. \text{ Because } \kappa^*(R, \tau_1) \geq 0 \text{ and } \tau_1 > 0, \text{ } (G - R(\kappa^*(R, \tau))) \leq E[G] \text{ with probability } 1. \text{ Then, for any } \tau_2 > \tau_1, \text{ } (G - R(\kappa^*(R, \tau_2))) \leq \tau_2 E[G]
\]

with probability 1, where the first inequality is by the optimality of \(\kappa^*(R, \tau_2)\) and the second inequality is by \(\tau_1(G - R(\kappa^*(R, \tau_1))) + \kappa^*(R, \tau_1) \leq \tau_1 E[G] \text{ and } (G - R(\kappa^*(R, \tau_1))) \leq E[G] \text{ (both with probability } 1). \text{ Consequently, for any } \tau_2 > \tau_1, \text{ } \tau_2(G - R(\kappa^*(R, \tau_2))) + \kappa^*(R, \tau_2) \leq \tau_2 E[G] \text{ with probability } 1. \text{ Because this is true for any } \tau_1 = \epsilon > 0, \text{ in the limit as } \epsilon \to 0, \text{ } (G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau E[G] \text{ with probability } 1 \text{ for all } \tau > 0.

Now, we focus on the scenario where \(\overline{\tau} > 0\) and we show that

\[
\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau E[G] \text{ with probability } 1 \text{ if and only if } \tau \geq \overline{\tau}. \text{ If } \tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau E[G] \text{ with probability } 1, \text{ then by the definition of } \overline{\tau}\text{ in (28) } \tau \geq \overline{\tau}. \text{ Now, we show that if } \tau \geq \overline{\tau}, \text{ then } \tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau E[G] \text{ with probability } 1. \text{ Note that } \overline{\tau}(G - R(\kappa^*(R, \overline{\tau}))) + \kappa^*(R, \overline{\tau}) \leq \overline{\tau} E[G] \text{ with probability } 1 \text{ by definition. Because } \kappa^*(R, \overline{\tau}) \geq 0 \text{ and } \overline{\tau} > 0, \text{ } (G - R(\kappa^*(R, \overline{\tau}))) \leq E[G] \text{ with probability } 1. \text{ Then, for } \tau > \overline{\tau}, \text{ }
\]

\[
\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau(G - R(\kappa^*(R, \overline{\tau}))) + \kappa^*(R, \overline{\tau}) \leq \tau E[G]
\]

(30)
with probability 1, where the first inequality is by the optimality of \( \kappa^\ast(R, \tau) \) and the second inequality is by \( \mathbb{P}(G - R(\kappa^\ast(R, \tau))) + \kappa^\ast(R, \tau) \leq \mathbb{P}E[G] \) and \( (G - R(\kappa^\ast(R, \tau))) \leq E[G] \) (both with probability 1). Hence, for any \( \tau > \bar{\tau} \), \( \tau(G - R(\kappa^\ast(R, \tau))) + \kappa^\ast(R, \tau) \leq \tau E[G] \) with probability 1.

(c.) By (7), the fact that \((-k + \tau R(k))\) has increasing differences with respect to \((k, \tau)\), and Topkis Theorem, \( \kappa^\ast(R) \) increases with \( \tau \). To show that the learning threshold increases with \( \tau \), let \( \kappa^\ast(R, \tau) \) represent the solution to (7) when the unit penalty equals \( \tau \), and let \( \bar{c}_{m,1} \) and \( \bar{c}_{m,2} \) represent the learning cost thresholds under a disclosure mandate when the unit penalty equals \( \tau_1 \) and \( \tau_2 \), respectively, with \( \tau_1 > \tau_2 \). By (15), we observe that \( \bar{c}_{m,1} - \bar{c}_{m,2} \geq E[(\tau_1 - \tau_2)R(\kappa^\ast(R, \tau_2))] \geq 0 \), where the first inequality is due to the optimality of \( \kappa^\ast(R, \tau_1) \), and the second inequality is due to \( \kappa^\ast(R, \tau_2) \geq 0 \), \( E[R(0)] > 0 \), \( R(\cdot) \) being an increasing function, and \( \tau_1 > \tau_2 \). For \( c \in (\bar{c}_{m,2}, \bar{c}_{m,1}] \), the manager learns about the impact and strictly reduces that impact for some realizations of \( R \) (because \( E[R(0)] > 0 \) and \( R \) is an increasing function) when unit penalty per impact equals \( \tau_1 \), but the manager does not learn or reduce the impact when unit penalty per impact equals \( \tau_2 \). Therefore, as \( \tau \) increases, the supplier’s impact decreases.

**Proofs of Analytical Results in Section 5.1**

**Preliminaries:** With an abuse of notation, we define \( \kappa^\ast(R, \tau_B) \) as the optimal cost to reduce the supplier’s impact that maximizes the expected discounted profit of the buying firm with per unit impact penalty \( \tau_B \). \( \kappa^\ast(R, \tau_B) \) is given by (7), with \( \tau \) replaced by the expected discounted cost per unit impact of the corresponding buying firm (i.e., \( \tau_B \) equals \( \tau \) and \( \tau_2 \) for the first and second buying firms respectively). With an abuse of notation, we define the disclosure threshold \( \hat{g}(R, M_\theta, \tau_B) \) as follows: after only the manager of a buying firm with expected discounted per unit impact cost \( \tau_B \) learns, the manager chooses to reduce the supplier’s impact according to \( \kappa^\ast(R, \tau_B) \) and disclose it if and only if \( G \leq \hat{g}(R, M_\theta, \tau_B) \), which satisfies

\[
\hat{g}(R, M_\theta, \tau_B) = M_\theta + \left( \tau_B R(\kappa^\ast(R, \tau_B)) - \kappa^\ast(R, \tau_B) \right) / (\tau_B),
\]

similar to (13). Otherwise, the manager does not disclose and pursues only the immediately-profitable impact reduction \( R(0) \).

The following lemma establishes the properties of \( \kappa^\ast(R, \tau_B) \) and \( \hat{g}(R, M_\theta, \tau_B) \) which will be used in the proofs of Propositions of 5, 9, and 10.

**LEMMA 3.** \( \kappa^\ast(R, \tau_B) \) and \( \hat{g}(R, M_\theta, \tau_B) \) are increasing with \( \tau_B \).

**Proof of Lemma 3:** By (7), the fact that \((-k + \tau R(k))\) has increasing differences with respect to \((k, \tau)\), and Topkis Theorem, \( \kappa^\ast(R, \tau_B) \) is increasing with \( \tau_B \). \( \hat{g}(R, M_\theta, \tau_B) \) is increasing with \( \tau_B \) because for any \( \tau_a > \tau_\theta > 0 \),

\[
\frac{\tau_\theta R(\kappa^\ast(R, \tau_\theta)) - \kappa^\ast(R, \tau_\theta)}{\tau_\theta} \leq \frac{\tau_a R(\kappa^\ast(R, \tau_a)) - \kappa^\ast(R, \tau_a)}{\tau_a} \leq \frac{\tau_a R(\kappa^\ast(R, \tau_a)) - \kappa^\ast(R, \tau_a)}{\tau_\theta},
\]

Author: Managing Supplier Social & Environmental Impacts with Voluntary vs. Mandatory Disclosure to Investors

Article submitted to Management Science; manuscript no.
where the first inequality is by $\kappa^*(\cdot) \geq 0$ and $\tau_a > \tau_b > 0$, and the second inequality is by the optimality of $\kappa^*(R, \tau_a)$.

Noncooperative Game

Robustness of Results in §4: The following proposition establishes the robustness of findings in §4 when the managers do not cooperate.

**Proposition 9.** In the noncooperative game, Propositions 1, 2, and 4 hold for both buying firms. Proposition 3 holds for the focal buying firm.

**Proof of Proposition 9:** We restrict our attention to pure strategies. We first prove that given investors’ estimated impact observing nondisclosure $M_\emptyset$ under voluntary disclosure, there exists an equilibrium of learning and impact reduction game between the buying firms’ managers, in which only the focal buying firm learns and helps to reduce the impact. In a rational expectations equilibrium, investors’ expectation of the supplier’s impact in the event of nondisclosure is consistent with managers’ strategies for learning, impact reduction and disclosure. Then, using Bayes’ Rule and the distribution for the cost of learning $C$, we identify rational expectations equilibrium conditions for $M_\emptyset$, learning threshold $\bar{c}_v$, and disclosure threshold $\hat{g}$. We analyze the equilibrium under voluntary disclosure only; the result can be verified for mandatory disclosure using similar steps as below.

If only one manager learns about the impact, this setting reduces to our base model. The disclosure decision and the cost to reduce the supplier’s impact are characterized by (10), with $\tau$ and $\kappa^*(R)$ replaced by $\tau_2$ and $\kappa^*(R, \tau_2)$ if only the second buying firm learned about the impact. If both buying firms’ managers learn about the impact, we identify the managers’ impact reduction equilibria after observing $(G, R)$ under the two disclosure scenarios: when the shared supplier’s impact is to be disclosed by at least one manager, and when neither manager discloses the impact. We consider these two scenarios because the investors know that both buying firms source from the same supplier and hence investors infer a buying firm’s supplier’s impact from the other buying firm’s disclosure. With no disclosure, by (3) the managers’ objectives after learning are $\min_k(\tau_B M_\emptyset - k)$ (with $\tau_B$ equal to $\tau$ and $\tau_2$ for the focal buying firm and the second buying firm, respectively). Both managers choose zero cost because their objectives are strictly decreasing with $k$. With disclosure by at least one manager, each manager’s objective after learning is

$$\min_{k_i}(\tau_i(G - R(k_i + k_{3-i}))) + k_i),$$

where $i = 1, 2$ and $\tau_1 = \tau$. We prove that an equilibrium exists in which only the focal buying firm reduces the impact by incurring $\kappa^*(R, \tau)$ and the second buying firm does not incur any additional cost. We show that neither manager has incentive to deviate from the outlined strategies. If the
second buying firm does not incur any additional cost, the focal buying firm does not deviate from $\kappa^*(R, \tau)$ due to (7) and (32). If the focal buying firm incurs $\kappa^*(R, \tau)$ to reduce the impact, the second buying firm cannot find a profitable deviation from incurring no additional cost. Suppose the second buying firm is strictly better off by incurring $\hat{\kappa}_2 > 0$.

$$\tau_2(G - R(\kappa^*(R, \tau) + \hat{\kappa}_2)) + \hat{\kappa}_2 < \tau_2(G - R(\kappa^*(R, \tau))). \quad (33)$$

This inequality together with $\tau > \tau_2$ leads to $\hat{\kappa}_2 < \tau_2(R(\kappa^*(R, \tau) + \hat{\kappa}_2) - R(\kappa^*(R, \tau))) < \tau(R(\kappa^*(R, \tau) + \hat{\kappa}_2) - R(\kappa^*(R, \tau)))$. By rearranging the terms and adding $\kappa^*(R, \tau)$ to both sides, we obtain

$$\tau(G - R(\kappa^*(R, \tau) + \hat{\kappa}_2)) + \kappa^*(R, \tau) + \hat{\kappa}_2 < \tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau), \quad (34)$$

which contradicts the fact that the focal buying firm’s discounted cost is minimized at $\kappa^*(R, \tau)$. Therefore, in the event that both managers learn $(G, R)$ and at least one chooses to disclose the impact, there exists an equilibrium in which the focal buying firm and the second buying firm incur costs $\kappa^*(R, \tau)$ and 0, respectively.

Next, we characterize the disclosure decisions after both managers learn about the impact. We show that in an equilibrium, both managers disclose the impact after learning $(G, R)$ if and only if

$$\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) \leq \tau M_\emptyset; \quad (35)$$

after observing such $(G, R)$, only the focal buying firm incurs $\kappa^*(R, \tau)$ to reduce the impact, and after observing other $(G, R)$ both managers incur zero cost. We prove that neither manager has incentive to deviate from the outlined strategies. (35) is equivalent to the disclosure condition in (10) in our base model, and therefore, the focal buying firm does not have incentive to deviate if the second buying firm follows the cost and disclosure strategy outlined above. For $(G, R)$ satisfying (35), disclosure is a weakly dominant strategy for the second buying firm (because investors know that both firms source from the same supplier). For $(G, R)$ not satisfying (35), we have $G - R(0) > M_\emptyset$, because $\tau(G - R(0)) \geq \tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) > \tau M_\emptyset$ (where the first inequality is due to the optimality of $\kappa^*(R, \tau)$) and $\tau > 0$. Hence, the impact after learning and impact reduction is strictly greater than the investors’ estimated impact, so the second buying firm does not have incentive to deviate and disclose unless the second buying firm incurs additional impact reduction cost. For such $(G, R)$, we have $\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau) > \tau M_\emptyset$, which is equivalent to $G > \hat{g}(R, M_\emptyset, \tau)$ and which by Lemma 3 and $\tau > \tau_2$ leads to $G > \hat{g}(R, M_\emptyset, \tau_2)$. Using (31), $G > \hat{g}(R, M_\emptyset, \tau_2)$ can be rewritten as $\tau_2(G - R(\kappa^*(R, \tau_2))) + \kappa^*(R, \tau_2) > \tau_2 M_\emptyset$, meaning that the second buying firm’s objective after choosing the optimal cost to reduce the supplier’s impact and
disclosing is greater than her objective without disclosure for \((G, R)\) that does not satisfy (35) and hence the second buying firm does not have incentive to deviate.

We now analyze the managers’ learning decisions given equilibrium impact reduction and disclosure strategies identified above. We first characterize the expected value of each manager’s objective (excluding the learning cost) given the learning strategies of both managers. For ease of notation, we use \((L_1, L_2)\) to refer to the focal buying firm and the second buying firm’s learning strategies \((L_1, L_2) \in \{L, N\}\) with L refering to “Learn” and N refering to “Not Learn”). The expected value of the focal buying firm’s objective (excluding the learning cost) under \((LL), (LN), (NL)\) and \((NN)\) are given by the following expressions:

\[
\phi_{1,LL} = \phi_{1,LN} = E[(\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau))1\{G \leq \hat{g}(R, M_\theta, \tau)\}] + E[(\tau M_\theta)1\{G > \hat{g}(R, M_\theta, \tau)\}],
\]

\[
\phi_{1,NL} = E[(\tau(G - R(\kappa^*(R, \tau_2)))1\{G \leq \hat{g}(R, M_\theta, \tau_2)\}] + E[(\tau M_\theta)1\{G > \hat{g}(R, M_\theta, \tau_2)\}],
\]

\[
\phi_{1,NN} = \tau M_\theta,
\]

where \(\hat{g}(R, M_\theta, \tau_B)\) is defined as in (31). \(\phi_{1,LL} = \phi_{1,LN}\) because only the focal buying firm helps the supplier to reduce the impact when both managers learn. The expected value of the second buying firm’s objective (excluding the learning cost) under \((LL), (LN), (NL)\) and \((NN)\) are given by the following expressions:

\[
\phi_{2,LL} = \phi_{2,LN} = E[\tau_2(G - R(\kappa^*(R, \tau)))1\{G \leq \hat{g}(R, M_\theta, \tau)\}] + E[\tau_2 M_\theta1\{G > \hat{g}(R, M_\theta, \tau)\}],
\]

\[
\phi_{2,NL} = E[(\tau_2(G - R(\kappa^*(R, \tau_2))) + \kappa^*(R, \tau_2))1\{G \leq \hat{g}(R, M_\theta, \tau_2)\}] + E[(\tau_2 M_\theta)1\{G > \hat{g}(R, M_\theta, \tau_2)\}],
\]

\[
\phi_{2,NN} = \tau_2 M_\theta.
\]  

(36)

The expected values of the managers’ objectives including the learning cost for \((LL), (LN), (NL)\) and \((NN)\) are given by \((\phi_{1,LL} + c, \phi_{2,LL} + c), (\phi_{1,LN} + c, \phi_{2,LN}), (\phi_{1,NL}, \phi_{2,NL} + c)\) and \((\phi_{1,NN}, \phi_{2,NN})\), respectively. \((LL)\) cannot be observed in equilibrium because not learning strictly dominates learning for the second buying firm when the focal buying firm learns (due to \(c > 0\) and \(\phi_{2,LL} = \phi_{2,LN}\)). To identify learning equilibria, we define \(\bar{c}_{1,LL} \equiv \phi_{1,NL} - \phi_{1,LL}, \bar{c}_{1,N} \equiv \phi_{1,NN} - \phi_{1,LN}\) and \(\bar{c}_{2,N} \equiv \phi_{2,NN} - \phi_{2,NL}\), where \(\bar{c}_{1,LL}\) and \(\bar{c}_{1,N}\) are the decreases in the expected value of investors’ valuation of the first buying firm’s discounted cost after learning when the second buying firm learns and does not learn, respectively, and \(\bar{c}_{2,N}\) is the decrease in the expected value of investors’ valuation of the second buying firm’s discounted cost after learning when the focal buying firm does not learn. Observe that \(\bar{c}_{1,LL} \leq \bar{c}_{1,N}\) because \(\phi_{1,LN} = \phi_{1,LL}\) and \(\phi_{1,NL} \leq \phi_{1,NN}\) (as \(G - R(\kappa^*(R, \tau_2)) \leq M_\theta\) for \(G \leq \hat{g}(R, M_\theta, \tau_2)\) due to the disclosure condition \(\tau_2(G - R(\kappa^*(R, \tau_2))) + \kappa^*(R, \tau_2) \leq \tau_2 M_\theta\) for \(G \leq \hat{g}(R, M_\theta, \tau_2), \tau_2 > 0\), and \(\kappa^*(R, \tau_2) \geq 0\)). \(\bar{c}_{1,N} \geq \bar{c}_{2,N}\) because \(\bar{c}_{1,N} - \bar{c}_{2,N} = (\phi_{1,NN} - \phi_{1,LN}) - (\phi_{2,NN} - \phi_{2,NL}) = (\tau - \tau_2) M_\theta + \phi_{2,NL} - \phi_{1,LL}\) and \(\phi_{2,NL} - \phi_{1,LL} = E[\min((\tau_2(G - R(\kappa^*(R, \tau_2))) + \kappa^*(R, \tau_2)), \tau_2 M_\theta)] - \)
managers are uncertain about the shared supplier’s impact. Initially, investors and the
cost each firm incurs to learn about and reduce the supplier’s impact. As in the base model, the valuation of each firm decreases with investors’ expectation of the firm’s
Cooperative Game: Detailed Formulation and Proofs of Propositions 5 and 10

In summary, in equilibrium, at most one of the buying firms learns. We identify two types of
equilibria: in the first type of equilibrium, only the focal buying firm learns about the impact if
and only if \( c \leq \bar{c}_{1,N} \), \( c > \bar{c}_{1,N} \), and \( \bar{c}_{1,L} < c \leq \tilde{c}_{2,N} \), respectively.

In the rational expectations equilibrium, investors’ beliefs are consistent with the managers’
equilibrium strategies. Therefore, in an equilibrium in which only the focal buying firm learns about
and reduces the supplier’s impact, investors’ estimated impact observing nondisclosure is given by
(14) in Lemma 1 and the learning threshold \( \bar{c}_{1,N} = \tilde{c}_v \) where \( \tilde{c}_v \) is defined as in (12) in Lemma 1.

In an equilibrium where only the focal buying firm learns and reduces the impact, equilibrium
conditions for our base model are satisfied. As a result, Propositions 1, 2, and 4 hold, and Proposition
3 holds for the first buying firm. The second buying firm does not incur any learning or impact reduction cost, and the firm’s expected discounted profit is affected only by the expected
discounted cost associated with the supplier’s impact. Moreover, the expected value of the second
buying firm’s discounted cost and investors’ valuation of that cost are equal, which is proven for
the first buying firm in Proposition 3 and can be extended in a straightforward manner for the
second buying firm. Therefore, a disclosure mandate reduces the firm’s profit and valuation if and
only if it increases the expected impact.

Cooperative Game: Detailed Formulation and Proofs of Propositions 5 and 10

As in the base model, the valuation of each firm decreases with investors’ expectation of the firm’s
future costs associated with the shared supplier’s impact and also decreases with any current
cost each firm incurs to learn about and reduce the supplier’s impact. Initially, investors and the
managers are uncertain about the shared supplier’s impact \( G \), the cost \( C \) for the firms to learn
about the supplier’s impact, and the potential for the firms to reduce the supplier’s impact \( R \).

They have common information represented by the joint probability distribution for the random variables \((C, G, R)\), which is the same as in the base model.

