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Optimal Disclosure Mandate in Supply Chains

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Abstract

We study a model in which a firm can acquire conclusive evidence about its supplier's social and environmental impacts. We identify the disclosure mandate that maximizes market information. A disclosure mandate determines whether (i) the firm's investigation effort is observable by the market and (ii) obtained evidence is disclosed to the market. When the supply chain visibility is low, the firm does not know its supplier's impacts. The combination of covert investigation and voluntary disclosure of obtained evidence incentivizes the firm to acquire evidence and constitutes the optimal disclosure mandate. When the supply chain visibility is high, the firm knows its supplier's impacts. Overt investigation and mandatory disclosure of obtained evidence together enable the firm to signal its private knowledge through the chosen investigation effort and maximize market information. The sharp contrast of these two cases highlights the importance of supply chain visibility in determining the optimal mandate.

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1 Introduction

Countries worldwide are increasingly enacting legislation aimed at promoting supply chain transparency and social responsibility. A recent milestone is the forthcoming EU Corporate Sustainability Due Diligence Directive (CSDD). Agreed upon by European countries in December 2022 and approved by member states in March 2024, this directive mandates EU companies to manage social and environmental impacts across their entire supply chain. Firms are obligated to identify and mitigate actual and potential impacts, alongside the transparency of due diligence processes. Prior to this EU directive, Germany enacted the Supply Chain Due Diligence Act in 2021, and France introduced the Corporate Duty of Vigilance Law in 2017. Additionally, policymakers have introduced similar mandates in various sectors globally, such as the Dodd-Frank Act’s requirement for U.S. listed companies to disclose their use of conflict minerals and France’s imposition of disclosure requirements for institutional investors and asset managers under the Energy Transition for Green Growth Act.¹ Alongside regulatory efforts, consumer demand for information regarding the production processes is also on the rise. For example, Kraft et al. (2018) find that consumers pay a premium for transparency regarding a company’s social responsibility practice in the upstream supply chain.

Existing literature examines the impact of disclosure mandate, both empirically and theoretically. While the empirical literature on disclosure mandates provides evidence that requiring a firm to disclose its impacts incentivizes it to reduce those impacts (Doshi et al., 2013), the theoretical literature demonstrates a peril of such a policy when the firm’s information about its impacts is endogenous – such mandate may deter firms from measuring and thus from improving their impacts (Kalanci et al. 2016; Kalanci and Plambeck 2020). While much of the existing literature focuses on the disclosure of impacts alone, this paper considers disclosure mandates across two dimensions. Firstly, we examine the disclosure of efforts to investigate impacts. For example, the German Supply Chain Due Diligence Act mandates the disclosure of efforts to identify and assess social and environmental impacts in supply chains. Similarly, under the California Transparency in Supply Chain Act

¹For detail, see Hilke et al. (2021).

(Senate Bill 657), firms are required to disclose efforts to combat forced labor. Despite the possibility of voluntary disclosures, such disclosures often contain vague or misleading content due to the nature of soft information. For example, it would be difficult for consumers to verify if efforts are genuinely spent on investigation. Thus, regulatory mandate is often necessary for meaningful communication.² Secondly, we consider the disclosure of investigation results. For instance, the U.S. Environmental Protection Agency’s Toxics Release Inventory (TRI) mandates thousands of establishments to publicly disclose emissions of toxic chemicals. Companies like Walmart, Target, and Costco voluntarily share environmental reports with the public. The Kering Group goes beyond regulatory requirements by disclosing greenhouse gas emissions, air and water pollution, land use, and water consumption incurred by its suppliers from Tier-1 to Tier-4. In contrast to the disclosure of investigation efforts, voluntary disclosures often comprise *hard information*, verifiable by the market, and fabricating such information can lead to severe repercussions, even criminal prosecution (Sarbanes-Oxley Act 2002). This dimension is the primary focus of most of the literature.

We analyze how a policymaker, whose aim is to maximize public access to information, optimally chooses mandates on supply chain transparency. A firm has the option to invest effort in acquiring evidence regarding its supplier’s social and environmental impacts. The policymaker faces two decisions: 1) whether to mandate the disclosure of the effort exerted in acquiring evidence, and 2) whether to mandate the disclosure of the evidence obtained. A higher effort level chosen by the firm increases the likelihood of acquiring evidence about its supplier’s impacts.³ However, since such effort consists mostly of soft information, we assume that the firm cannot credibly communicate it to the public unless mandated to do

²For example, the new EU sustainability reporting standards are criticized as “moving away from mandatory disclosure of key reporting requirements” and consequently “will allow greenwashing”. See <https://www.energymonitor.ai/reporting-and-disclosure/eu-sustainability-reporting-standards-will-allow-greenwashing-say-ngos/>.

³Effort can also be interpreted as the cost of investigation, incurred by the firm when engaging a third-party to scrutinize its suppliers. This cost reflects the scope of the investigation, which in turn influences its thoroughness.

so.⁴ Given any effort level, there is a possibility that the firm fails to obtain evidence.⁵ When the firm successfully obtains the evidence, it can then decide whether to disclose it to the public. If evidence disclosure is not mandated, the firm can conceal unfavorable evidence. Based on all available information, the market determines the firm’s valuation, and the firm’s goal is to maximize its valuation.

We examine disclosure mandates in two distinct information environments: high and low supply chain visibility scenarios. In the high supply chain visibility case, the firm is privately informed of its supplier’s impacts. In the low supply chain visibility case, the firm has *no* information about these impacts.⁶ Supply chain visibility is influenced by the complexity of the supply chain. While a firm with a simple supply chain may be knowledgeable about the impacts of its entire supply chain, this is less likely for multinational companies with complex supply chains. According to a survey of 335 global manufacturing executives, 49% admitted that their companies had limited knowledge about their supply chain beyond Tier-1 suppliers, let alone the entire supply chain (KPMG 2013). Similarly, another survey covering 600 supply chain professionals in 17 countries found that only 6% believed their firms had achieved full supply chain visibility (GEODIS 2017). By studying the optimal disclosure mandate in different information environments, we offer new insights into how these mandates interact with changes in supply chain visibility.

We show that the optimal disclosure mandate is contingent upon supply chain visibility. In the case with low visibility, the firm lacks information about its supplier. By conducting investigations, the firm can acquire *both* information and evidence. In such case, it is

⁴For example, an article in Harvard Business Review (Pucker 2021) lists “lack of mandates and auditing” as one of the problems with sustainability reporting: “Most companies have complete discretion over what standard-setting body to follow and what information to include in their sustainability reports. In addition, although 90% of the world’s largest companies now produce CSR reports, a minority of them are validated by third parties. As a result, a lot of the input data is misleading and incomplete.”

⁵For instance, in response to complaints about the challenges of tracing conflict minerals in intricate supply chains, the Securities and Exchange Commission (SEC) permits firms to label their product’s conflict mineral status as “undeterminable” (SEC 2012).

⁶There is no consensus on the terminologies in the literature (Budler et al. 2024). Sodhi and Tang (2019) contrast the term supply chain visibility