**Voluntary Disclosure**

Investors form rational expectations about the managers’ decisions about learning, impact reduction and disclosure in the cooperative game. As in the base model, investors cannot observe the managers’ decisions about learning and impact reduction and do not update their beliefs about those decisions upon observing the current period profits. (The rationale for that assumption is provided in the sixth paragraph of §3.) Accordingly, investors cannot observe a deviation to non-cooperative behavior in learning and impact reduction, even if that occurs. Let \( M^{\text{coop}}_0 \) represent investors’ expectation of the supplier’s impact in the event of nondisclosure by both firms’ managers in the cooperative game. (The proof of Proposition 6 derives \( M^{\text{coop}}_0 \) from investors’ rational expectations about managers’ decisions about learning, impact reduction and disclosure in equilibrium in the cooperative game.)

The cooperative game between the managers in the current period evolves in three stages. In the first stage, the managers observe the realization of the learning cost \( C = c \) and decide whether or not to jointly incur cost \( c \) and learn about the supplier’s impact (i.e., observe the supplier’s initial impact \( G = g \) and impact reduction potential \( R = r \)) and how to share the learning cost \( c \). In that first stage, the managers’ disagreement alternative is the noncooperative game, as formulated in §5.1 except that \( M^{\text{coop}}_0 \) substitutes for \( M_0 \) to reflect investors’ rational expectations in the cooperative game, because investors cannot observe a deviation to noncooperative behavior in learning and impact reduction. If the managers learned together, they proceed to the second stage, in which they choose how much additional cost \( k \) to incur together to reduce the supplier’s impact to \( g - r(k) \) and how to share that cost \( k \). In that second stage, the managers’ disagreement alternative is the continuation game of impact reduction and disclosure for the noncooperative game formulated in §5.1 except that \( M^{\text{coop}}_0 \) substitutes for \( M_0 \). In the third and final stage, each manager that learned decides whether or not to disclose the supplier’s impact to investors. If either does so, investors set the valuations of both buying firms accordingly.

In the future, the buying firms may incur costs associated with the shared supplier’s impact. The expected discounted value of any such cost to each firm is proportional to the magnitude of the supplier’s impact; \( \tau > 0 \) and \( \tau_2 > 0 \) denote the discounted expected costs per unit impact by the supplier to the focal and second buying firm, respectively.

The focal buying firm’s valuation at the end of the current period is

\[
V_1 = \begin{cases} 
\tau M^{\text{coop}}_0 & \text{if the managers do not learn} \\
\delta C + \beta k + \tau M^{\text{coop}}_0 & \text{if the managers jointly learn, incur impact-reduction cost } k, \text{ and don’t disclose} \\
\delta C + \beta k + \tau(G - R(k)) & \text{if the managers jointly learn, incur impact-reduction cost } k, \text{ and disclose}
\end{cases}
\]  

(37)
wherein $\delta \in [0, 1]$ is the fraction of the learning cost borne by the focal buying firm, $\beta \in [0, 1]$ is the fraction of the impact reduction cost borne by the focal buying firm, and $V_1$ is investors’ current period valuation of the focal buying firm excluding cost associated with the supplier’s impact and any cost of learning about and reducing that impact. Similarly, the second buying firm’s valuation at the end of the current period is

\[
V_2 = \begin{cases} 
\tau_2 M_\emptyset^\text{coop} & \text{if the managers do not learn} \\
(1 - \delta)C + (1 - \beta)k + \tau_2 M_\emptyset^\text{coop} & \text{if the managers jointly learn, incur impact-reduction cost } k, \text{ and don’t disclose,} \\
(1 - \delta)C + (1 - \beta)k + \tau_2 (G - R(k)) & \text{if the managers jointly learn, incur impact-reduction cost } k, \text{ and disclose.}
\end{cases}
\]

(38)

wherein $V_2$ is investors’ current period valuation of the second buying firm excluding cost associated with the supplier’s impact and any cost of learning about and reducing that impact.

In stage one and stage two of the cooperative game (learning and impact reduction, respectively) utility is transferrable between the managers, because each manager’s objective (expected valuation) decreases linearly with the cost of learning and the cost of impact reduction. Therefore at stage one and again at stage two, the managers maximize the sum of the expected valuations, subject to the constraint that each achieves a higher expected valuation than with the disagreement alternative. In the third stage, the managers’ incentives are aligned: each will optimally disclose the supplier’s impact if and only if that impact is less than $M_\emptyset^\text{coop}$, investors’ expected impact observing nondisclosure. Therefore, assuming that the learning and impact reduction costs can be allocated between buying firms such that neither manager has incentive to behave noncooperatively (as will be established in the proof of Proposition 10) the managers’ problem simplifies to

\[
\min \left( (\tau + \tau_2) M_\emptyset^\text{coop}, \ c + E \left[ \min_{k \in [0, \infty), d \in \{1, \emptyset\}} \{k + (\tau + \tau_2) M_d^\text{coop}\} \right] \right) \text{ wherein } M_1^\text{coop} \equiv G - R(k) \text{.} \tag{39}
\]

The managers learn if and only if the second term in (39) achieves the minimum. After learning $(G, R) = (g, r)$, the managers choose the cost $k$ to incur to reduce the supplier’s impact and whether to disclose ($d = 1$) or not disclose ($d = \emptyset$) the resulting impact to minimize that second term in (39). As in the base model, we assume that the managers break ties in favor of learning and disclosing. The managers’ optimal joint strategy for learning, impact reduction and disclosure in the cooperative equilibrium (i.e., the solution to (39)) is denoted by $(l^\text{coop}, k^\text{coop}, d^\text{coop})$.

In a cooperative rational expectations equilibrium, investors’ beliefs regarding the managers’ joint strategy for learning, impact reduction and disclosure is consistent with $(l^\text{coop}, k^\text{coop}, d^\text{coop})$, so that $M_\emptyset^\text{coop}$ coincides with the supplier’s expected impact conditional on $l^\text{coop} = 0$ or $d^\text{coop} = \emptyset$.

**Mandatory Disclosure**

If the managers learn about the shared supplier’s impact then the managers must disclose that impact to investors. If the managers do not disclose the supplier’s impact, investors know that
the managers did not learn or reduce the supplier’s impact, which remains at $G$. Hence the focal buying firm’s valuation is

$$V_1 = \begin{cases} \tau E[G] & \text{if the managers do not learn} \\ \delta C + \beta k + \tau (G - R(k)) & \text{if the managers jointly learn and incur impact-reduction cost } k \end{cases}$$

(40)

wherein $\delta \in [0,1]$ is the fraction of the learning cost borne by the focal buying firm and $\beta \in [0,1]$ is the fraction of the impact reduction cost borne by the focal buying firm. The second buying firm’s valuation is

$$V_2 = \begin{cases} \tau_2 E[G] & \text{if the managers do not learn} \\ (1-\delta)C + (1-\beta)k + \tau_2 (G - R(k)) & \text{if the managers jointly learn and incur impact-reduction cost } k \end{cases}$$

(41)

As with voluntary disclosure, in stage one and stage two of the cooperative game (learning and impact reduction, respectively) utility is transferrable between the managers, because each manager’s objective (expected capital market price) decreases linearly with the cost of learning and the cost of impact reduction. Therefore at stage one and again at stage two, the managers maximize the sum of the expected valuations, subject to the constraint that each achieves a higher expected valuation than with the disagreement alternative. (The managers’ disagreement alternative in the first stage is the noncooperative game as formulated in §5.1, and in the second stage is the continuation game of impact reduction for that noncooperative game.) In the third stage, the managers must disclose what they know about the supplier’s impact. Therefore, assuming that the learning and impact reduction costs can be allocated between buying firms such that neither manager has incentive to behave noncooperatively (as will be established in the proof of Proposition 10) the managers’ problem simplifies to

$$\min \left( (\tau + \tau_2) E[G], c + E[ \min_{k \in [0,\infty)} \{k + (\tau + \tau_2)(G - R(k))\}] \right).$$

(42)

The managers learn if and only if the second term in (42) achieves the minimum. After learning, the managers decide how much to reduce the supplier’s impact, choosing $k$ to minimize the second term in (42). After learning $(G, R) = (g, r)$, the managers choose the cost $k$ to incur to reduce the supplier’s impact to minimize that second term in (42). As in the base model, we assume that the managers break ties in favor of learning. The managers’ optimal joint strategy for learning and impact reduction in the cooperative equilibrium (i.e., the solution to (42)) is denoted by $(l^{\text{coop}}, k^{\text{coop}})$.

**Robustness of Results in §4:** The following proposition establishes the robustness of findings in §4 when the managers cooperate.

**PROPOSITION 10.** *In the cooperative game, Propositions 1, 2, 3, and 4 hold.*
Proof of Proposition 10: As established in the proof of Proposition 9, for any value of the investors’ estimated impact observing nondisclosure $M_\emptyset$ under voluntary disclosure, there exists an equilibrium of the noncooperative game between buying firms’ managers in which only the focal buying firm learns and helps to reduce the impact. We assume that this noncooperative game is the disagreement alternative for the first stage of the cooperative game, in which managers decide whether or not to learn and how to share the learning cost $c$. Furthermore, the continuation game of impact reduction and disclosure for that noncooperative game is the disagreement alternative for the second stage of the cooperative game, in which managers decide how much cost to incur to help the supplier to reduce the impact. Footnote 6 in §5.1 explains why the equilibrium of the noncooperative game in which only the focal buying firm learns and helps to reduce the impact is the most plausible equilibrium despite the possibility of other, more complex equilibria.

In this proposition, we first prove that given investors’ beliefs about the supplier’s expected impact observing nondisclosure by both firms’ managers in the cooperative game $M_{\emptyset}^{coop}$, a feasible impact reduction and learning cost allocation can be identified such that both managers obtain higher valuations for the corresponding buying firms by cooperating compared to the disagreement alternative. In a rational expectations equilibrium, investors’ expectation of the supplier’s impact in the event of nondisclosure is consistent with managers’ strategies for learning, impact reduction and disclosure. Then, using Bayes’ Rule and the distribution for the cost of learning $C$, we identify cooperative rational expectations equilibrium conditions for $M_{\emptyset}^{coop}$, learning threshold $\bar{c}_v$, and disclosure threshold $\hat{g}$. We analyze the equilibrium under voluntary disclosure only; the result can be verified for mandatory disclosure using similar steps as below.

Given investors’ beliefs about the supplier’s expected impact in the event of nondisclosure $M_{\emptyset}^{coop}$, the learning and disclosure thresholds $\bar{c}_v$ and $\hat{g}$ in the equilibrium of the noncooperative game (identified in Proposition 9) can be defined as in (12) and (13) in Lemma 1, respectively, with $M_{\emptyset}^{coop}$ substituting for $M_\emptyset$.

Now, we consider the managers’ incentives to cooperate, keeping the investors’ beliefs regarding the supplier’s expected impact observing nondisclosure fixed. As evident from (3) and (42), the managers’ joint optimization with cooperation is equivalent to a single buying firm’s manager’s maximization of the capital market price when that buying firm’s expected discounted per unit impact cost is $\tau + \tau_2$. The managers’ joint impact reduction cost with and without disclosure are $\kappa(R, \tau + \tau_2)$ and 0, respectively. The managers choose to incur cost $\kappa(R, \tau + \tau_2)$ to reduce the impact if and only if $G \leq \hat{g}(R, M_{\emptyset}^{coop}, \tau + \tau_2)$ with $\hat{g}$ defined in (31). The managers choose to learn if and only if the learning cost satisfies $C \leq \tau_{v, coop}$ with

$$\tau_{v, coop} = (\tau + \tau_2)M_{\emptyset}^{coop} - E[\min((\tau + \tau_2)M_{\emptyset}^{coop}, \kappa(R, \tau + \tau_2) + (\tau + \tau_2)(G - R(\kappa(R, \tau + \tau_2))))]$$
\[
= (\tau + \tau_2)M_\theta^{\text{coop}} - E[\{\kappa^*(R, \tau + \tau_2) + (\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2)))\} \{G \leq \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\}]
- E[((\tau + \tau_2)M_\theta^{\text{coop}})1\{G > \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\}],
\]

where the second equality follows from (31).

In the disclosure stage of the cooperative game, it is in the best interest of both managers to disclose the supplier’s resulting impact if and only if that impact is less than \(M_\theta^{\text{coop}}\). For \(G \leq \hat{g}(R, M_\theta^{\text{coop}}, (\tau + \tau_2))\), the resulting impact after the impact reduction stage of the cooperative game is less than \(M_\theta^{\text{coop}}\) by (31), \(\tau + \tau_2 > 0\) and \(\kappa^*(R, \tau + \tau_2) \geq 0\). Conversely, for \(G > \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\), we observe that \((\tau + \tau_2)(G - R(0)) \geq (\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2))) + \kappa^*(R, \tau + \tau_2) > (\tau + \tau_2)M_\theta^{\text{coop}}\) (where the first inequality is by the optimality of \(\kappa^*(R, \tau + \tau_2)\) and the second inequality is by (31) and \(G > \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\)). Therefore, \(\tau + \tau_2 > 0\) leads to \(G - R(0) > M_\theta^{\text{coop}}\), meaning that the resulting impact after the impact reduction stage of the cooperative game is greater than \(M_\theta^{\text{coop}}\) for \(G > \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\). Therefore, if the managers jointly reduce the supplier’s impact according to the strategy outlined in the previous paragraph, then both managers choose to disclose the resulting impact if and only if \(G \leq \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\).

In the next two steps, we show that the impact reduction and learning costs can be allocated such that both managers are at least weakly better off with cooperation than with the disagreement alternative, for each realization of \((C, G, R)\).

**Impact Reduction Cost Allocation:** By Lemma 3 and \(\tau_2 > 0\), \(\hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2) \geq \hat{g}(R, M_\theta^{\text{coop}}, \tau)\), meaning that the managers incur additional cost to reduce the supplier’s impact and the resulting impact is disclosed for a wider range of \(G\) with cooperation. Therefore, we identify three possibilities depending on the realization of \((G, R)\): \(G \leq \hat{g}(R, M_\theta^{\text{coop}}, \tau)\), \(\hat{g}(R, M_\theta^{\text{coop}}, \tau) < G \leq \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\), or \(G > \hat{g}(R, M_\theta^{\text{coop}}, \tau + \tau_2)\). In the latter case, the cooperative outcome and the disagreement alternative are equivalent because the managers do not incur any additional cost to reduce the impact. Therefore, we analyze only the first two cases in more detail below. Cost sharing with \(\kappa^*(R, \tau + \tau_2) = 0\) is trivial, therefore, we restrict our attention to \(\kappa^*(R, \tau + \tau_2) > 0\).

First suppose that \(G \leq \hat{g}(R, M_\theta^{\text{coop}}, \tau)\), meaning that the managers jointly incur \(\kappa^*(R, \tau + \tau_2)\) to reduce the supplier’s impact in the cooperative game whereas only the focal buying firm incurs \(\kappa^*(R, \tau)\) to reduce the supplier’s impact in the disagreement alternative. For the focal firm and second firm to cooperate, \(\beta\) (i.e., the focal buying firm’s share of the impact reduction cost with cooperation) must satisfy \(\tau(G - R(\kappa^*(R, \tau + \tau_2))) + \beta \kappa^*(R, \tau + \tau_2) \leq \tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau)\) and \(\tau_2(G - R(\kappa^*(R, \tau + \tau_2))) + (1 - \beta) \kappa^*(R, \tau + \tau_2) \leq \tau_2(G - R(\kappa^*(R, \tau)))\), or equivalently, \(\beta \leq t_1 = \tau(R(\kappa^*(R, \tau + \tau_2)) - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau + \tau_2) - R(\kappa^*(R, \tau)))/\kappa^*(R, \tau + \tau_2)\) and \(1 - \beta \leq t_2 = \tau_2(R(\kappa^*(R, \tau + \tau_2)) - R(\kappa^*(R, \tau)))/\kappa^*(R, \tau + \tau_2)\). The existence of such an allocation rule \(\beta\) is guaranteed if \(t_1 + t_2 \geq 1\), \(t_1 \geq 0\), and \(t_2 \geq 0\). By the optimality of \(\kappa^*(R, \tau + \tau_2)\), we have \((\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2))) + \)}
\( \kappa^*(R, \tau + \tau_2) \leq (\tau + \tau_2)(G - R(\kappa^*(R, \tau_2))) + \kappa^*(R, \tau) \) leading to \( t_1 + t_2 = ((\tau + \tau_2)(R(\kappa^*(R, \tau + \tau_2)) - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau + \tau_2)) \geq 1 \). \( t_1 \geq 0 \) and \( t_2 \geq 0 \) because \( \kappa^*(R, \tau + \tau_2) \geq \kappa^*(R, \tau) \) by Lemma 3, \( R(\cdot) \) is increasing, \( \tau > \tau_2 > 0 \) and \( \kappa^*(R, \tau) \geq 0 \).

Now, we suppose that \( \hat{g}(R, M^\text{coop}_0, \tau) < G \leq \hat{g}(R, M^\text{coop}_0, \tau + \tau_2) \), meaning that the managers jointly incur \( \kappa^*(R, \tau + \tau_2) \) to reduce the supplier’s impact in the cooperative game whereas neither manager incurs additional cost to reduce the supplier’s impact in the disagreement alternative. For \( G \leq \hat{g}(R, M^\text{coop}_0, \tau + \tau_2) \), by the managers choosing to incur \( \kappa^*(R, \tau + \tau_2) \) to reduce the supplier’s impact with cooperation, it must be that

\[
(\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2))) + \kappa^*(R, \tau + \tau_2) \leq (\tau + \tau_2)M^\text{coop}_0.
\] (44)

In this case, the focal firm’s share of the impact reduction cost must satisfy \( \tau(G - R(\kappa^*(R, \tau + \tau_2))) + \beta \kappa^*(R, \tau + \tau_2) \leq \tau M^\text{coop}_0 \) and \( \tau_2(G - R(\kappa^*(R, \tau + \tau_2))) + (1 - \beta) \kappa^*(R, \tau + \tau_2) \leq \tau_2 M^\text{coop}_0 \) for the focal buying firm and the second buying firm to prefer cooperation over the disagreement alternative respectively, or equivalently, \( \beta \leq t_1 = \tau(M^\text{coop}_0 - (G - R(\kappa^*(R, \tau + \tau_2))))/\kappa^*(R, \tau + \tau_2) \) and \( 1 - \beta \leq t_2 = \tau_2(M^\text{coop}_0 - (G - R(\kappa^*(R, \tau + \tau_2))))/\kappa^*(R, \tau + \tau_2) \). The existence of such an allocation rule \( \beta \) is guaranteed if \( t_1 + t_2 \geq 1, \ t_1 \geq 0, \) and \( t_2 \geq 0 \). By (44), we have \( t_1 + t_2 = (\tau + \tau_2)(M^\text{coop}_0 - (G - R(\kappa^*(R, \tau + \tau_2))))/\kappa^*(R, \tau + \tau_2) \geq 1 \). By (44), \( \tau_2 > 0 \) and \( \kappa^*(R, \tau + \tau_2) \geq 0 \), \( M^\text{coop}_0 - (G - R(\kappa^*(R, \tau + \tau_2))) \geq 0 \) which together with \( \tau > \tau_2 > 0 \) implies that \( t_1 \geq 0 \) and \( t_2 \geq 0 \).

**Learning Cost Allocation:** We first show that the learning cost threshold is higher with cooperation than in the equilibrium of the noncooperative game, \( \bar{v}_{\text{v, coop}} \geq \bar{v}_v \). Note that \( E[\min((\tau + \tau_2)M^\text{coop}_0, \kappa^*(R, \tau + \tau_2) + (\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2))))] - E[\min(\tau M^\text{coop}_0, \kappa^*(R, \tau) + (G - R(\kappa^*(R, \tau))))] \leq \tau_2 M^\text{coop}_0 \) because \( \min((\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2))) + \kappa^*(R, \tau + \tau_2), (\tau + \tau_2)M^\text{coop}_0) = (\tau + \tau_2)M^\text{coop}_0 \) if and only if \( G > \hat{g}(R, M^\text{coop}_0, \tau + \tau_2) \), \( \min(\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau), \tau M^\text{coop}_0) = \tau M^\text{coop}_0 \) if and only if \( G > \hat{g}(R, M^\text{coop}_0, \tau) \), \( \hat{g}(R, M^\text{coop}_0, \tau + \tau_2) \geq \hat{g}(R, M^\text{coop}_0, \tau) \) by Lemma 3 and \( \tau_2 > 0 \), and \( ((\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2))) + \kappa^*(R, \tau + \tau_2)) - (\tau(G - R(\kappa^*(R, \tau))) + \kappa^*(R, \tau)) \leq \tau_2(G - R(\kappa^*(R, \tau))) \leq \tau_2 M^\text{coop}_0 \) for \( G \leq \hat{g}(R, M^\text{coop}_0, \tau) \) which is implied by the definition of \( \hat{g} \) in (31), \( \kappa^*(R, \tau) \geq 0, \tau_2 > 0, \) and \( \tau > 0 \).

Then, by (12) and (43), \( \bar{v}_{\text{v, coop}} - \bar{v}_v = \tau_2 M^\text{coop}_0 - E[\min((\tau + \tau_2)M^\text{coop}_0, \kappa^*(R, \tau + \tau_2) + (\tau + \tau_2)(G - R(\kappa^*(R, \tau + \tau_2))))] + E[\min(\tau M^\text{coop}_0, \kappa^*(R, \tau) + (G - R(\kappa^*(R, \tau))))] \geq 0 \). Hence, we consider the cost allocation in two different cases depending on the realization of the learning cost \( C \): either \( c \leq \bar{c}_v \leq \bar{v}_{\text{v, coop}} \) meaning that learning is optimal for the managers in the cooperative game and for the focal buying firm in the disagreement alternative, or \( \bar{c}_v < c \leq \bar{v}_{\text{v, coop}} \) meaning that learning is optimal for the managers in the cooperative game, but not optimal for either manager in the disagreement alternative.
In the first case \((c \leq \bar{c}_v \leq \bar{v}_{v,\text{coop}})\), all of the learning cost can be allocated to the focal buying firm with cooperation because this is identical to the learning cost allocation of the disagreement alternative. In the second case \((\bar{c}_v < c \leq \bar{v}_{v,\text{coop}})\), for the focal buying firm and the second buying firm to benefit from cooperation, we must have \[E[(\beta(G,R)\kappa^*(R,\tau + \tau_2) + \tau(G - R(\kappa^*(R,\tau + \tau_2))))1\{G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}] + E[(\tau M_\emptyset^{\text{coop}})1\{G > \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}] + \delta c \leq \tau M_\emptyset^{\text{coop}} \text{ and } E[((1 - \beta(G,R))\kappa^*(R,\tau + \tau_2) + \tau_2(G - R(\kappa^*(R,\tau + \tau_2))))1\{G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}] + E[(\tau_2 M_\emptyset^{\text{coop}})1\{G > \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}] + (1 - \delta)c \leq \tau_2 M_\emptyset^{\text{coop}}, \text{ respectively. These two inequalities are equivalent to} \]
\[
\delta \leq l_1 \text{ and } 1 - \delta \leq l_2 \text{ where } l_1 = E[(\tau(M_\emptyset^{\text{coop}} - (G - R(\kappa^*(R,\tau + \tau_2)))) - \beta(G,R)\kappa^*(R,\tau + \tau_2))1\{G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}] / c \text{ and } l_2 = E[(\tau_2(M_\emptyset^{\text{coop}} - (G - R(\kappa^*(R,\tau + \tau_2)))) - (1 - \beta(G,R))\kappa^*(R,\tau + \tau_2))1\{G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}] / c. \text{ The existence of such an allocation rule } \delta \text{ is guaranteed if } l_1 + l_2 \geq 1, l_1 \geq 0 \text{ and } l_2 \geq 0. \text{ Note that } l_1 + l_2 = ((\tau + \tau_2)M_\emptyset^{\text{coop}} - E[(\kappa^*(R,\tau + \tau_2) + (\tau + \tau_2)(G - R(\kappa^*(R,\tau + \tau_2))))1\{G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}] - E[(\tau + \tau_2)M_\emptyset^{\text{coop}}1\{G > \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)\}]]) / c = \bar{c}_v / c \geq 1 \text{ (where the second equality follows from (43) and the inequality is by the condition } \bar{c}_v < c \leq \bar{v}_{v,\text{coop}} \text{ for this case).} \]
\[
l_1 \geq 0 \text{ follows from the impact cost allocation condition } \tau(G - R(\kappa^*(R,\tau + \tau_2))) + \beta(G,R)\kappa^*(R,\tau + \tau_2) \leq \min(\tau M_\emptyset^{\text{coop}}, \tau(G - R(\kappa^*(R,\tau))) + \kappa^*(R,\tau) \leq \tau M_\emptyset^{\text{coop}} \text{ for the focal buying firm for } G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2). \text{ Similarly, } l_2 \geq 0 \text{ follows from the impact cost allocation conditions for the second buying firm that } \tau_2(G - R(\kappa^*(R,\tau + \tau_2))) + (1 - \beta(G,R))\kappa^*(R,\tau + \tau_2) \leq \tau_2 M_\emptyset^{\text{coop}} \text{ for } \hat{g}(R, M_\emptyset^{\text{coop}}, \tau) < G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2) \text{ and } \tau_2(G - R(\kappa^*(R,\tau + \tau_2))) + (1 - \beta(G,R))\kappa^*(R,\tau + \tau_2) \leq \tau_2(G - R(\kappa^*(R,\tau))) \text{ for } G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau). \text{ In the latter case, } G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau), \kappa^*(R,\tau) \geq 0, \text{ and } \tau > 0 \text{ imply that } G - R(\kappa^*(R,\tau)) \leq M_\emptyset^{\text{coop}}, \text{ which by } \tau_2 > 0 \text{ leads to } \tau_2(G - R(\kappa^*(R,\tau))) \leq \tau_2 M_\emptyset^{\text{coop}}. \text{ As a result, both buyers are at least weakly better off by cooperation compared to the disagreement alternative.} \]

In a cooperative rational expectations equilibrium, investors anticipate that both buyers benefit from cooperation and update their valuations accordingly. As such, the managers’ joint optimal learning, impact reduction, and disclosure strategy in the cooperative equilibrium \((l^{\text{coop}}, k^{\text{coop}}, d^{\text{coop}})\) can be characterized as in (10) and (11), except that \(\tau + \tau_2\) substitutes for \(\tau, M_\emptyset^{\text{coop}} \text{ substitutes for } M_\emptyset\), and \(\kappa^*(R,\tau + \tau_2) \text{ substitutes for } \kappa^*(R)\). The learning threshold \(\bar{v}_v\) and the disclosure threshold \(\hat{g}\) of the cooperative equilibrium can be characterized similarly to Lemma 1, except that \(\tau + \tau_2\) substitutes for \(\tau, M_\emptyset^{\text{coop}} \text{ substitutes for } M_\emptyset\), and \(\kappa^*(R,\tau + \tau_2) \text{ substitutes for } \kappa^*(R)\). In that equilibrium, investors’ expectation of the impact equals

\[
M_\emptyset^{\text{coop}} = E[(1 - l^{\text{coop}}(C))G + l^{\text{coop}}(C)(G - R(k^{\text{coop}}(G,R))))d^{\text{coop}}(C,G,R) = \emptyset]. \tag{45}
\]

By (10) and (11), the independence of \(C\) and \((G,R)\) and Bayes’ Rule, expression (45) becomes (14) (with \(\tau, M_\emptyset\), and \(\kappa^*(R)\) replaced with \(\tau + \tau_2, M_\emptyset^{\text{coop}}, \) and \(\kappa^*(R,\tau + \tau_2)\), respectively). All the arguments in the proofs of Propositions 1, 2, 3, and 4 hold with the substitution of the impact cost.
τ + τ₂ because the managers' objective function in the cooperative game is the same as a manager's objective in the base model, except that τ + τ₂ substitutes for τ.

**Proof of Proposition 5:** (a.) We provide a numerical example to prove that with voluntary disclosure cooperation can strictly reduce the learning cost threshold and result in higher impact. Suppose that \( G \sim U[L, L + v] \) and \( R(k) = 0 \) with probability 0.5, \( G \sim U[H, H + v] \) and \( R(k) = 1 + H \cdot \mathbb{1}\{k \geq 113.389\} \) with probability 0.45 and \( G \sim U[H, H + v] \) and \( R(k) = 1 \) with probability 0.05, where \( L = 100, H = 123.95 \), and \( v \leq 0.08 \); the learning cost \( C \) follows an Exponential distribution with \( \lambda = 0.013 \), and \( \tau = 1.008 \) and \( \tau_2 = 0.005 \). Equilibrium learning cost threshold is 6.25 with noncooperation and 6.09 with cooperation. For \( c \in (6.09, 6.25] \), the managers choose not to learn and consequently do not reduce the supplier's impact with cooperation. However, with noncooperation, the focal buying firm learns and reduces the impact by at least \( R(0) \) (which is positive with positive probability because \( E[R(0)] > 0 \)). Therefore, cooperation can result in higher impact for \( c \in (6.09, 6.25] \).

We next prove that under a disclosure mandate cooperation strictly increases the learning cost threshold and results in lower impact. By (15) and Proposition 9, the learning threshold \( \bar{c}_m \) in a noncooperative equilibrium equals \( \bar{c}_m = \tau E[G] = E[\kappa^*(R, \tau) + \tau(G - R(\kappa^*(R, \tau)))] = \tau E[R(\kappa^*(R, \tau))] - \kappa^*(R, \tau) \). Under mandatory disclosure and cooperation, the learning cost threshold \( \bar{c}_{m, coop} \) can be found from (15) replacing \( \tau \) with \( \tau + \tau_2 \) and therefore \( \bar{c}_{m, coop} = E[(\tau + \tau_2)R(\kappa^*(R, \tau + \tau_2))] - \kappa^*(R, \tau + \tau_2) \). \( \bar{c}_{m, coop} - \bar{c}_m \geq E[\tau_2 R(\kappa^*(R, \tau))] > 0 \), where the first inequality is by the optimality of \( \kappa^*(R, \tau + \tau_2) \), and the second inequality is by \( \kappa^*(R, \tau) \geq 0 \), \( E[R(0)] > 0 \), \( R(\cdot) \) being an increasing function, and \( \tau_2 > 0 \). Under a mandate, the managers’ additional cost to reduce the impact in a cooperative and noncooperative equilibrium are \( \kappa^*(R, \tau + \tau_2) \) and \( \kappa^*(R, \tau) \), respectively and \( \kappa^*(R, \tau + \tau_2) \geq \kappa^*(R, \tau) \) by Lemma 3 (due to \( \tau_2 > 0 \)). The managers are more likely to learn and incur a higher cost to reduce the impact after learning with cooperation, which implies that the impact is lower.

(b.) We refer to the buying firm’s discounted cost associated with the supplier’s impact and the cost of learning about and reducing that impact as the buying firm’s discounted impact-related cost in the remainder of the proof. We prove that with voluntary disclosure cooperation can increase the expected value of the buying firm’s discounted impact-related cost and investors’ valuation of that cost, which is equivalent to the statement of the proposition. To prove this result, we provide a numerical example. Suppose that the learning cost \( C \) follows an Exponential distribution with rate 0.001, \( \tau = 200, \tau_2 = 100, G \sim U[2, 5], R(k) = 0.25 \), which implies that \( \kappa^*(R, \tau + \tau_2) = \kappa^*(R, \tau) = \kappa^*(R, \tau_2) = 0 \) by (7). In this example, the managers do not incur additional cost for impact reduction and share only the learning costs when they cooperate. An allocation wherein the first buying firm pays for all of the learning cost for \( c \leq 107.1 \) and 67% of the learning cost
for $107.1 < c \leq 160.6$ sustains a cooperative equilibrium. With that allocation, the expected values of investors' valuations of the discounted impact-related costs for the focal and second buying firms are 702.1 and 348.4, respectively. In a noncooperative equilibrium, the expected values of investors' valuations of the discounted impact-related costs for the focal and second buying firms are 700.2 and 347.5, respectively. The expected discounted impact-related cost of a buying firm and the expected value of its investors' valuation of that cost are equal. (That was argued in the proof of Proposition 3 for a sole buying firm, extension of that argument to this setting with two firms is straightforward.) In this example, alternative allocations of the learning cost could sustain a cooperative equilibrium in which one of the buying firms has lower expected discounted impact-related cost than in the noncooperative equilibrium, but none could yield lower expected discounted impact-related cost for both firms than in the noncooperative equilibrium.

With a disclosure mandate, the disagreement alternatives of the cooperative game in the learning and impact reduction stages are equivalent to the learning and impact reduction equilibria of the noncooperative game because investors' beliefs regarding the supplier's impact observing nondisclosure in the disagreement alternative are equivalent to the beliefs in the noncooperative equilibrium (i.e., $M^\text{coop}_\emptyset = M_\emptyset = E[G]$). Moreover, in the cooperative equilibrium, both of the managers achieve at least weakly greater valuations for their respective firms than the disagreement alternative for each realization of $(C,G,R)$. This implies that both managers achieve weakly greater valuations with cooperation than with noncooperation. As argued above, the expected discounted impact-related cost of a buying firm and the expected value of its investors' valuation of that cost are equal. Therefore, with a disclosure mandate, both managers achieve lower expected discounted impact-related cost for their respective firms than in the noncooperative equilibrium.

(c.) For the parameter region given in (b.), the supplier's expected impact under a disclosure mandate with cooperation is 3.482 whereas the expected impact is 3.475 with voluntary disclosure and noncooperation.

**Preliminaries for Proposition 6 with Alternative Suppliers:**

Under voluntary disclosure, the manager's optimal objective value is

$$
\tilde{v}_\text{vol}(\gamma c) = \min \left( \tau M_\emptyset, \gamma c + E[v^*_\text{vol}(G,R,\gamma c)] \right)
$$

wherein $M_1 \equiv (G - R(k))$, $M_\emptyset$ is the investors' expectation of the chosen supplier's impact in the event of nondisclosure, and

$$
v^*_\text{vol}(G,R,\gamma c) = \min \left( \min_{k \in [0,\infty),d \in \{0,1\}} \{k + \tau M_d\}, \gamma c + E[v^*_\text{vol}(G,R,\gamma c)] \right).
$$

The manager chooses not to learn if the first term in (46), alone, achieves the minimum in the manager's objective (46). Otherwise the manager learns about at least one supplier's impact.
Contingent on the realization of the supplier’s impact $G = g$ and impact reduction potential $R = r$, the manager learns about an alternative supplier if the second term achieves the minimum in (47). Otherwise the manager sources from the current supplier, deciding how much to reduce the impact and whether to disclose the resulting impact according to the inner minimization in (47), for which the optimal solution is characterized in (10).

The proof of Lemma 4a characterizes the unique equilibrium, including the learning cost threshold $\bar{c}_\infty$ below which the manager learns about at least one supplier’s impact.

**Lemma 4.** (a.) In the unique equilibrium with voluntary disclosure, the manager learns if and only if $c \leq \bar{c}_\infty$ where $\bar{c}_\infty > 0$, and if the manager learns then the manager discloses the impact of the chosen supplier. The unique equilibrium under mandatory disclosure is identical. The threshold $\bar{c}_\infty$ is invariant with respect to the distribution of $C$.

(b.) Unique equilibrium expected value of the buying firm’s valuation strictly decreases with $\gamma$.

**Proof of Lemma 4:** (a.) We first prove that in any equilibrium, if the manager learns, then she discloses the impact of the chosen supplier. After learning, the manager discloses the chosen supplier’s impact unless

$$\kappa^*(R) + \tau(G - R(\kappa^*(R))) > \tau M_0;$$

(48)

it remains to show that a manager that learns does not stop with a supplier for which (48) holds. If the manager stops and does not disclose the impact, $k^*(G, R) = 0$ and the manager’s objective (47) is equal to $\tau M_0$. As the manager chose to learn initially, the first term in (46) must be greater than the second term

$$\tau M_0 \geq \gamma c + E[v^*_{vol}(G, R, \gamma c)],$$

(49)

which implies that $\gamma c + E[v^*_{vol}(G, R, \gamma c)]$ achieves the minimum in (47). As a result, the manager prefers to learn again, rather than choose a supplier with (48).

Now, assuming existence of an equilibrium with the manager learning at least once for some $c$ in the support of $C$, $(0, \infty)$, we characterize the manager’s unique equilibrium strategy for choosing a supplier for each such $c$. In an equilibrium with the manager with $C = c$ learning at least once, (46)-(47) imply

$$E[\min\{\kappa^*(R) + \tau(G - R(\kappa^*(R))), \gamma c + E[v^*_{vol}(G, R, \gamma c)]\}] = E[v^*_{vol}(G, R, \gamma c)].$$

(50)

If after learning the manager learns again with probability $1$, then $E[v^*_{vol}(G, R, \gamma c)] = \gamma c + E[v^*_{vol}(G, R, \gamma c)]$, contradicting our assumptions $\gamma > 0$ and $c > 0$. Therefore we can restrict attention to candidate values for $E[v^*_{vol}(G, R, \gamma c)]$ such that with strictly positive probability, $\kappa^*(R) +$
\( \tau(G - R(\kappa^*(R))) < E[v^*_vol(G, R, \gamma c)] + \gamma c \), i.e., with strictly positive probability, \((G, R)\) is such that the manager sources from a supplier with observed \((G, R)\). From (47), \(E[v^*_vol(G, R, \gamma c)]\) must be a fixed point of

\[
T(\psi) \equiv E[\min\{\kappa^*(R) + \tau(G - R(\kappa^*(R))), \gamma c + \psi\}].
\]  

(51)

For any candidate values \(\psi_1\) and \(\psi_2\) for \(E[v^*_vol(G, R, \gamma c)]\) with \(\psi_1 > \psi_2\),

\[
T(\psi_1) - T(\psi_2) = E[\min\{\kappa^*(R) + \tau(G - R(\kappa^*(R))), \gamma c + \psi_1\} - \min\{\kappa^*(R) + \tau(G - R(\kappa^*(R))), \gamma c + \psi_2\}] < \psi_1 - \psi_2,
\]

because \(\psi_2 + \gamma c > \kappa^*(R) + \tau(G - R(\kappa^*(R)))\) with strictly positive probability. Therefore \(E[v^*_vol(G, R, \gamma c)]\) is unique and, after learning a supplier’s \((G, R)\), the manager sources from the supplier (rather than learn again) if and only if \(\kappa^*(R) + \tau(G - R(\kappa^*(R))) < \gamma c + E[v^*_vol(G, R, \gamma c)]\); the inequality is strict due to the assumption that the manager breaks ties in favor of learning.

We now show that in equilibrium with voluntary disclosure, the manager learns at least once if and only if \(c \leq \tau_\infty\) where \(\tau_\infty > 0\) is the unique \(c\) that satisfies

\[
-\gamma c - E[v^*_vol(G, R, \gamma c)] + \tau E[G] = 0.
\]  

(52)

Investors have rational expectations that a manager that learns will disclose the impact of the chosen supplier so \(M_0 = E[G]\). Hence (46) and the assumption that the manager breaks ties in favor of learning imply that a manager with learning cost \(c\) learns at least once if and only if the LHS of (52) is nonnegative. The LHS of (52) is strictly negative as \(c \to \infty\) (because \(\lim_{c \to \infty} (E[v^*_vol(G, R, \gamma c)] + \gamma c) = \infty\)) and is strictly positive as \(c \to 0\) (because \(\lim_{c \to 0} E[v^*_vol(G, R, \gamma c)] = \inf\{\kappa^*(R) + \tau(G - R(\kappa^*(R)))\} < \tau E[G]\)). Therefore, to establish the claim, it remains to show that the LHS of (52) is continuous and strictly decreasing with \(c\). With slight abuse of notation, let \(T(\gamma c, \psi)\) denote the RHS of (51), which is differentiable with respect to \(c\) for \(c \in (0, \infty)\) and \(\psi \in \mathbb{R}\) because \(G\) follows a continuous distribution conditional on \(R\) and the support of \(R\) is a finite discrete set of functions. Recalling that \(T(\gamma c, E[v^*_vol(G, R, \gamma c)]) - E[v^*_vol(G, R, \gamma c)] = 0\) and applying the Implicit Function Theorem,

\[
dE[v^*_vol(G, R, \gamma c)]/dc = (\gamma Pr(G > \hat{g}(R, E[v^*_vol(G, R, \gamma c)], \gamma c)))/\Pr(G > \hat{g}(R, E[v^*_vol(G, R, \gamma c)], \gamma c)) \geq 0,
\]

where \(\hat{g}(R, \psi, \gamma c)\) is the unique solution to \(\kappa^*(R) + \tau(G - R(\kappa^*(R))) = \psi + \gamma c\). As \(\gamma > 0\), that establishes that the LHS of (52) is continuous and strictly decreasing with \(c\). We conclude that with voluntary disclosure, there exists a unique equilibrium in which a manager that learns discloses the impact of the chosen supplier. That uniqueness and full disclosure imply existence of a unique
The equilibrium under mandatory disclosure, identical to the unique equilibrium under voluntary disclosure. The full disclosure in the unique equilibrium implies that $M_1 = (G - R(k))$ in (47) so $E[v^*_{vol}(G, R, \gamma c)]$ and thus $\tau_\infty$ are invariant to the distribution of $C$.

(b.) We prove that the expected value of investors’ valuation of the buying firm’s discounted cost associated with the impact and the cost of learning about and reducing that impact strictly increases with $\gamma$, which is equivalent to the statement of Lemma 4b. With $\tau_\infty(\gamma)$ representing the unique $c$ that satisfies (52), the expected value of investors’ valuation of the firm’s discounted impact-related cost is

$$\int_{c_\infty}^{\tau_\infty(\gamma)} \left( E[v^*_{vol}(G, R, \gamma c)] + \gamma c \right) f(c) dc + \int_{\tau_\infty(\gamma)}^{\infty} (\tau E[G]) f(c) dc,$$

The expression above is strictly increasing with $\gamma$ because $E[v^*_{vol}(G, R, \gamma c)] + \gamma c$ strictly increases with $\gamma$ (implied by $E[v^*_{vol}(G, R, \gamma c)] + \gamma c$ strictly increasing with $c$, as shown in the proof of part (a)), and the partial derivative of the expression above with respect to $\tau_\infty(\gamma)$ is zero (due to (52)).

**Proof of Proposition 6:** (a.) The fact that the manager commits to a supplier if and only if $\gamma > \hat{\gamma}$ where $\hat{\gamma} > 1$ is immediate from Lemma 4b. With alternative suppliers, by Lemma 4a, the expected value of the buying firm’s valuation is the same under voluntary and mandatory disclosure. With commitment to a supplier, by Proposition 3, the expected value of the buying firm’s valuation is strictly higher under mandatory disclosure than with voluntary disclosure. Hence, a disclosure mandate strictly decreases the commitment threshold $\hat{\gamma}$.

(b.) For $\gamma > \hat{\gamma}_c$, by Proposition 6a, the manager commits to a supplier before learning under voluntary and mandatory disclosure. Therefore, Propositions 1, 2, 3, and 4 hold. For $\gamma \leq \hat{\gamma}_m$, Proposition 6a imply that the manager maintains the option to choose an alternative supplier under voluntary and mandatory disclosure. From the second sentence of Lemma 4a, learning, supplier selection and impact reduction are identical under voluntary and mandatory disclosure, so a disclosure mandate is ineffective.

Now, we show that for $\gamma \in (\hat{\gamma}_m, \hat{\gamma}_c)$, a mandate for disclosure strictly increases the probability that a manager learns, i.e., strictly increases $\tau$, the threshold such that the manager learns if and only if $c \leq \tau$. In this region, the manager commits to a supplier under a mandate, and sources from alternative suppliers under voluntary disclosure. To show that $\tau$ is strictly greater with a mandate in this region, we first show that at $\hat{\gamma}_m$ (where the manager is indifferent between commitment and sourcing from alternative suppliers), $\tau$ with supplier commitment is greater than with alternative suppliers. The threshold $\tau$ with supplier commitment ($\tau_m$) and alternative suppliers ($\tau_\infty$) satisfy (15) and (52), respectively. Therefore,

$$E[v^*_{vol}(G, R, \hat{\gamma}_m \bar{c}_\infty)] + \hat{\gamma}_m \bar{c}_\infty = E[\kappa^*(R) + \tau(G - R(\kappa^*(R)))] + \bar{c}_m.$$

(53)
Suppose that \( \bar{c}_\infty > \bar{c}_m \). By \( E[v^*_{\text{vol}}(G, R, \gamma_m c)] \) increasing with \( c \) (established in the proof of Lemma 4a) and \( \hat{\gamma}_m > 1 \), it must be that for all \( \hat{c} \leq \bar{c}_m \)

\[
(E[v^*_{\text{vol}}(G, R, \hat{\gamma}_m \hat{c})] + \hat{\gamma}_m \hat{c}) - (E[v^*_{\text{vol}}(G, R, \gamma_m \bar{c}_m)] + \hat{\gamma}_m \bar{c}_m) \leq \hat{c} - \bar{c}_m
\]

\[
= (E[\kappa^*(R) + \tau(G - R(\kappa^*(R)))] + \hat{c}) - (E[\kappa^*(R) + \tau(G - R(\kappa^*(R)))] + \bar{c}_m).
\]

By \( E[v^*_{\text{vol}}(G, R, \gamma c)] + \gamma c \) strictly increasing with \( c \) for \( \gamma > 0 \) (established in the proof of Lemma 4a) and (53), \( \gamma \) decreases with \( \hat{\gamma}_m \gamma_m \bar{c}_m \) - (\( E[\kappa^*(R) + \tau(G - R(\kappa^*(R)))] \) + \( \bar{c}_m \)) < 0, which together with (54) leads to

\[
(E[v^*_{\text{vol}}(G, R, \hat{\gamma}_m \hat{c})] + \hat{\gamma}_m \hat{c}) - (E[\kappa^*(R) + \tau(G - R(\kappa^*(R)))] + \hat{c}) < 0
\]

for all \( \hat{c} \leq \bar{c}_m \). Then, the expected value of investors’ valuation of the buying firm’s discounted net cost (associated with the impact as well as with learning about and reducing that impact) with alternative suppliers must be strictly less than with commitment because

\[
\int_{\xi}^{\tau\infty} \left( E[v^*_{\text{vol}}(G, R, \gamma c)] + \gamma c \right) f(c) dc + \int_{\tau\infty}^{\tau m} (\tau E[G]) f(c) dc < \int_{\xi}^{\tau m} \left( E[v^*_{\text{vol}}(G, R, \gamma c)] + \gamma c \right) f(c) dc + \int_{\tau m}^{\tau\infty} \left( \tau E[G] \right) f(c) dc,
\]

where the first inequality is due to \( \int_{\xi}^{\hat{c}} \left( E[v^*_{\text{vol}}(G, R, \gamma c)] + \gamma c \right) f(c) dc + \int_{\hat{c}}^{\tau\infty} (\tau E[G]) f(c) dc \) strictly decreasing with \( \hat{c} \) for \( \hat{c} \leq \tau\infty \) (by (52)), and the second inequality is due to (55). (56) contradicts that the manager is indifferent between commitment and sourcing from alternative suppliers at \( \hat{\gamma}_m \) and therefore \( \tau\infty \leq \bar{c}_m \) at \( \hat{\gamma}_m \). This implies that \( \tau\infty < \bar{c}_m \) for \( \gamma \in (\hat{\gamma}_m, \bar{\gamma}_m) \) because \( \tau\infty \) is strictly decreasing with \( \gamma \) (which we observe by applying Implicit Function Theorem to (52) and noting that the LHS of (52) is strictly decreasing with \( \gamma \) and \( c \), and \( \bar{c}_m \) is invariant to \( \gamma \).

**Proofs of the Analytical Results in Section 5.3**

We first prove that all propositions in this paper hold for the extension with the manager’s generalized objective/information for investors. Then, we provide the proofs for Propositions 7 and 8.

**Preliminaries:** In the remainder of the proofs, we denote the weight assigned to investors’ valuation in (17) with \( \alpha \), i.e.,

\[
\alpha = 1 - \theta.
\]

Under voluntary disclosure, if the manager chooses not to disclose the impact after learning \((G, R)\), the manager’s optimal additional cost to reduce the supplier’s impact, the optimal \( k \) with \( d = 0 \) in (17) is:

\[
\kappa^*(\alpha, R) = \arg \min_{k \in [0, \infty)} \left( \alpha \tau M_\theta + (1 - \alpha) \tau(G - R(k)) + k \right).
\]
If the manager discloses the impact after learning, \( d = 1 \) in (17) then the optimal cost to reduce the supplier’s impact is equal to \( \kappa^*(0, R) \). The manager discloses the impact if and only if doing so maximizes the weighted sum of the firm’s expected discounted profit and valuation (17) (by assumption the manager breaks ties in favor of disclosure). Hence the manager’s optimal disclosure decision and additional cost to reduce the supplier’s impact are:

\[
(d^*, k^*(G, R)) = \begin{cases} (1, \kappa^*(0, R)), & \text{if } \tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R) \geq \alpha \tau M_\emptyset + (1 - \alpha) \tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R) \\ (\emptyset, \kappa^*(\alpha, R)), & \text{otherwise.} \end{cases}
\]

\[
(59)
\]

The weighted sum of the firm’s expected discounted cost (associated with the supplier’s impact as well as reducing that impact) and investors’ expectation of that discounted cost after learning and without learning are given by (60) and (61), respectively:

\[
w_{vol}^*(G, R) = \min \left( \tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R), \alpha \tau M_\emptyset + (1 - \alpha) \tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R) \right),
\]

\[
\alpha \tau M_\emptyset + (1 - \alpha) \tau E[G].
\]

\[
(60)
\]

\[
(61)
\]

The manager chooses to learn if and only if \( \alpha \tau M_\emptyset + (1 - \alpha) \tau E[G] \) is greater than \( C + E[w_{vol}^*(G, R)] \), i.e.,

\[
l^*(C) = \begin{cases} 1 & \text{if } \alpha \tau M_\emptyset + (1 - \alpha) \tau E[G] \geq C + E[w_{vol}^*(G, R)] \\ 0 & \text{otherwise.} \end{cases}
\]

\[
(62)
\]

**Lemma 5.** (a.) In an equilibrium, the manager learns if and only if \( C \leq \bar{\tau}_v \). After learning, the manager chooses to reduce the supplier’s impact according to \( \kappa^*(0, R) \) and disclose it if and only if \( G \leq \hat{g}(R, \alpha, M_\emptyset) \); otherwise, the manager does not disclose and chooses to reduce the supplier’s impact according to \( \kappa^*(\alpha, R) \). Together, \( \bar{\tau}_v, \hat{g}(R, \alpha, M_\emptyset) \) and \( M_\emptyset \) satisfy:

\[
\bar{\tau}_v = \alpha \tau M_\emptyset + (1 - \alpha) \tau E[G] - E[w_{vol}^*(G, R)]
\]

\[
(63)
\]

\[
\hat{g} = M_\emptyset + \left( \tau R(\kappa^*(0, R)) - \kappa^*(0, R) - (1 - \alpha) \tau R(\kappa^*(\alpha, R)) + \kappa^*(\alpha, R) \right) / (\tau \alpha)
\]

\[
(64)
\]

\[
M_\emptyset = \frac{F(\bar{\tau}_v) E[(G - R(\kappa^*(\alpha, R))) \mid G > \hat{g}(R, \alpha, M_\emptyset)] + (1 - F(\bar{\tau}_v)) E[G]}{F(\bar{\tau}_v) Pr(G > \hat{g}(R, \alpha, M_\emptyset)) + (1 - F(\bar{\tau}_v))},
\]

\[
(65)
\]

with \( w_{vol}^*(G, R) \) as defined in (60).

(b.) An equilibrium exists.

(c.) In any equilibrium, investors’ expectation of the impact in the event of nondisclosure \( M_\emptyset \) is strictly greater than the expected impact prior to learning \( E[G] \), i.e., \( M_\emptyset > E[G] \).

(d.) If the equilibrium is unique, decreasing the learning cost \( C \) (in first order stochastic dominance) and increasing the weight assigned to the valuation \( \alpha \) strictly increases the learning cost threshold \( \bar{\tau}_v \).
Proof of Lemma 5: (a.) After learning, the necessary and sufficient condition for the manager to disclose the impact (the inequality in the top line of (59)) is equivalent to \( G \leq \hat{g}(R, \alpha, M_\emptyset) \), where \( \hat{g}(R, \alpha, M_\emptyset) \) is defined as in (64). We also observe that

\[
\hat{g}(R, \alpha, M_\emptyset) - R(\kappa^*(\alpha, R)) = M_\emptyset + (\tau R(\kappa^*(0, R)) - \kappa^*(0, R)) - (\tau R(\kappa^*(\alpha, R)) - \kappa^*(\alpha, R)))/(\tau \alpha) \geq M_\emptyset,
\]

where the equality is by (64), and the inequality is due to the optimality of \( \kappa^*(0, R) \), \( \tau > 0 \) and \( \alpha > 0 \).

Learning minimizes the manager’s objective (i.e., the second part of (17) is less than the first part and consequently \( l^*(c) = 1 \) if and only if \( c \leq \overline{c}_v \) with the \( \overline{c}_v \) defined in (63). Therein, using the weighted sum of the firm’s expected discounted cost (associated with the supplier’s impact as well as reducing that impact) and investors’ expectation of that discounted cost \( w^*_vol(G, R) \) expressed in (60),

\[
E[w^*_vol(G, R)] = E[(\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R))1\{G \leq \hat{g}(R, \alpha, M_\emptyset)\} + (\alpha \tau M_\emptyset + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R))1\{G > \hat{g}(R, \alpha, M_\emptyset)\}].
\]

Investors’ expectation of the impact (1) then equals

\[
M_\emptyset = E[(1 - l^*(C))G + l^*(C)(G - R(k^*(G, R)))|d = \emptyset]
\]

\[
= (Pr\{l^*(C) = 0\}E[G] + Pr\{l^*(C) = 1\}E[G - R(k^*(G, R))|d = \emptyset, l^*(C) = 1])/(Pr\{l^*(C) = 0\} + Pr\{d = \emptyset, l^*(C) = 1\})
\]

where the second equality follows from the independence of \( C \) and \( (G, R) \) and Bayes’ Rule. By (59) and given that the manager chooses to learn if and only if \( c \leq \overline{c}_v \), expression (67) becomes (65).

(b.) We characterize an equilibrium under voluntary disclosure by characterizing a solution to the equilibrium conditions (63)-(64). We first solve for an equilibrium \( M_\emptyset \) by using (63) to express \( \overline{c}_v \) in terms of \( M_\emptyset \), and substituting that expression into (65). With an abuse of notation, we use \( \overline{c}_v(M_\emptyset, \alpha) \) to denote the \( \overline{c}_v \) that corresponds to a given \( M_\emptyset \) and \( \alpha \) in (63), so (65) can be written as

\[
P = F(\overline{c}_v(M_\emptyset, \alpha))E[(G - R(\kappa^*(\alpha, R)) - M_\emptyset)1\{G > \hat{g}(R, \alpha, M_\emptyset)\}] + (1 - F(\overline{c}_v(M_\emptyset, \alpha)))E[G] - M_\emptyset) = 0.
\]

An equilibrium \( M_\emptyset \) is a solution to (68). We will show that \( P > 0 \) at \( M_\emptyset = E[G] \), \( P < 0 \) at \( g = \overline{g} > E[G] \) and that \( P \) is continuous so by the Intermediate Value Theorem, a solution to (68) exists in \((E[G], \overline{g})\) at which \( P \) is decreasing with respect to \( M_\emptyset \). First, we evaluate \( P \) at \( M_\emptyset = E[G] \).

\[
c_v(E[G], \alpha) \geq -E[\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)] + \tau E[G] \geq \tau E[R(0)] > 0 \text{ where the first inequality is by (60) and (63), the second inequality is by the optimality of } \kappa^*(0, R), \text{ and the last inequality is by } \tau > 0 \text{ and } E[R(0)] > 0. \text{ Therefore, } \]

\[
F(c_v(E[G], \alpha)) > 0 \text{ (because } C \text{ has support on } (0, \infty)).
\]
The first term on the RHS of (68) is positive at \( M_\theta = E[G] \) because (75) and (58) imply that with positive probability \( G - R(\kappa^*(\alpha, R)) > E[G] \). The second term is zero, leading to \( P > 0 \). Now we evaluate \( P \) at \( M_\theta = \bar{g} \). \( \hat{g}(R, \alpha, \bar{g}) \geq \bar{g} \) by (66) and \( R \geq 0 \). \( \bar{c}_v(\bar{g}, \alpha) = -E[\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)] + \alpha \tau \bar{g} + (1 - \alpha) \tau E[G] \geq \tau E[R(0)] + \alpha \tau (\bar{g} - E[G]) > 0 \) where the equality is by (60), (63) and \( \hat{g}(R, \alpha, \bar{g}) \geq \bar{g} \), the first inequality is by the optimality of \( \kappa^*(0, R) \), and the last inequality is by \( \tau > 0 \) and \( E[R(0)] > 0 \). \( 0 < F(\bar{c}_v(\bar{g}, \alpha)) < 1 \) because \( \bar{c}_v(\bar{g}, \alpha) \) is positive and finite. At \( M_\theta = \bar{g} \), \( Pr(G > \hat{g}(R, \alpha, \bar{g})) = 0 \) and the second term on the RHS of (68) is negative, implying

\[
P|_{M_\theta = \bar{g}} < 0. \tag{69}
\]

Finally, we show that \( P \) is continuous in the region \( M_\theta \in [E[G], \bar{g}] \) by showing that \( \bar{c}_v(M_\theta, \alpha) \) and \( E[\{G - R(\kappa^*(\alpha, R)) - M_\theta\}1\{G > \hat{g}(R, \alpha, M_\theta)\}] \) are continuous. \( \bar{c}_v(M_\theta, \alpha) \) and and \( E[\{G - R(\kappa^*(\alpha, R)) - M_\theta\}1\{G > \hat{g}(R, \alpha, M_\theta)\}] \) are continuous in the region \( M_\theta \in [E[G], \bar{g}] \) because \( \hat{g}(R, \alpha, M_\theta) \) is continuous in \( M_\theta \), \( G \) follows a continuous distribution conditional on \( R \), and the support of \( R \) is a finite set of functions.

(c.) Consider the investors’ expectation of the impact in the event of nondisclosure given by (67). Suppose \( Pr\{l^*(C) = 1\} > 0 \) and \( M_\theta \leq E[G] \). In the event that the manager learns and \( \tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R) \leq \alpha \tau M_\theta + (1 - \alpha) \tau (G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R) \), then according to (59) the manager discloses the impact. In the event that the manager learns and \( \tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R) > \alpha \tau M_\theta + (1 - \alpha) \tau (G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R) \) (which occurs with strictly positive probability by (75)), the manager does not disclose, according to (59). For such \( (G, R) \), (75) and (58) imply that \( G - R(\kappa^*(\alpha, R)) > M_\theta \). Therefore \( E[G - R(\kappa^*(\alpha, R))]|d = \emptyset > M_\theta \), and with \( Pr\{l^*(C) = 1\} > 0 \), the RHS of (67) is strictly greater than \( M_\theta \), a contradiction. It remains to show that in any equilibrium under voluntary disclosure, the manager learns with strictly positive probability: \( Pr\{l^*(C) = 1\} > 0 \). Suppose \( Pr\{l^*(C) = 1\} = 0 \), leading to \( M_\theta = E[G] \) according to (67). The manager’s objective without learning is \( \tau E[G] \) (by (61)). The expected value of the manager’s objective after learning satisfies \( E[w_{\kappa^*(C)}(G, R)] \leq E[\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)] \leq \tau E[G - R(0)] < \tau E[G] \), where the first two inequalities are due to (60) and the optimality of \( \kappa^*(0, R) \), respectively, and the last inequality is due to \( \tau > 0 \) and \( E[R(0)] > 0 \). Therefore, a manager with \( c \leq \tau E[R(0)] \) would choose to learn and \( Pr\{l^*(C) = 1\} > Pr\{c \leq \tau E[R(0)]\} > 0 \), contradicting \( Pr\{l^*(C) = 1\} = 0 \).

(d.) To show that the learning threshold strictly increases with \( \alpha \), we first establish that \( M_\theta \) is strictly increasing with \( \alpha \) using (68). Suppose that \( M_{\theta_1} \) satisfies (68) when \( \alpha = \alpha_1 \). We show that \( P \) in (68) evaluates to a positive value at \( \alpha = \alpha_2 > \alpha_1 \) and \( M_\theta = M_{\theta_1} \), by showing that \( \hat{g}(R, \alpha, M_\theta) \) and \( \kappa^*(\alpha, R) \) are decreasing with \( \alpha \), and \( \bar{c}_v(M_{\theta_1}, \alpha_2) > \bar{c}_v(M_{\theta_1}, \alpha_1) \) for any \( \alpha_2 > \alpha_1 \) and \( M_{\theta_1} > E[G] \). \( \kappa^*(\alpha, R) \) decreasing with \( \alpha \) is immediate from (58), the fact that \( (1 - \alpha) \tau R(k) - k \) has increasing differences with respect to \( (k, -\alpha) \) and Topkis Theorem. By (64) and the optimality of \( \kappa^*(0, R) \),
\[ \frac{\partial \hat{g}(R, \alpha, M_\theta)}{\partial \alpha} = ((\tau R(\kappa^*(\alpha, R)) - \kappa^*(\alpha, R)) - (\tau R(\kappa^*(0, R)) - \kappa^*(0, R)))/(\tau \alpha^2) \leq 0. \]

To show \( \tau_v(M_\theta, \alpha_2) > \tau_v(M_\theta, \alpha_1) \) for any \( \alpha_2 > \alpha_1 \) and \( M_\theta > E[G] \), by (63) we first prove \( E[w^\ast_{\text{vol}}(G, R)]_{|\alpha = \alpha_2} < E[w^\ast_{\text{vol}}(G, R)]_{|\alpha = \alpha_1} \leq E[(\tau(G - R(\kappa^*(0, R)))) + \kappa^*(0, R))] \leq \kappa(R, \alpha_1, M_\theta) \) + \((\alpha_2 \tau M_\theta + (1 - \alpha_2)\tau(G - R(\kappa^*(\alpha_2, R)))) + \kappa^*(\alpha_2, R)]) \leq \kappa(R, \alpha_1, M_\theta) \) for any \( \alpha_2 > \alpha_1 \) and \( M_\theta > E[G] \) and \( P \) in (68) evaluates to a positive value at \( \alpha = \alpha_2 > \alpha_1 \) and \( M_\theta = M_{\theta_1} \). This observation, together with (69) and Intermediate Value Theorem, establishes the existence of a solution to (68) satisfying \( M_{\theta_2} > M_{\theta_1} \).

As a final step, we show that \( \tau_v(M_{\theta_2}, \alpha_2) > \tau_v(M_{\theta_1}, \alpha_1) \). We have already established that \( \tau_v(M_{\theta_2}, \alpha_2) > \tau_v(M_{\theta_1}, \alpha_1) \) for \( \alpha_2 > \alpha_1 \) and \( M_\theta > E[G] \), therefore, it suffices to show that \( \tau_v(M_{\theta_2}, \alpha) > \tau_v(M_{\theta_1}, \alpha) \) for \( M_{\theta_2} > M_{\theta_1} > E[G] \) and any \( \alpha \). Note that \( E[w^\ast_{\text{vol}}(G, R)]_{|M_\theta = M_{\theta_2}} - E[w^\ast_{\text{vol}}(G, R)]_{|M_\theta = M_{\theta_1}} \leq \alpha \tau(M_{\theta_2} - M_{\theta_1})Pr(G > \hat{g}(R, \alpha, M_{\theta_2})) \). Therefore, by (63), \( \tau_v(M_{\theta_2}, \alpha) - \tau_v(M_{\theta_1}, \alpha) \leq \alpha \tau(M_{\theta_2} - M_{\theta_1})(1 - Pr(G > \hat{g}(R, \alpha, M_{\theta_2}))) > 0 \), where, together with \( \alpha > 0 \), \( \tau > 0 \) and \( M_{\theta_1} > M_{\theta_2} \), the last inequality follows from \( Pr(G > \hat{g}(R, \alpha, M_{\theta_2})) \leq Pr(G > \hat{g}(R, \alpha, E[G])) \leq Pr(G > E[G]) < 1 \) because \( \hat{g}(R, \alpha, M_\theta) \geq M_\theta \) (by (66)) and \( \hat{g}(R, \alpha, M_\theta) \) is strictly increasing with \( M_\theta \).

Now, we show that the learning cost threshold is increasing with a first order stochastic dominance decrease in the distribution of the learning cost \( C \). Suppose \( F_\delta(\cdot) \) is a learning cost distribution dominated by \( F(\cdot) \) in the first order and that \( M_\theta \) satisfies (68) when the learning cost follows \( F(\cdot) \). If \( F_\delta(\tau_v(M_\delta, \alpha)) = F(\tau_v(M_\delta, \alpha)) \), \( P \) in (68) evaluated at the learning cost distribution \( F(\cdot) \) and \( M_\delta \) is zero. Otherwise, \( F_\delta(\tau_v(M_\delta, \alpha)) > F(\tau_v(M_\delta, \alpha)) \) and \( P \) evaluates to a positive value at \( M_\delta \), which, by (69) and Intermediate Value Theorem, establishes the existence of a solution that satisfies \( M_\Theta > M_\delta \). The result then follows from \( \tau_v(M_\delta, \alpha) \) strictly increasing with \( M_\delta \) when \( M_\delta > E[G] \), which we established above.

**Lemma 6.** A unique equilibrium exists. The manager learns if and only if \( C \leq \tau_m \) with

\[ \tau_m \equiv \tau E[R(\kappa^*(0, R))] - E[\kappa^*(0, R)], \]

and, after learning, incurs cost \( \kappa^*(0, R) \) in (58) to reduce the supplier’s impact.

**Proof of Lemma 6:** Under a disclosure mandate, the manager’s objective without learning (first term in (17)) is \( \tau E[G] \) and the manager’s objective with learning (second term in (17)) is \( E[\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)] + c \). In equilibrium, therefore, the manager learns if and only if \( c \leq \tau_m \), with \( \tau_m \) as defined in (70). (By assumption, the manager breaks ties in favor of learning.) If the
manager learns, she discloses the impact, and if the manager does not learn, she does not disclose the impact, so investors know that the manager did not learn. Therefore the firm’s valuation equals the expected discounted cost of the buying firm, and the equilibrium is unique.

Proof of Proposition 1: That $\tau_v > \tau_m$ follows from (63), (70), Lemma 5c and the fact that the manager’s objective after learning (and ignoring the learning cost) is higher under mandatory than voluntary disclosure, $\min(\kappa^*(\alpha, R) + \alpha \tau M_0 + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R))), \kappa^*(0, R) + \tau(G - R(\kappa^*(0, R)))) \leq \kappa^*(0, R) + \tau(G - R(\kappa^*(0, R)))$, because under voluntary disclosure the manager has the flexibility to choose not to disclose the impact.

The manager’s optimal cost to reduce the supplier’s impact equals either $\kappa^*(0, R)$ or $\kappa^*(\alpha, R)$ under voluntary disclosure (by Lemma 5a), and equals $\kappa^*(0, R)$ under a mandate by Lemma 6. A disclosure mandate increases $R(k^*(G, R))$ because $\kappa^*(0, R) \geq \kappa^*(\alpha, R)$ (by (58), the fact that $(1 - \alpha)\tau R(k) - k$ has increasing differences with respect to $(k, -\alpha)$ and Topkis Theorem).

Proof of Proposition 2: The proof follows similarly to the scenario where the manager maximizes the valuation because Lemma 5a and Lemma 6 imply that in equilibrium under voluntary disclosure, the manager learns and reduces the supplier’s impact by $R(0)$ for $c \leq \tau_v$, whereas the manager does so in equilibrium under mandatory disclosure for $c \leq \tau_m$ where $\tau_m < \tau_v$. By assumption, the learning cost $C$ has a continuous distribution and is independent of $R(0)$, so under the conditions $k^*(G, R) = 0$ and $E[R(0)] > 0$, a disclosure mandate increases the supplier’s expected impact by $(F(\tau_v) - F(\tau_m))E[R(0)] > 0$.

Proof of Proposition 3: As in the proof under the scenario where the manager maximizes the valuation, we prove that a mandate strictly decreases the expected value of the buying firm’s discounted impact-related cost (which includes the expected impact penalty and the cost of learning about and reducing the impact) and investors’ valuation of that cost. We provide the proof under voluntary disclosure only, because the proof under mandatory disclosure is similar.

In equilibrium under voluntary disclosure, the expected value of investors’ valuation of the buying firm’s discounted impact-related cost is:

$$
\int_0^{\tau_v} \left[ c + E[(\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R))]1\{G \leq \hat{g}(R, \alpha, M_\theta)\} + E[(\tau M_\theta + \kappa^*(\alpha, R))]1\{G > \hat{g}(R, \alpha, M_\theta)\}] f(c)dc + \int_{\tau_v}^\infty \tau M_\theta f(c)dc,
$$

with $\tau_v$, $M_\theta$, and $\hat{g}(R, \alpha, M_\theta)$ as characterized in Lemma 5a. Observe that (71) is equal to

$$
\int_0^{\tau_v} \left[ c + E[(\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R))]1\{G \leq \hat{g}(R, \alpha, M_\theta)\} + E[(\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R))]1\{G > \hat{g}(R, \alpha, M_\theta)\}] f(c)dc + \tau E[G(1 - F(\tau_v)) + \tau M_\theta (\hat{g}(R, \alpha, M_\theta)) + (1 - F(\tau_v)) \hat{g}(R, \alpha, M_\theta)) - E[G(1 - F(\tau_v))],
$$
wherein the quantity in the first two lines is the expected discounted cost of the buying firm, and the quantity in the last line is equal to zero due to the value of $M_\theta$ in (65) in Lemma 5a.

It remains to show that a mandate for disclosure strictly reduces the buying firm’s expected discounted impact-related cost in equilibrium. The firm’s expected discounted impact-related cost under a disclosure-mandate is

$$t_{\text{man}} = \int_0^{\tau_m} \left[ c + E[\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)] \right] f(c) dc + \tau E[G](1 - F(\tau_m)),$$

with $\tau_m$ as characterized in Lemma 6. The firm’s expected discounted impact-related cost with voluntary disclosure $t_{\text{vol}}$ can be defined similarly to $t_{\text{man}}$, by replacing $\tau_m$ with $\tau_v$ (which is characterized in Lemma 5) in the expression above. We will show that $t_{\text{man}} \geq \omega(\tau_m) > t_{\text{vol}}$, with $\omega$ defined as

$$\omega(\hat{c}) = \int_0^{\hat{c}} \left[ c + E[\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)]1\{G \leq \hat{g}(R, \alpha, M_\theta)\} \right] f(c) dc + \tau E[G](1 - F(\hat{c})).$$

From the optimality of $\kappa^*(0, R)$, $\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R) \geq \tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)$, and as a result, $t_{\text{man}} \leq \omega(\tau_m)$. The second inequality, $\omega(\tau_m) < t_{\text{vol}}$, holds if $\omega$ is increasing with $\hat{c}$ for all $\tau_m \leq \hat{c} \leq \tau_v$ (and strictly increasing for some $\hat{c}$ values in this region), because $t_{\text{vol}} = \omega(\tau_v)$.

$$\frac{d\omega}{d\hat{c}} = f(\hat{c}) \left( \hat{c} + E[\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R)]1\{G \leq \hat{g}(R, \alpha, M_\theta)\} \right) + E[\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R)1\{G > \hat{g}(R, \alpha, M_\theta)\}] + \tau E[G](1 - F(\hat{c})). \quad (72)$$

By the expression of $\tau_m$ in (70), $\frac{d\omega}{d\hat{c}} \geq 0$ for $\hat{c} = \tau_m$ and $\frac{d\omega}{d\hat{c}} > 0$ for $\hat{c} > \tau_m$. By Proposition 1, $\tau_v > \tau_m$, which establishes $\omega(\tau_m) < t_{\text{vol}}$.

**Proof of Proposition 4:** (a.) We refer to the impact reduction cost that satisfies (58) as $\kappa^*(\alpha, R, \tau)$ without loss of generality, by (58), the fact that $-k + \tau(1 - \alpha)R(k)$ has increasing differences in $(k, -\alpha)$ and Topkis Theorem, $\kappa^*(\alpha, R, \tau)$ is decreasing with $\alpha$; i.e.,

$$\kappa^*(\alpha, R, \tau) \leq \kappa^*(0, R, \tau). \quad (73)$$

Furthermore, $\kappa^*(0, R, \tau)$ is increasing with $\tau$ by (58), the fact that $(-k + \tau R(k))$ has increasing differences in $(k, \tau)$ and Topkis Theorem. $\kappa^*(0, R, \tau) = 0$ at $\tau = 0$ because the manager’s objective in (58) at $\tau = 0$ is strictly decreasing with $k$. Therefore, there exists a $\tau$ defined as

$$\tau \equiv \sup\{\tau : \kappa^*(0, R, \tau) = 0 \text{ with probability 1}, \tau \in [0, \infty)\}, \quad (74)$$

such that $\kappa^*(0, R, \tau) = 0$ for $\tau \leq \tau$, which by (73) and Lemmas 5 and 6 implies that the buyer’s optimal cost to incur to reduce the supplier’s impact is $0$ under both voluntary and mandatory
disclosure for $\tau \leq \bar{\tau}$. By Proposition 2, a disclosure mandate thus results in strictly greater expected impact for $\tau \leq \bar{\tau}$. For a disclosure mandate to strictly reduce the supplier’s expected impact, it must be that $\tau > \bar{\tau}$.

(b.) We first show that with voluntary disclosure the manager withholds information from investors with positive probability if and only if

$$\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R) > \alpha\tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R),$$

(75)

where $\alpha = 1 - \theta$ as defined in (57). If (75) holds, we can show by contradiction that full disclosure cannot be observed in equilibrium. Suppose there exists an equilibrium with full disclosure. By observing nondisclosure, investors expect that the manager did not learn and that the supplier’s expected impact is $E[G]$. Hence, the valuation is reduced by $\tau E[G]$ after observing nondisclosure. However, for $(G, R)$ that satisfy $\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R) > \alpha\tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R)$ (which occurs with positive probability by (75)) the manager is strictly better off by not disclosing the impact, contradicting the existence of a full disclosure equilibrium.

Now we show that if the manager withholds information with positive probability, (75) holds. Note that in a rational expectations equilibrium, investors’ expectation of the impact (1) equals

$$M = E[(1 - l^*(C))G + l^*(C)(G - R(k^*(G, R)))|d = \emptyset]$$

$$= (Pr\{l^*(C) = 0\}E[G] + Pr\{l^*(C) = 1\}E[G - R(k^*(\alpha, R))|d = \emptyset, l^*(C) = 1]/(Pr\{l^*(C) = 0\} + Pr\{d = \emptyset, l^*(C) = 1\})$$

(76)

where the second equality follows from the independence of $C$ and $(G, R)$, Bayes’ Rule and $k^*(G, R) = \kappa^*(\alpha, R)$ by (59).

Suppose that the manager withholds information with positive probability but (75) does not hold; i.e., $\tau(G - R(\kappa^*(0, R))) + \kappa^*(0, R) \leq \alpha\tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R)$ with probability 1. Then, $M$ must be strictly less than $E[G]$ because otherwise disclosing would weakly dominate not disclosing for all $(G, R)$. $M < E[G]$ implies that $Pr\{l^*(C) = 1\} > 0$ (because $Pr\{l^*(C) = 1\} = 0$ would lead to $M = E[G]$ by (76)). Consequently,

$$E[G - R(\kappa^*(\alpha, R))|d = \emptyset, l^*(C) = 1] < E[G] < M.$$

(77)

Let $(\tilde{g}, \tilde{r})$ belong to the set of $(G, R)$ for which not disclosing is optimal and which satisfy

$$\tilde{g} - \tilde{r}(\kappa^*(\alpha, \tilde{r})) = \inf\{G - R(\kappa^*(\alpha, R)) : \kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))) > \alpha\tau M + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R)\}. By the definition of $(\tilde{g}, \tilde{r})$ and (77), \tilde{g} - \tilde{r}(\kappa^*(\alpha, \tilde{r})) < M. Then,

$$\tau(\tilde{g} - \tilde{r}(\kappa^*(0, \tilde{r}))) + \kappa^*(0, \tilde{r}) \leq \tau(\tilde{g} - \tilde{r}(\kappa^*(\alpha, \tilde{r}))) + \kappa^*(\alpha, \tilde{r}) < \alpha\tau M + (1 - \alpha)\tau(\tilde{g} - \tilde{r}(\kappa^*(\alpha, \tilde{r}))) + \kappa^*(\alpha, \tilde{r}),$$

(78)
where the second inequality is due to $\tilde{g} - \tilde{r}(\kappa^*(\alpha, \tilde{r})) < M_0$ and $\tau > 0$, and the first inequality is by the optimality of $\kappa^*(0, \tilde{r})$. The inequality above contradicts the assertion that the manager would not reduce and disclose the impact for $G = \tilde{g}$ and $R = \tilde{r}$.

We now show that (75) does not hold if and only if $\tau \geq \overline{\tau}$. For this part, we refer to the impact reduction cost that satisfies (58) for a given $\tau$ as $\kappa^*(\alpha, R, \tau)$ without loss of generality. Moreover, let $\overline{\tau}$ satisfy

$$\overline{\tau} = \max\{\tau > 0 : \tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau) \quad \text{with probability 1}\}.$$  

(79)

Here, the max is taken over the finite support of $R$ and inf is taken over all possible $\tau$ for a given realization of $R$. We prove the result for $\overline{\tau} = 0$ and $\overline{\tau} > 0$ separately. First, suppose $\overline{\tau} > 0$. If $\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ with probability 1, then $\tau \geq \overline{\tau}$ by the definition of $\overline{\tau}$ in (79). Now, we show that if $\tau \geq \overline{\tau}$, then $\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ with probability 1. For this purpose, we show that the inequality below holds for any $\tau \geq \overline{\tau}$:

$$G \leq E[G] + \frac{\tau R(\kappa^*(0, R, \tau)) - \kappa^*(0, R, \tau) - (1 - \alpha)\tau R(\kappa^*(\alpha, R, \tau)) + \kappa^*(\alpha, R, \tau)}{\tau \alpha}.$$  

(80)

This inequality is satisfied for $\tau = \overline{\tau}$ by definition (79). It is also straightforward to verify that the inequality above will be satisfied for any $\tau \geq \overline{\tau}$ because the RHS is increasing with $\tau$ (which can be verified by differentiation and noting that $\kappa^*(0, R, \tau) \geq \kappa^*(\alpha, R, \tau)$ for any value of $\tau$, $\tau \geq \overline{\tau} > 0$, and $\alpha > 0$.

Now we prove that $\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ with probability 1 for all $\tau > 0$ if and only if $\overline{\tau} = 0$. If $\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ with probability 1 for all $\tau > 0$, then by the definition of $\overline{\tau}$ in (28) $\overline{\tau} = 0$. If $\overline{\tau} = 0$, then there exists $\tau = \epsilon > 0$ (i.e., arbitrarily close to 0 and positive) such that $\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ with probability 1, which is equivalent to (80). Then, for any $\tau_1 > \tau$ substituting for $\tau$, (80) continues to hold because the RHS of (80) increasing with $\tau$ (which can be verified by differentiation and noting that $\kappa^*(0, R, \tau) \geq \kappa^*(\alpha, R, \tau)$ for any value of $\tau$, $\tau > 0$, and $\alpha > 0$).

Since (80) holds for any $\tau = \epsilon > 0$, in the limit as $\epsilon \to 0$, $\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ with probability 1 for all $\tau > 0$.

As $\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \alpha \tau E[G] + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ with probability 1 if and only if $\tau \geq \overline{\tau}$, (75) does not hold if and only if $\tau \geq \overline{\tau}$.

(c.) The manager’s objective under the mandate becomes equivalent to maximizing the buying firm’s expected discounted profit by Proposition 7, regardless of our assumption about whether the
manager is maximizing the buying firm’s valuation or a weighted sum of the buying firm’s expected discounted profit and valuation. Therefore, the proof follows from the proof of Proposition 4c under the scenario where the manager maximizes the buying firm’s valuation.

**Preliminaries for Propositions 5, 9, and 10:** Let \( \kappa^*(\alpha, R, \tau_B) \) as the optimal cost to reduce the supplier’s impact when the manager of a buying firm with per unit impact penalty \( \tau_B \) chooses not to disclose the supplier’s impact. \( \kappa^*(\alpha, R, \tau_B) \) is given by (58), with \( \tau \) replaced by the expected discounted cost per unit impact of the corresponding buying firm (i.e., \( \tau_B \) equals \( \tau \) and \( \tau_2 \) for the first and second buying firms respectively). With an abuse of notation, we define the disclosure threshold \( \hat{g}(R, \alpha, M_\theta, \tau_B) \) as follows: given the investors’ beliefs regarding the supplier’s expected impact observing nondisclosure \( M_\theta \), in the event that only the manager of a buying firm with expected discounted per unit impact cost \( \tau_B \) learns, the manager chooses to reduce the supplier’s impact according to \( \kappa^*(0, R, \tau_B) \) and disclose it if and only if \( G \leq \hat{g}(R, \alpha, M_\theta, \tau_B) \), which satisfies

\[
\hat{g}(R, \alpha, M_\theta, \tau_B) = M_\theta + \left( \tau_B R(\kappa^*(0, R, \tau_B)) - \kappa^*(0, R, \tau_B) - (1 - \alpha)\tau_B R(\kappa^*(\alpha, R, \tau_B)) + \kappa^*(\alpha, R, \tau_B) \right) / (\tau_B \alpha),
\]

(81)

similar to (64). Otherwise, the manager does not disclose and chooses to reduce the supplier’s impact according to \( \kappa^*(\alpha, R, \tau_B) \). Similar to (60), we denote the weighted sum of the expected discounted cost (associated with the supplier’s impact as well as with reducing that impact) and investors’ expectation of that discounted cost after learning for a buying firm with per unit impact penalty \( \tau_B \) as:

\[
w^*_\text{vol}(G, R, \tau_B) = \min \left( \tau_B (G - R(\kappa^*(0, R, \tau_B))) + \kappa^*(0, R, \tau_B), \alpha \tau_B M_\theta + (1 - \alpha)\tau_B (G - R(\kappa^*(\alpha, R, \tau_B))) + \kappa^*(\alpha, R, \tau_B) \right).
\]

(82)

By (59) and Lemma 5,

\[
E[w^*_\text{vol}(G, R, \tau_B)] = E[\tau_B (G - R(\kappa^*(0, R, \tau_B))) + \kappa^*(0, R, \tau_B)1\{G \leq \hat{g}(R, \alpha, M_\theta, \tau_B)\}]
+ E[\alpha \tau_B M_\theta + (1 - \alpha)\tau_B (G - R(\kappa^*(\alpha, R, \tau_B))) + \kappa^*(\alpha, R, \tau_B)1\{G > \hat{g}(R, \alpha, M_\theta, \tau_B)\}].
\]

(83)

We establish the properties of \( \kappa^*(\alpha, R, \tau_B) \) and \( \hat{g}(R, \alpha, M_\theta, \tau_B) \) in the following Lemma. We assume that \( R \) is differentiable and strictly concave to show that \( \hat{g}(R, \alpha, M_\theta, \tau_B) \) is increasing with \( \tau_B \).

**Lemma 7.** \( \kappa^*(\alpha, R, \tau_B) \) and \( \hat{g}(R, \alpha, M_\theta, \tau_B) \) are increasing with \( \tau_B \).

**Proof of Lemma 7:** \( \kappa^*(\alpha, R, \tau_B) \) increasing with \( \tau_B \) follows from (58), the fact that \( (k + \tau(1 - \alpha)R(k)) \) has increasing differences with respect to \( (k, \tau) \), and Topkis Theorem. \( \hat{g}(R, \alpha, M_\theta, \tau_B) \) increasing with \( \tau_B \) follows from the RHS of (81) increasing with \( \tau_B \) (which can be verified by differentiation and noting that \( \kappa^*(0, R, \tau_B) \geq \kappa^*(\alpha, R, \tau_B), \tau_B > 0, \) and \( \alpha > 0 \)).
Proof of Proposition 9: We restrict our attention to pure strategies. We first prove that given investors’ estimated impact observing nondisclosure $M_0$ under voluntary disclosure, there exists an equilibrium of learning and impact reduction game between the buying firms’ managers, in which only the focal buying firm learns and helps to reduce the impact. In a rational expectations equilibrium, investors’ expectation of the supplier’s impact in the event of nondisclosure is consistent with managers’ strategies for learning, impact reduction and disclosure. Then, using Bayes’ Rule and the distribution for the cost of learning $C$, we identify rational expectations equilibrium conditions for $M_0$, learning threshold $\bar{c}_v$, and disclosure threshold $\hat{g}$. We analyze the equilibrium under voluntary disclosure only; the result can be verified for mandatory disclosure using similar steps as below.

If only one manager learns about the impact, this setting reduces to the model with a single buyer. The disclosure decision and the cost to reduce the supplier’s impact are characterized by (59), with $\tau$, $\kappa^*(0, R)$ and $\kappa^*(\alpha, R)$ replaced by $\tau_2$, $\kappa^*(0, R, \tau_2)$ and $\kappa^*(\alpha, R, \tau_2)$ if only the second buying firm learned about the impact. If both buying firms’ managers learn about the impact, we identify the managers’ impact reduction equilibria after observing $(G, R)$ under the two disclosure scenarios: when the shared supplier’s impact is to be disclosed by at least one manager, and when neither manager discloses the impact. We consider these two scenarios only because the investors know that both buying firms source from the same supplier and hence investors infer a buying firm’s supplier’s impact from the other buying firm’s disclosure. With disclosure by at least one manager, we can follow the analysis of the noncooperative game in Section 5.1 to prove that an equilibrium exists in which only the focal buying firm reduces the impact by incurring $\kappa^*(0, R, \tau)$ and the second buying firm does not incur any additional cost. Moreover, this analysis can be extended to the case with no disclosure in a straightforward manner to show that an equilibrium exists in which only the focal buying firm reduces the impact by incurring $\kappa^*(\alpha, R, \tau)$ and the second buying firm does not incur any additional cost.

Next, we characterize the disclosure decisions after both managers learn about the impact. We show that in an equilibrium, both managers disclose the impact after learning $(G, R)$ if and only if

$$\tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \leq \tau(\alpha M_0 + (1 - \alpha)(G - R(\kappa^*(\alpha, R, \tau)))) + \kappa^*(\alpha, R, \tau); \quad (84)$$

after observing such $(G, R)$, only the focal buying firm incurs $\kappa^*(0, R, \tau)$ to reduce the impact, and after observing other $(G, R)$, only the focal buying firm incurs $\kappa^*(\alpha, R, \tau)$. We prove that neither manager has incentive to deviate from the outlined strategies. (84) is equivalent to the disclosure condition in (59), and therefore, the focal buying firm does not have incentive to deviate if the second buying firm follows the cost and disclosure strategy outlined above. For $(G, R)$ satisfying (84), disclosure is a weakly dominant strategy for the second buying firm (because
investors know that both firms source from the same supplier). For \((G,R)\) not satisfying (84), we have \(G - R(\kappa^*(\alpha, R, \tau)) > M_\emptyset\), because \(\tau \alpha (G - R(\kappa^*(\alpha, R, \tau)) - M_\emptyset) > (\tau R(\kappa^*(0, R, \tau)) - \kappa^*(0, R, \tau)) - (\tau R(\kappa^*(\alpha, R, \tau)) - \kappa^*(\alpha, R, \tau)) \geq 0\) (where the second inequality is due to the optimality of \(\kappa^*(0, R, \tau)\) and \(\tau > 0, \alpha > 0\). Hence, the impact after learning and impact reduction is strictly greater than the investors' estimated impact, so the second buying firm does not have incentive to deviate and disclose unless the second buying firm incurs additional impact reduction cost. That the second buying firm does not deviate by incurring additional impact reduction cost and disclosing trivially follows when \(\kappa^*(0, R, \tau_2) \leq \kappa^*(\alpha, R, \tau)\) (i.e., the second buying firm’s optimal additional impact reduction cost with disclosure is lower than the focal buying firm’s optimal impact reduction cost without disclosure) because the second buying firm’s objective with disclosure, \(\min_{k \geq \kappa^*(\alpha, R, \tau)} \tau_2 (G - R(k)) + (k - \kappa^*(\alpha, R, \tau))\), is convex with respect to \(k\) and minimized at \(\kappa^*(\alpha, R, \tau)\), and \(G - R(\kappa^*(\alpha, R, \tau)) > M_\emptyset\) as observed above. Now we focus on the case where \(\kappa^*(0, R, \tau_2) \leq \kappa^*(\alpha, R, \tau)\). Note that for \(G > \hat{g}(R, \alpha, M_\emptyset, \tau)\), we have \(G > M_\emptyset + R(\kappa^*(\alpha, R, \tau)) + (\tau R(\kappa^*(0, R, \tau)) - \kappa^*(0, R, \tau) - (\tau R(\kappa^*(\alpha, R, \tau)) - \kappa^*(\alpha, R, \tau)))/(\tau \alpha)\). This condition implies that

\[
G > M_\emptyset + R(\kappa^*(\alpha, R, \tau)) + \left(\tau_2 R(\kappa^*(0, R, \tau_2)) - \kappa^*(0, R, \tau_2) - (\tau_2 R(\kappa^*(\alpha, R, \tau)) - \kappa^*(\alpha, R, \tau))\right)/(\tau_2 \alpha),
\]

because \(\left(\tau R(\kappa^*(0, R, \tau)) - \kappa^*(0, R, \tau) - (\tau R(\kappa^*(\alpha, R, \tau)) - \kappa^*(\alpha, R, \tau))\right)/(\tau \alpha)\) is increasing with \(\tau\) when \(\kappa^*(0, R, \tau) \geq \kappa^*(\alpha, R, \tau)\) (which can be verified by differentiation). Therefore, condition (85) can be rewritten as \(\tau_2 (G - R(\kappa^*(0, R, \tau_2))) + (\kappa^*(0, R, \tau_2) - \kappa^*(\alpha, R, \tau)) > \alpha \tau_2 M_\emptyset + (1 - \alpha) \tau_2 (G - R(\kappa^*(\alpha, R, \tau)))\), which shows that the second buying firm cannot be better off by incurring an additional cost of \(\kappa^*(0, R, \tau_2) - \kappa^*(\alpha, R, \tau)\) and disclosing the resulting impact (as opposed to not incurring any cost and not disclosing).

We now analyze the managers’ learning decisions given equilibrium impact reduction and disclosure strategies identified above. We first characterize the expected value of each manager’s objective (excluding the learning cost) given the learning strategies of both managers. For ease of notation, we use \((L_1, L_2)\) to refer to the focal buying firm and the second buying firm’s learning strategies \((L_1, L_2 \in \{L, N\} \text{ with } L \text{ refering to “Learn” and } N \text{ refering to “Not Learn”})\). The expected value of the focal buying firm’s objective (excluding the learning cost) under (LL), (LN), (NL) and (NN) are given by the following expressions:

\[
\phi_{1,LL} = \phi_{1,LN} = \int w^*_{vol}(G, R, \tau)
\]

\[
\phi_{1,NL} = \int \tau (G - R(\kappa^*(0, R, \tau_2))) 1\{G \leq \hat{g}(R, \alpha, M_\emptyset, \tau_2)\}
\]

\[
+ \int (\alpha \tau M_\emptyset + (1 - \alpha) \tau (G - R(\kappa^*(\alpha, R, \tau_2)))) 1\{G > \hat{g}(R, \alpha, M_\emptyset, \tau_2)\},
\]

\[
\phi_{1,NN} = \alpha \tau M_\emptyset + (1 - \alpha) \tau \int G,
\]
where \( \hat{g}(R, M_0, \tau_B) \) is defined as in (81) and \( w^*_{vol}(G, R, \tau_B) \) is defined as in (82). \( \phi_{1,LL} = \phi_{1,LN} \) because only the focal buying firm helps the supplier to reduce the impact when both managers learn. The expected value of the second buying firm’s objective (excluding the learning cost) under (LL), (LN), (NL) and (NN) are given the following expressions:

\[
\phi_{2,LL} = \phi_{2,LN} = E[\tau_2(G - R(\kappa^*(0, R, \tau)))1\{G \leq \hat{g}(R, \alpha, M_0, \tau)\}]
\]
\[
+ E[(\alpha \tau_2 M_0 + (1 - \alpha) \tau_2(G - R(\kappa^*(\alpha, R, \tau))))1\{G > \hat{g}(R, \alpha, M_0, \tau)\}],
\]
\[
\phi_{2,NL} = E[w^*_{vol}(G, R, \tau_2)],
\]
\[
\phi_{2,NN} = \alpha \tau_2 M_0 + (1 - \alpha) \tau_2 E[G].
\] (86)

The expected values of the managers’ objectives including the learning cost for (LL), (LN), (NL) and (NN) are given by \((\phi_{1,LL} + c, \phi_{2,LL} + c)\), \((\phi_{1,LN} + c, \phi_{2,LN})\), \((\phi_{1,NL}, \phi_{2,NL} + c)\) and \((\phi_{1,NN}, \phi_{2,NN})\), respectively. \((LL)\) cannot be observed in equilibrium because not learning strictly dominates learning for the second buying firm when the focal buying firm learns (due to \(c > 0\) and \(\phi_{2,LL} = \phi_{2,LN}\)).

To identify learning equilibria, we define \(\tilde{c}_{1,L} \equiv \phi_{1,NL} - \phi_{1,LL}, \tilde{c}_{1,N} \equiv \phi_{1,NN} - \phi_{1,LN}\), and \(\tilde{c}_{2,N} \equiv \phi_{2,NN} - \phi_{2,NL}\), where \(\tilde{c}_{1,L}\) and \(\tilde{c}_{1,N}\) are the decreases in the weighted sum of the first buying firm’s discounted impact-related cost and investors’ expectation of that cost after learning when the second buying firm learns and does not learn, respectively, and \(\tilde{c}_{2,N}\) is the decrease in the weighted sum of the second buying firm’s discounted impact-related cost and investors’ expectation of that cost after learning when the focal buying firm does not learn.

Observe that \(\tilde{c}_{1,L} \leq \tilde{c}_{1,N}\) because \(\phi_{1,LN} = \phi_{1,LL}\) and \(\phi_{1,NL} \leq \phi_{1,NN}\) (as \(\phi_{1,NL} \leq E[(\alpha \tau M_0 + (1 - \alpha) \tau(G - R(\kappa^*(0, R, \tau_2)))1\{G \leq \hat{g}(R, \alpha, M_0, \tau_2)\}) + E[(\alpha \tau M_0 + (1 - \alpha) \tau(G - R(\kappa^*(\alpha, R, \tau_2)))1\{G > \hat{g}(R, \alpha, M_0, \tau_2)\})] \leq \phi_{1,NN}\) where the first inequality is by the necessary condition for disclosure to be optimal for the second buying firm in the region \(G \leq \hat{g}(R, \alpha, M_0, \tau_2)\) \((G - R(\kappa^*(0, R, \tau_2)) \leq M_0)\), the second inequality is by \(\kappa^*(0, R, \tau_2) \leq \kappa^*(\alpha, R, \tau_2)\) (by (58), the fact that \((1 - \alpha) \tau R(k) - k\) has increasing differences with respect to \((k, -\alpha)\) and Topkis Theorem) and the last inequality is by \(E[R(0)] > 0, \kappa^*(\alpha, R, \tau_2) \geq 0, \tau > 0,\) and \(0 < \alpha \leq 1\).

\(\tilde{c}_{1,N} \geq \tilde{c}_{2,N}\) because \(\tilde{c}_{1,N} - \tilde{c}_{2,N} = (\phi_{1,NN} - \phi_{1,LN}) - (\phi_{2,NN} - \phi_{2,NL}) = (\tau - \tau_2)(\alpha M_0 + (1 - \alpha)\tau(G)) + \phi_{2,NL} - \phi_{1,LN}\) and \(\phi_{2,NL} - \phi_{1,LN} = E[w^*_{vol}(G, R, \tau_2)] - E[w^*_{vol}(G, R, \tau)].\) Note that \(\hat{g}(R, \alpha, M_0, \tau_2) \leq \hat{g}(R, \alpha, M_0, \tau)\) by Lemma 7. For \(G > \hat{g}(R, \alpha, M_0, \tau_2),\)

\[
w^*_{vol}(G, R, \tau_2) - w^*_{vol}(G, R, \tau)
\]
\[
\geq [\alpha \tau_2 M_0 + (1 - \alpha) \tau_2(G - R(\kappa^*(\alpha, R, \tau_2))) + \kappa^*(\alpha, R, \tau_2)] - [\alpha \tau M_0 + (1 - \alpha) \tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)]
\]
\[
\geq (\tau_2 - \tau)(\alpha M_0 + (1 - \alpha)(G - R(\kappa^*(\alpha, R, \tau_2))))
\] (87)
where the first inequality is by the optimality of not disclosing for \( G > \hat{g}(R, \alpha, M_\emptyset, \tau_2) \) when only the second buying firm learns, and the second inequality is by the optimality of \( \kappa^*(\alpha, R, \tau) \). For \( G \leq \hat{g}(R, \alpha, M_\emptyset, \tau_2) \),

\[
w_{vol}^*(G, R, \tau_2) - w_{vol}^*(G, R, \tau) = [\tau_2(G - R(\kappa^*(0, R, \tau_2)) + \kappa^*(0, R, \tau_2)] - [\tau(G - R(\kappa^*(0, R, \tau)) + \kappa^*(0, R, \tau)] \\
\geq (\tau_2 - \tau)(G - R(\kappa^*(0, R, \tau_2))) \geq (\tau_2 - \tau)(\alpha M_\emptyset + (1 - \alpha)(G - R(\kappa^*(0, R, \tau_2))))
\]

(88)

where the equality is by the optimality of disclosure for \( G \leq \hat{g}(R, \alpha, M_\emptyset, \tau_2)(\leq \hat{g}(R, \alpha, M_\emptyset, \tau) \) when only the first or only the second buying firm learns, the first inequality is by the optimality of \( \kappa^*(0, R, \tau) \), and the last inequality is by \( \tau > \tau_2 \), \( 0 < \alpha \leq 1 \), and the necessary condition for disclosure to be optimal for the second buying firm when only that firm learns \( (G - R(\kappa^*(0, R, \tau_2)) \leq M_\emptyset) \). By \( (87), (88), \kappa^*(0, R, \tau_2) \geq \kappa^*(\alpha, R, \tau_2) \) (by (58), the fact that \( (1 - \alpha)\tau R(k) - k \) has increasing differences with respect to \( (k, -\alpha) \) and Topkis Theorem), and \( \tau > \tau_2, \phi_2, NL - \phi_1, LN \geq (\tau_2 - \tau)E[(\alpha M_\emptyset + (1 - \alpha)(G - R(\kappa^*(\alpha, R, \tau_2))))]. \) Then, \( \bar{c}_{1,N} \geq \bar{c}_{2,N} \) follows from \( \tau > \tau_2, E[R(0)] > 0, \) and \( \kappa^*(\alpha, R, \tau_2) \geq 0. \) Therefore, \( (LN), (NN) \) and \( (NL) \) can be sustained in equilibrium if and only if \( c \leq \bar{c}_{1,N}, c > \bar{c}_{1,N}, \) and \( \bar{c}_{1,L} < c \leq \bar{c}_{2,N} \), respectively.

In summary, in equilibrium, at most one of the buying firms learns. We identify two types of equilibria: in the first type of equilibrium, only the focal buying firm learns about the impact if and only if \( c \leq \bar{c}_{1,N} \) and the managers do not learn otherwise. In the second type of equilibrium, only the focal buying firm learns about the impact if and only if \( c \leq \bar{c}_{1,L} \) or \( \bar{c}_{2,N} < c \leq \bar{c}_{1,N} \), only the second buying firm learns about the impact if and only if \( \bar{c}_{1,L} < c \leq \bar{c}_{2,N} \), and the managers do not learn otherwise. We focus on the equilibrium in which only the focal buying firm learns because that is the most plausible equilibrium, due to its relative simplicity and because the focal firm has the higher expected cost per unit impact by the supplier \( \tau > \tau_2 \), and correspondingly higher incentive to learn about and reduce the supplier’s impact.

In the rational expectations equilibrium, investors’ beliefs are consistent with the managers’ equilibrium strategies. Therefore, in an equilibrium in which only the focal buying firm learns about and reduces the supplier’s impact, investors’ estimated impact observing nondisclosure is given by (65) in Lemma 5 and the learning threshold \( \bar{c}_{1,N} = \bar{c}_v \) where \( \bar{c}_v \) is defined as in (63) in Lemma 5.

In an equilibrium where only the focal buying firm learns and reduces the impact, equilibrium conditions for the model which includes only the focal firm are satisfied. As a result, Propositions 1, 2, and 4 hold, and Proposition 3 holds for the first buying firm. The second buying firm does not incur any learning or impact reduction cost, and the firm’s expected discounted profit is affected only by the expected discounted cost associated with the supplier’s impact. Moreover, the expected value of the second buying firm’s discounted cost and investors’ expectation of that cost are equal,
which is proven for the first buying firm in Proposition 3 and can be extended in a straightforward manner for the second buying firm. Therefore, a disclosure mandate reduces the firm’s profit and valuation if and only if it increases the expected impact.

**Proof of Proposition 10:** As established in the proof of Proposition 9, for any value of the investors’ estimated impact observing nondisclosure \( M_\emptyset \) under voluntary disclosure, there exists an equilibrium of the noncooperative game between buying firms’ managers in which only the focal buying firm learns and helps to reduce the impact. We assume that this noncooperative game is the disagreement alternative for the first stage of the cooperative game, in which managers decide whether or not to learn and how to share the learning cost \( c \). Furthermore, the continuation game of impact reduction and disclosure for that noncooperative game is the disagreement alternative for the second stage of the cooperative game, in which managers decide how much cost to incur to help the supplier to reduce the impact. Footnote 6 in §5.1 explains why the equilibrium of the noncooperative game in which only the focal buying firm learns and helps to reduce the impact is the most plausible equilibrium despite the possibility of other, more complex equilibria.

In this proposition, we first prove that given investors’ beliefs about the supplier’s expected impact observing nondisclosure by both firms’ managers in the cooperative game \( M_\emptyset^{coop} \), a feasible impact reduction and learning cost allocation can be identified such that both managers obtain higher weighted sums of expected discounted profit and valuation for their respective firm by cooperating. In a rational expectations equilibrium, investors’ expectation of the supplier’s impact in the event of nondisclosure is consistent with managers’ strategies for learning, impact reduction and disclosure. Then, using Bayes’ Rule and the distribution for the cost of learning \( C \), we identify cooperative rational expectations equilibrium conditions for \( M_\emptyset^{coop} \), learning threshold \( \bar{c}_v \), and disclosure threshold \( \hat{g} \) when managers cooperate. We analyze the equilibrium under voluntary disclosure only; the result can be verified for mandatory disclosure using similar steps as below.

Given investors’ beliefs about the supplier’s expected impact in the event of nondisclosure \( M_\emptyset^{coop} \), the learning and disclosure thresholds \( \bar{c}_v \) and \( \hat{g} \) in the equilibrium of the noncooperative game (identified in Proposition 9) can be defined as in (63) and (64) in Lemma 5, respectively, with \( M_\emptyset^{coop} \) substituting for \( M_\emptyset \).

Now, we consider the managers’ incentives to cooperate, keeping the investors’ beliefs regarding managers’ decisions fixed. With cooperation, the managers’ joint optimization is equivalent to a single buying firm’s manager’s maximization of the weighted sum of the expected discounted profit and valuation when that buying firm’s expected discounted per unit impact cost is \( \tau + \tau_2 \). This is because each manager seeks to maximize her firm’s weighted sum of the expected discounted profit and valuation and utility is transferrable through the sharing of the learning and impact reduction costs. Moreover, the managers’ individual objectives are aligned in the final decision regarding
whether or not to disclose the impact information to investors. Disclosure increases a buying firm’s valuation if and only if it also increases the other buying firm’s valuation. (These claims can be established in a straightforward manner following the detailed formulation and analysis of the cooperative game for the base model.) The managers’ joint impact reduction cost with and without disclosure are \( \kappa^*(0, R, \tau + \tau_2) \) and \( \kappa^*(\alpha, R, \tau + \tau_2) \), respectively. The managers choose to disclose the impact if and only if \( G \leq \hat{g}(R, \alpha, M_0^{coop}, \tau + \tau_2) \) with \( \hat{g} \) defined in (81). The managers choose to learn if and only if the learning cost satisfies \( C \leq \bar{w}_{v, coop} \) with

\[
\bar{w}_{v, coop} = \alpha(\tau + \tau_2)M_0^{coop} + (1 - \alpha)(\tau + \tau_2)E[G] - E[w_{vol}(G, R, \tau + \tau_2)]
\]

\[
= \alpha(\tau + \tau_2)M_0^{coop} + (1 - \alpha)(\tau + \tau_2)E[G] - E[(\alpha(\tau + \tau_2)M_0^{coop} + (1 - \alpha)(\tau + \tau_2)(G - R(\kappa^*(\alpha, R, \tau + \tau_2)))) + \kappa^*(\alpha, R, \tau + \tau_2))1\{G > \hat{g}(R, \alpha, M_0^{coop}, \tau + \tau_2)\}],
\]

(89)

where the second equality follows from (81).

In the next two steps, we show that the impact reduction and learning costs can be allocated such that both managers are at least weakly better off with cooperation than with the disagreement alternative, for each realization of \((C, G, R)\).

**Impact Reduction Cost Allocation:** By Lemma 7 and \( \tau_2 > 0 \), \( \hat{g}(R, \alpha, M_0^{coop}, \tau + \tau_2) \geq \hat{g}(R, \alpha, M_0^{coop}, \tau) \) meaning that the managers incur additional cost to reduce the supplier’s impact and the resulting impact is disclosed for a wider range of \( G \) with cooperation. Therefore, we identify three possibilities depending on the realization of \((G, R)\): \( G \leq \hat{g}(R, \alpha, M_0^{coop}, \tau) \), \( \hat{g}(R, \alpha, M_0^{coop}, \tau) < G \leq \hat{g}(R, \alpha, M_0^{coop}, \tau + \tau_2) \), or \( G > \hat{g}(R, \alpha, M_0^{coop}, \tau + \tau_2) \). In the latter case, the cooperative outcome and the disagreement alternative are equivalent because the managers do not incur any additional cost to reduce the impact. Therefore, we analyze only the first two cases in more detail below.

Cost sharing with \( \kappa^*(0, R, \tau + \tau_2) = 0 \) (when the impact is to be disclosed) or \( \kappa^*(\alpha, R, \tau + \tau_2) = 0 \) (when the impact is to be not disclosed) is trivial, therefore, we restrict our attention to the scenarios where the managers prefer to incur additional costs to reduce the supplier’s impact with cooperation.

First suppose that \( G \leq \hat{g}(R, \alpha, M_0^{coop}, \tau) \), meaning that the managers jointly incur \( \kappa^*(0, R, \tau + \tau_2) \) to reduce the supplier’s impact in the cooperative game whereas only the focal buying firm incurs \( \kappa^*(0, R, \tau) \) to reduce the supplier’s impact in the disagreement alternative. Let \( \beta \in [0, 1] \) represent the focal buying firm’s share of the impact reduction cost with cooperation. For the focal firm and second firm to cooperate, \( \beta \) must satisfy \( \tau(G - R(\kappa^*(0, R, \tau + \tau_2))) + \beta \kappa^*(0, R, \tau + \tau_2) \leq \tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \) and \( \tau_2(G - R(\kappa^*(0, R, \tau + \tau_2))) + (1 - \beta) \kappa^*(0, R, \tau + \tau_2) \leq \tau_2(G - R(\kappa^*(0, R, \tau))) \), or equivalently, \( \beta \leq t_1 = (\tau(R(\kappa^*(0, R, \tau + \tau_2)) - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau))/\kappa^*(0, R, \tau + \tau_2) \) and \( 1 - \beta \leq t_2 = \tau_2(R(\kappa^*(0, R, \tau + \tau_2)) - R(\kappa^*(0, R, \tau)))/\kappa^*(0, R, \tau + \tau_2) \).
The existence of such an allocation rule $\beta$ is guaranteed if $t_1 + t_2 \geq 1$, $t_1 \geq 0$, and $t_2 \geq 0$. By the optimality of $\kappa^*(0, R, \tau + \tau_2)$, we have $(\tau + \tau_2)(G - R(\kappa^*(0, R, \tau + \tau_2))) + \kappa^*(0, R, \tau + \tau_2) \leq (\tau + \tau_2)(G - R(\kappa^*(0, R, \tau)) + \kappa^*(0, R, \tau))$ leading to $t_1 + t_2 = ((\tau + \tau_2)(R(\kappa^*(0, R, \tau + \tau_2)) - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau))/\kappa^*(0, R, \tau + \tau_2) \geq 1$. $t_1 \geq 0$ and $t_2 \geq 0$ because $\kappa^*(0, R, \tau + \tau_2) \geq \kappa^*(0, R, \tau)$ by Lemma 7, $R(\cdot)$ is increasing, $\tau > \tau_2 > 0$ and $\kappa^*(0, R, \tau) \geq 0$.

The case with $G > \hat{g}(R, \alpha, M_\emptyset^{\text{coop}}, \tau + \tau_2)$ is a straightforward extension of the first case analyzed above and we omit the details for brevity.

Now, we suppose that $\hat{g}(R, \alpha, M_\emptyset^{\text{coop}}, \tau + \tau_2) < G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)$, meaning that the managers jointly incur $\kappa^*(0, R, \tau + \tau_2)$ to reduce the supplier’s impact in the cooperative game whereas only the focal buying firm incurs $\kappa^*(\alpha, R, \tau)$ to reduce the supplier’s impact in the disagreement alternative. For $G \leq \hat{g}(R, M_\emptyset^{\text{coop}}, \tau + \tau_2)$, by the managers choosing to incur $\kappa^*(0, R, \tau + \tau_2)$ with cooperation, it must be that

$$
(\tau + \tau_2)(G - R(\kappa^*(0, R, \tau + \tau_2))) + \kappa^*(0, R, \tau + \tau_2)
\leq \alpha(\tau + \tau_2)M_\emptyset^{\text{coop}} + (1 - \alpha)(\tau + \tau_2)(G - R(\kappa^*(\alpha, R, \tau + \tau_2))) + \kappa^*(\alpha, R, \tau + \tau_2).
$$

(90)

The focal buying firm’s share of the impact reduction cost $\beta \in [0, 1]$ must satisfy $\tau(G - R(\kappa^*(0, R, \tau + \tau_2))) + \beta\kappa^*(0, R, \tau + \tau_2) \leq \alpha\tau M_\emptyset^{\text{coop}} + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$ and $\tau_2(G - R(\kappa^*(0, R, \tau + \tau_2))) + (1 - \beta)\kappa^*(0, R, \tau + \tau_2) \leq \alpha\tau_2 M_\emptyset^{\text{coop}} + (1 - \alpha)\tau_2(G - R(\kappa^*(\alpha, R, \tau)))$ for the focal buying firm and second buying firm to benefit from cooperation respectively, or equivalently, $\beta \leq t_1 = (\alpha\tau M_\emptyset^{\text{coop}} + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau)))) - \tau(G - R(\kappa^*(0, R, \tau + \tau_2))) + \kappa^*(\alpha, R, \tau))/\kappa^*(0, R, \tau + \tau_2)$ and $1 - \beta \leq t_2 = (\alpha\tau_2 M_\emptyset^{\text{coop}} + (1 - \alpha)\tau_2(G - R(\kappa^*(\alpha, R, \tau)))) - \tau_2(G - R(\kappa^*(0, R, \tau + \tau_2))) + \kappa^*(\alpha, R, \tau + \tau_2)$ (due to the optimality of $\kappa^*(\alpha, R, \tau + \tau_2)$). That the managers choose to disclose the impact with cooperation implies that $G - R(\kappa^*(0, R, \tau + \tau_2)) \leq M_\emptyset^{\text{coop}}$. We also observe that $\kappa^*(0, R, \tau + \tau_2) \geq \kappa^*(0, R, \tau) \geq \kappa^*(\alpha, R, \tau)$ (where the first inequality is by Lemma 7 and $\tau_2 > 0$ and the second inequality is by (58), the fact that $(1 - \alpha)\tau R(k) - k$ has increasing differences with respect to $(k, -\alpha)$ and Topkis Theorem). $G - R(\kappa^*(0, R, \tau + \tau_2)) \leq M_\emptyset^{\text{coop}}$ and $\kappa^*(0, R, \tau + \tau_2) \geq \kappa^*(\alpha, R, \tau)$, together with $\kappa^*(\alpha, R, \tau) \geq 0$, $\alpha > 0$, $\tau > 0$ and $\tau_2 > 0$ imply that $t_1 \geq 0$ and $t_2 \geq 0$.

**Learning Cost Allocation:** First, we show that the learning cost threshold is higher with cooperation than in the equilibrium of the noncooperative game, $\bar{\tau}_{v, \text{coop}} \geq \bar{\tau}_v$. By (63) and (89), $\bar{\tau}_{v, \text{coop}} - \bar{\tau}_v = \tau_2(\alpha M_\emptyset^{\text{coop}} + (1 - \alpha)E[G]) - E[w^*_v(G, R, \tau + \tau_2)] + E[w^*_v(G, R, \tau)]$. By (82) and (81) (and $M_\emptyset^{\text{coop}}$ substituting for $M_\emptyset$), $w^*_v(G, R, \tau) = \alpha\tau M_\emptyset^{\text{coop}} + (1 - \alpha)\tau(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)$
if and only if \( G > \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau) \) and \( w^*_v(G, R, \tau + \tau_2) = \alpha(\tau + \tau_2)M_\emptyset^{coop} + (1 - \alpha)(\tau + \tau_2)(G - R(\kappa^*(\alpha, R, \tau + \tau_2))) + \kappa^*(\alpha, R, \tau + \tau_2) \) if and only if \( G > \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau + \tau_2) \). Then, by (82) and \( \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau) \leq \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau + \tau_2) \) (by Lemma 7), we observe for \( G > \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau) \) that

\[
w^*_v(G, R, \tau) - w^*_v(G, R, \tau + \tau_2) \geq [\alpha(\tau + \tau_2)M_\emptyset^{coop} + (1 - \alpha)(\tau + \tau_2)(G - R(\kappa^*(\alpha, R, \tau))) + \kappa^*(\alpha, R, \tau)]
\]

\[-[\alpha(\tau + \tau_2)M_\emptyset^{coop} + (1 - \alpha)(\tau + \tau_2)(G - R(\kappa^*(\alpha, R, \tau + \tau_2))) + \kappa^*(\alpha, R, \tau + \tau_2)]
\]

\[\geq -\tau_2(\alpha M_\emptyset^{coop} + (1 - \alpha)(G - R(\kappa^*(\alpha, R, \tau)))) \quad (91)\]

where the second inequality is by the optimality of \( \kappa^*(\alpha, R, \tau + \tau_2) \) with cooperation. For \( G \leq \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau) \),

\[
w^*_v(G, R, \tau) - w^*_v(G, R, \tau + \tau_2) = [\tau(G - R(\kappa^*(0, R, \tau)))] + [\kappa^*(0, R, \tau)] - [(\tau + \tau_2)(G - R(\kappa^*(0, R, \tau + \tau_2))) + \kappa^*(0, R, \tau + \tau_2)]
\]

\[\geq -\tau_2(G - R(\kappa^*(0, R, \tau))) \geq -\tau_2(\alpha M_\emptyset^{coop} + (1 - \alpha)(G - R(\kappa^*(0, R, \tau)))) \quad (92)\]

where the equality is because \( w^*_v(G, R, \tau) = \tau(G - R(\kappa^*(0, R, \tau))) + \kappa^*(0, R, \tau) \) and \( w^*_v(G, R, \tau + \tau_2) = (\tau + \tau_2)(G - R(\kappa^*(0, R, \tau + \tau_2))) + \kappa^*(0, R, \tau + \tau_2) \) for \( G \leq \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau) \), the first inequality is by the optimality of \( \kappa^*(0, R, \tau + \tau_2) \), and the last inequality is by \( G - R(\kappa^*(0, R, \tau)) \leq M_\emptyset^{coop} \), the necessary condition for disclosure to be preferred over nondisclosure in the equilibrium of the noncooperative game for \( G \leq \hat{g}(R, \alpha, M_\emptyset^{coop}, \tau) \). By (91), (92), \( \kappa^*(0, R, \tau) \geq \kappa^*(\alpha, R, \tau) \geq 0 \) (by (58), the fact that \( (1 - \alpha)\tau R(k) - k \) has increasing differences with respect to \( (k, -\alpha) \) and Topkas Theorem), \( R \geq 0 \), and \( \tau_2 > 0 \), \( E[w^*_v(G, R, \tau)] - E[w^*_v(G, R, \tau + \tau_2)] \geq -\tau_2(\alpha M_\emptyset^{coop} + (1 - \alpha)E[G]) \) and consequently \( \tau_{v,coop} \geq \tau_v \). Hence, we consider the cost allocation in two different cases depending on the realization of the learning cost \( C \): either \( c \leq \tilde{c}_v \leq \tau_{v,coop} \) meaning that learning is optimal for the managers in the cooperative game and for the focal buying firm in the disagreement alternative, or \( \tilde{c}_v < c \leq \tau_{v,coop} \) meaning that learning is optimal for the managers in the cooperative game, but not optimal for either manager in the disagreement alternative.

In the first case, all of the learning cost can be allocated to the focal buying firm with cooperation because this is identical to the learning cost allocation of the disagreement alternative. For the second case, let \( \beta(G, R) \) represent the focal buying firm’s share of the impact reduction cost after learning and with cooperation which satisfies the allocation rules identified above, and \( \delta \in [0, 1] \) denote the focal buying firm’s share of the learning cost. In addition, let \( y_1 \) and \( y_2 \) represent the weighted sum of the expected discounted cost (associated with the impact as well as with reducing
that impact) and investors’ expectation of that cost after learning under cooperation for the focal
buying firm and second buying firm, respectively:

\[
y_1 = E[\tau (G - R (\kappa^* (0, R, \tau + \tau_2))) + \beta(G, R) \kappa^* (0, R, \tau + \tau_2)] 1\{G \leq \hat{g}(R, \alpha, M_\emptyset, \tau + \tau_2)\}
+ E[\alpha \tau M_0^{\text{coop}} + (1 - \alpha) \tau (G - R (\kappa^* (\alpha, R, \tau + \tau_2))) + \beta(G, R) \kappa^* (\alpha, R, \tau + \tau_2)] 1\{G > \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau + \tau_2)\},
\]

\[
y_2 = E[\tau_2 (G - R (\kappa^* (0, R, \tau + \tau_2))) + (1 - \beta(G, R)) \kappa^* (0, R, \tau + \tau_2)] 1\{G \leq \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau + \tau_2)\}
+ E[\alpha \tau_2 M_0^{\text{coop}} + (1 - \alpha) \tau_2 (G - R (\kappa^* (\alpha, R, \tau + \tau_2))) + (1 - \beta(G, R)) \kappa^* (\alpha, R, \tau + \tau_2)] 1\{G > \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau + \tau_2)\}.
\]

For the focal buying firm and the second buying firm to benefit from cooperation, we must have
\(y_1 + \delta c \leq \alpha \tau M_0^{\text{coop}} + (1 - \alpha) \tau E[G]\) and \(y_2 + (1 - \delta) c \leq \alpha \tau_2 M_0^{\text{coop}} + (1 - \alpha) \tau_2 E[G]\), respectively. These
two inequalities are equivalent to \(\delta \leq l_1\) and \(1 - \delta \leq l_2\) where
\(l_1 = (\alpha \tau M_0^{\text{coop}} + (1 - \alpha) \tau E[G] - y_1) / c\) and
\(l_2 = (\alpha \tau_2 M_0^{\text{coop}} + (1 - \alpha) \tau_2 E[G] - y_2) / c\). The existence of such an allocation rule \(\delta\) is guaranteed
if \(l_1 + l_2 \geq 1\), \(l_1 \geq 0\) and \(l_2 \geq 0\). Note that \(l_1 + l_2 = (\alpha (\tau + \tau_2) M_0^{\text{coop}} + (1 - \alpha) (\tau + \tau_2) E[G] - (y_1 + y_2)) / c = \bar{\varepsilon}_{\text{coop}} / c \geq 1\) (where the equality follows from (99), (93) and (94) and the inequality is by
the condition \(\bar{\varepsilon}_v < c \leq \bar{\varepsilon}_{\text{coop}}\) in this case).

\(l_1 \geq 0\) follows from impact cost allocation for the focal buying firm: for the focal buying firm to
cooperate for impact reduction when \(G \leq \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau + \tau_2)\), it must be that \(\tau (G - R (\kappa^* (0, R, \tau + \tau_2))) + \beta(G, R) \kappa^* (0, R, \tau + \tau_2) \leq \min \left( \tau \alpha M_0^{\text{coop}} + \tau (1 - \alpha) (G - R (\kappa^* (\alpha, R, \tau))) + \kappa^* (\alpha, R, \tau), \tau (G - R (\kappa^* (0, R, \tau))) + \kappa^* (0, R, \tau) \right) \leq \alpha \tau M_0^{\text{coop}} + \tau (1 - \alpha) (G - R (\kappa^* (\alpha, R, \tau))) + \kappa^* (\alpha, R, \tau)\) which by the optimality of \(\kappa^* (\alpha, R, \tau)\) leads to \(\tau (G - R (\kappa^* (0, R, \tau + \tau_2))) + \beta(G, R) \kappa^* (0, R, \tau + \tau_2) \leq \alpha \tau M_0^{\text{coop}} + \tau (1 - \alpha) (G - R (0))\). By similar reasoning for \(G > \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau + \tau_2)\), we can show that \(\alpha \tau M_0^{\text{coop}} + (1 - \alpha) \tau (G - R (\kappa^* (\alpha, R, \tau + \tau_2))) + \beta(G, R) \kappa^* (\alpha, R, \tau + \tau_2) \leq \alpha \tau M_0^{\text{coop}} + \tau (1 - \alpha) (G - R (0)).\) As a
result, \(y_1 \leq E[\tau \alpha M_0^{\text{coop}} + \tau (1 - \alpha) (G - R (0))] \leq \alpha \tau M_0^{\text{coop}} + (1 - \alpha) \tau E[G]\) (where the last inequality is by \(E[R(0)] > 0\) and \(0 < \alpha \leq 1\)) and consequently \(l_1 \geq 0\).

Now, we show that \(l_2 \geq 0\). For the second buying firm to cooperate for impact reduction when
\(G \leq \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau) \leq \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau + \tau_2)\) by Lemma 7, it must be that \(\tau_2 (G - R (\kappa^* (0, R, \tau + \tau_2))) + (1 - \beta(G, R)) \kappa^* (0, R, \tau + \tau_2) \leq \tau_2 (G - R (\kappa^* (0, R, \tau)))\). By the necessary condition for
disclosure in the equilibrium of the noncooperative game \(G - R (\kappa^* (0, R, \tau)) \leq M_0^{\text{coop}}\) for \(G \leq \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau)\). Therefore, when \(G \leq \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau)\), we have \(\tau_2 (G - R (\kappa^* (0, R, \tau + \tau_2))) + (1 - \beta(G, R)) \kappa^* (0, R, \tau + \tau_2) \leq \tau_2 \alpha M_0^{\text{coop}} + \tau_2 (1 - \alpha) (G - R (G (\kappa^* (0, R, \tau))) \leq \tau_2 \alpha M_0^{\text{coop}} + \tau_2 (1 - \alpha) (G - R (G (\kappa^* (\alpha, R, \tau)))\) (where the last inequality is by \(\kappa^* (0, R, \tau) \geq \kappa^* (\alpha, R, \tau)\) which is due to (58),
the fact that \((1 - \alpha) \tau R(k) - k\) has increasing differences with respect to \((k, -\alpha)\) and Topkis
Theorem)). For the second buying firm to benefit from cooperation for impact reduction when
\(G > \hat{g}(R, \alpha, M_0^{\text{coop}}, \tau)\), we must have \(\tau_2 (G - R (\kappa^* (0, R, \tau + \tau_2))) + (1 - \beta(G, R)) \kappa^* (0, R, \tau + \tau_2) \leq \tau_2 \alpha M_0^{\text{coop}} + \tau_2 (1 - \alpha) (G - R (G (\kappa^* (\alpha, R, \tau)))\) (where the last inequality is by \(\kappa^* (0, R, \tau) \geq \kappa^* (\alpha, R, \tau)\) which is due to (58),
the fact that \((1 - \alpha) \tau R(k) - k\) has increasing differences with respect to \((k, -\alpha)\) and Topkis
Theorem)).
\[ \alpha \tau_2 M_{\theta}^{coop} + (1 - \alpha) \tau_2 (G - R(\kappa^*(\alpha, R, \tau))) \] in the region \( G \leq \hat{g}(R, \alpha, M_{\theta}^{coop}, \tau + \tau_2) \) and \( \alpha \tau_2 M_{\theta}^{coop} + (1 - \alpha) \tau_2 (G - R(\kappa^*(\alpha, R, \tau + \tau_2))) + (1 - \beta(G, R)) \kappa^*(\alpha, R, \tau + \tau_2) \leq \alpha \tau_2 M_{\theta}^{coop} + \tau_2 (1 - \alpha)(G - R(\kappa^*(\alpha, R, \tau))) \] in the region \( G > \hat{g}(R, \alpha, M_{\theta}^{coop}, \tau + \tau_2) \). As a result, \( \hat{y}_2 \leq E[\tau_2 \alpha M_{\theta}^{coop} + \tau_2 (1 - \alpha)] \) which together with \( \kappa^*(\alpha, R, \tau) \geq 0 E[R(0)] > 0, \tau_2 > 0 \) and \( 0 < \alpha \leq 1 \) leads to \( \hat{y}_2 \leq \tau_2 \alpha M_{\theta}^{coop} + \tau_2 (1 - \alpha)E[G] \), and consequently, \( l_2 \geq 0 \). As a result, both buyers are at least weakly better off by cooperation compared to the disagreement alternative.

In a cooperative rational expectations equilibrium, investors anticipate that both buyers benefit from cooperation and update their valuations accordingly. As such, the managers’ joint optimal learning, impact reduction, and disclosure strategy in the cooperative equilibrium \( (l^{coop}, k^{coop}, d^{coop}) \) can be characterized as in (59) and (62), except that \( \tau + \tau_2 \) substitutes for \( \tau, M_{\theta}^{coop} \) substitutes for \( M_{\theta}, \kappa^*(0, R, \tau + \tau_2) \) substitutes for \( \kappa^*(0, R) \), and \( \kappa^*(\alpha, R, \tau + \tau_2) \) substitutes for \( \kappa^*(\alpha, R) \). The learning threshold \( \tau_\theta \) and the disclosure threshold \( \hat{g} \) of the cooperative equilibrium can be characterized similarly to Lemma 5, except that \( \tau + \tau_2 \) substitutes for \( \tau, M_{\theta}^{coop} \) substitutes for \( M_{\theta}, \kappa^*(0, R, \tau + \tau_2) \) substitutes for \( \kappa^*(0, R) \), and \( \kappa^*(\alpha, R, \tau + \tau_2) \) substitutes for \( \kappa^*(\alpha, R) \). In that equilibrium, investors’ expectation of the impact equals

\[
M_{\theta}^{coop} = E[(1 - l^{coop}(C))G + l^{coop}(C)(G - R(k^{coop}(G, R)))|d^{coop}(C, G, R) = \emptyset].
\] (95)

By (59) and (62), the independence of \( C \) and \( (G, R) \) and Bayes’ Rule, expression (95) becomes (65) (with \( \tau, M_{\theta}, \kappa^*(0, R) \) and \( \kappa^*(\alpha, R) \) replaced with \( \tau + \tau_2, M_{\theta}^{coop}, \kappa^*(0, R, \tau + \tau_2) \) and \( \kappa^*(\alpha, R, \tau + \tau_2) \) respectively). All the arguments in the proofs of Propositions 1, 2, 3, and 4 hold with the substitution of the impact cost \( \tau + \tau_2 \) because the managers’ objective function in the cooperative game is the same as a manager’s objective in the base model, except that \( \tau + \tau_2 \) substitutes for \( \tau \).

**Proof of Proposition 5:** (a.) The result under voluntary disclosure follows from the numerical example provided in the proof of Proposition 5a for the base model. The manager’s objective under the mandate becomes equivalent to maximizing the buying firm’s expected discounted profit by Proposition 7, regardless of our assumption about whether the manager is maximizing the buying firm’s valuation or a weighted sum of the buying firm’s expected discounted profit and valuation. Therefore, the proof of the result under the disclosure mandate follows from the proof of Proposition 5a under the scenario where each manager maximizes the corresponding buying firm’s valuation.

(b.) The result under voluntary disclosure follows from the numerical example provided in the proof of Proposition 5b for the base model. Since the manager’s objective under the mandate is equivalent to maximizing the buying firm’s expected discounted profit by Proposition 7, regardless of our assumption about whether the manager is maximizing the buying firm’s valuation or a weighted sum of the buying firm’s expected discounted profit and valuation, the result under the disclosure mandate follows from the proof of Proposition 5b for the base model.
(c.) The proof follows from the numerical example provided in the proof of Proposition 5c for the base model.

**Preliminaries for Proposition 6 with Alternative Suppliers:**

Under voluntary disclosure, the manager’s optimal objective value is

\[
\tilde{v}_{vol}(\gamma c) = \min \left( \alpha \tau M_0 + (1 - \alpha) E[\tau G], \gamma c + E[v^*_{vol}(G, R, \gamma c)] \right)
\]

wherein \( M_1 = (G - R(k)) \), \( M_0 \) is investors’ expectation of the chosen supplier’s impact in the event of nondisclosure, and

\[
v^*_{vol}(G, R, \gamma c) = \min \left( \min_{k \in [0, \infty), d \in \{0, 1\}} \{\alpha M_d + (1 - \alpha) \tau (G - R(k)) + k\}, \gamma c + E[v^*_{vol}(G, R, \gamma c)] \right)
\]

The manager chooses not to learn if the first term in (96), alone, achieves the minimum in the manager’s objective (96). Otherwise the manager learns about at least one supplier’s impact. Contingent on the realization of the supplier’s impact \( G = g \) and impact-reduction potential \( R = r \), the manager learns about an alternative supplier if the second term achieves the minimum in (97). Otherwise the manager sources from the current supplier, deciding how much to reduce the impact and whether to disclose the resulting impact according to the inner minimization in (97), for which the optimal solution is characterized in (59).

We first provide a proof of Lemma 4 under the generalized manager’s objective/information for investors. Then, the proofs of Proposition 6 under the generalized manager’s objective/information for investors follow from the respective proofs under the scenario where the manager maximizes the buying firm’s valuation.

**Proof of Lemma 4:** (a.) We first show that in any equilibrium with voluntary disclosure

\[
M_0 \geq E[G].
\]

The manager’s objective value with learning is greater than or equal to \( \gamma c + \tau g + \inf \{\kappa^*(0, R) - \tau R(\kappa^*(0, R))\} \) because, by assumption, \( G \geq g \), \( \tau \) is nonnegative, \( k - \tau R(k) \geq \kappa^*(0, R) - \tau R(\kappa^*(0, R)) \). The expected objective value without learning is \( \alpha \tau M_0 + (1 - \alpha) E[\tau G] \), with \( M_0 \leq \bar{g} \) because \( G \leq \bar{g} \) and \( R \) is nonnegative. Therefore a manager with \( \gamma c > \tau (\bar{g} - g) - \inf \{\kappa^*(0, R) - \tau R(\kappa^*(0, R))\} \) will not learn, which occurs with probability \( 1 - F((\tau (\bar{g} - g) - \inf \{\kappa^*(0, R) - \tau R(\kappa^*(0, R))\})/\gamma) > 0 \) because \( C \) has support on \((0, \infty)\), \( G \) has support on a finite interval (i.e., \( 0 \leq g < \bar{g} < \infty \)), \( \tau \) is nonnegative, \( \gamma \) is strictly positive, and \( \inf \{\kappa^*(0, R) - \tau R(\kappa^*(0, R))\} \) is finite by our initial assumption that the support of the impact reduction function \( R \) is a finite set and, conditional on \( R \), \( \kappa^*(R) \) is finite.
Analogous to (67),

\[
M_\emptyset = \frac{Pr\{l^*(C) = 0\} E[G] + Pr\{l^*(C) = 1\} E[G - R(k^*(G, R))|d = \emptyset, l^*(C) = 1]}{Pr\{l^*(C) = 0\} + Pr\{d = \emptyset, l^*(C) = 1\}}
\]  

(99)

wherein \(G - R(k^*(G, R))\) is the impact of the supplier chosen after learning at least once, \(l^*(C) = 1\) denotes the event that the manager learns at least once and \(l^*(C) = 0\) the event that the manager does not learn. After learning and choosing a supplier, for no disclosure to be optimal, it must be that disclosing the impact would strictly increase investors’ valuation of the buying firm’s supplier’s impact,

\[
G - R(k^*(G, R)) > M_\emptyset,
\]

(100)

so \(E[G - R(k^*(G, R))|d = \emptyset, l^*(C) = 1] > M_\emptyset\). With (99) and \(Pr\{l^*(C) = 0\} \geq 1 - F((\tau - g) - \inf\{\kappa^*(0, R) - \tau R(\kappa^*(0, R))\})/\gamma) > 0\), that implies (98).

Next, we prove that in any equilibrium, if the manager learns, then the manager discloses the impact of the chosen supplier. After learning, the manager discloses the chosen supplier’s impact unless (100); it remains to show that a manager that learns does not stop with a supplier for which (100) holds. Together, (100), (98) and \(\kappa^*(\alpha, R) \geq 0\) imply

\[
\tau \alpha M_\emptyset + \tau (1 - \alpha)(G - R(\kappa^*(\alpha, R))) + \kappa^*(\alpha, R) > \alpha \tau M_\emptyset + (1 - \alpha)\tau E[G].
\]

(101)

As the manager chose to learn initially, the first term in (96) must be greater than the second term

\[
\alpha \tau M_\emptyset + (1 - \alpha)\tau E[G] \geq \gamma c + E[v^*_\text{vol}(G, R, \gamma c)].
\]

(102)

Together, (101) and (102) imply that \(\gamma c + E[v^*_\text{vol}(G, R, \gamma c)]\) achieves the minimum in (97), meaning that the manager learns again, rather than choose a supplier with (100).

Now, assuming existence of an equilibrium with the manager learning at least once for some \(c\) in the support of \(C\), \((0, \infty)\), we characterize the manager’s unique equilibrium strategy for choosing a supplier for each such \(c\). In an equilibrium with the manager with \(C = c\) learning at least once, (96)-(97) imply

\[
E[\min\{\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))), \gamma c + E[v^*_\text{vol}(G, R, \gamma c)]\}] = E[v^*_\text{vol}(G, R, \gamma c)].
\]

(103)

If after learning the manager learns again with probability 1, then \(E[v^*_\text{vol}(G, R, \gamma c)] = \gamma c + E[v^*_\text{vol}(G, R, \gamma c)]\), contradicting our assumptions \(\gamma > 0\) and \(c > 0\). Therefore we can restrict attention to candidate values for \(E[v^*_\text{vol}(G, R, \gamma c)]\) such that with strictly positive probability, \(\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))) < E[v^*_\text{vol}(G, R, \gamma c)] + \gamma c\), i.e., with strictly positive probability, \((G, R)\) is such
that the manager sources from a supplier with observed \((G, R)\). From (97), \(E[v_{\text{vol}}^*(G, R, \gamma c)]\) must be a fixed point of
\[
T(\psi) \equiv E[\min\{\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))), \gamma c + \psi\}].
\]
(104)

For any candidate values \(\psi_1\) and \(\psi_2\) for \(E[v_{\text{vol}}^*(G, R, \gamma c)]\) with \(\psi_1 > \psi_2\),
\[
T(\psi_1) - T(\psi_2) = E[\min\{\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))), \gamma c + \psi_1\} - \min\{\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))), \gamma c + \psi_2\}]
< \psi_1 - \psi_2,
\]
(105)

because \(\psi_2 + \gamma c > \kappa^*(0, R) + \tau(G - R(\kappa^*(0, R)))\) with strictly positive probability. Therefore \(E[v_{\text{vol}}^*(G, R, \gamma c)]\) is unique and, after learning a supplier’s \((G, R)\), the manager sources from the supplier (rather than learn again) if and only if \(\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))) < \gamma c + E[v_{\text{vol}}^*(G, R, \gamma c)]\); the inequality is strict due to the assumption that the manager breaks ties in favor of learning.

We now show that in equilibrium with voluntary disclosure, the manager learns at least once if and only if \(c \leq \overline{c}_\infty\) where \(\overline{c}_\infty > 0\) is the unique \(c\) that satisfies
\[
-\gamma c - E[v_{\text{vol}}^*(G, R, \gamma c)] + \tau E[G] = 0.
\]
(106)

Investors have rational expectations that a manager that learns will disclose the impact of the chosen supplier so \(M_0 = E[G]\). Hence (96) and the assumption that the manager breaks ties in favor of learning imply that a manager with learning cost \(c\) learns at least once if and only if the LHS of (106) is nonnegative. The LHS of (106) is strictly negative as \(c \to \infty\) (because \(\lim_{c \to \infty} (E[v_{\text{vol}}^*(G, R, \gamma c)] + \gamma c) = \infty\) and is strictly positive as \(c \to 0\) (because \(\lim_{c \to 0} E[v_{\text{vol}}^*(G, R, \gamma c)] = \inf\{\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R)))\} < \tau E[G]\)). Therefore, to establish the claim, it remains to show that the LHS of (106) is continuous and strictly decreasing with \(c\). With slight abuse of notation, let \(T(\gamma c, \psi)\) denote the RHS of (104), which is differentiable with respect to \(c\) for \(c \in (0, \infty)\) and \(\psi \in \mathbb{R}\) because \(G\) follows a continuous distribution conditional on \(R\) and the support of \(R\) is a finite set of functions. Recalling that \(T(\gamma c, E[v_{\text{vol}}^*(G, R, \gamma c)]) - E[v_{\text{vol}}^*(G, R, \gamma c)] = 0\) and applying the Implicit Function Theorem,
\[
dE[v_{\text{vol}}^*(G, R, \gamma c)]/dc = (\gamma Pr(G > \hat{g}(R, E[v_{\text{vol}}^*(G, R, \gamma c)], \gamma c)))/\left(1 - Pr(G > \hat{g}(R, E[v_{\text{vol}}^*(G, R, \gamma c)], \gamma c))\right) \geq 0,
\]

where \(\hat{g}(R, \psi, \gamma c)\) is the unique solution to \(\kappa^*(0, R) + \tau(G - R(\kappa^*(0, R))) = \psi + \gamma c\). As \(\gamma > 0\), that establishes that the LHS of (106) is continuous and strictly decreasing with \(c\). We conclude that with voluntary disclosure, there exists a unique equilibrium, and in that equilibrium, a manager that learns discloses the impact of the chosen supplier. That uniqueness and full disclosure imply existence of a unique equilibrium under mandatory disclosure, which is identical to the unique equilibrium under voluntary disclosure. The full disclosure in the unique equilibrium implies that
(b.) We prove that the expected value of investors’ valuation of the buying firm’s discounted cost (associated with the impact and the cost of learning about and reducing that impact) strictly increases with $\gamma$, which is equivalent to the statement of Lemma 4b. With $c_\infty(\gamma)$ representing the unique $c$ that satisfies (106), the expected value of investors’ valuation of the firm’s discounted impact-related cost is

$$
\int_{\tau E[G]}^{c_\infty(\gamma)} \left( E[v^*_\text{vol}(G, R, \gamma c)] + \gamma c \right) f(c) dc + \int_{c_\infty(\gamma)}^{\infty} (\tau E[G]) f(c) dc.
$$

The expression above is strictly increasing with $\gamma$ because $E[v^*_\text{vol}(G, R, \gamma c)] + \gamma c$ strictly increases with $\gamma$ (implied by $E[v^*_\text{vol}(G, R, \gamma c)] + \gamma c$ strictly increasing with $c$, as shown in the proof of part (a.)), and the partial derivative of the expression above with respect to $c_\infty(\gamma)$ is zero (due to (106)).

**Proof of Proposition 6:** (a.) The fact that the manager commits to a supplier if and only if $\gamma > \hat{\gamma}$ where $\hat{\gamma} > 1$ is immediate from Lemma 4b. With alternative suppliers, by Lemma 4a, the weighted sum of the buying firm’s expected discounted profit and valuation is the same under voluntary and mandatory disclosure. With commitment to a single supplier, by Proposition 3, the weighted sum of the buying firm’s expected discounted profit and valuation is strictly greater under mandatory disclosure than with voluntary disclosure. Therefore, a disclosure mandate strictly decreases the commitment threshold $\hat{\gamma}$.

(b.) For $\gamma > \hat{\gamma}_c$, by Proposition 6a, the manager commits to a supplier before learning under voluntary and mandatory disclosure. Therefore, Propositions 1, 2, 3, and 4 hold. For $\gamma \leq \hat{\gamma}_m$, Proposition 6a imply that the manager maintains the option to choose an alternative supplier under voluntary and mandatory disclosure. From the second sentence of Lemma 4a, learning, supplier selection and impact reduction are identical under voluntary and mandatory disclosure, so a disclosure mandate is ineffective.

In the region $\gamma \in (\hat{\gamma}_m, \hat{\gamma}_c]$, the manager commits to a supplier under mandatory disclosure while the manager maintains the option to choose an alternative supplier under voluntary disclosure. By Proposition 7, the manager’s objective under the mandate becomes equivalent to maximizing the buying firm’s expected discounted profit, regardless of our assumption about whether the manager is maximizing the buying firm’s valuation or a weighted sum of the buying firm’s expected discounted profit and valuation. Under voluntary disclosure, the manager’s objective becomes equivalent to maximizing the buying firm’s expected discounted profit as well, because the manager discloses the impact of the chosen supplier’s impact, and hence, the buying firm’s expected discounted profit and valuation are equivalent. Consequently, in the region $\gamma \in (\hat{\gamma}_m, \hat{\gamma}_c]$, the scenario where the manager’s objective is to maximize the buying firm’s valuation and the extension with
generalized manager’s objective lead to the same outcome and the comparison of a mandate with voluntary disclosure follows from the proof of Proposition 6 provided before.

**Proof of Proposition 7:** The manager’s objective (17) evaluated at \( \theta = 1 \) is given by

\[
\min \left( \tau E[G] , c + E\left[ \min_{k \in [0, \infty)} \{k + \tau(G - R(k))\} \right] \right),
\]

which is equivalent to (6), the manager’s objective under a disclosure mandate. Hence, when \( \theta \) is increased to 1, the manager chooses the same strategy for learning and impact reduction as under a disclosure mandate.

**Proof of Proposition 8:** The result follows from Lemma 5d.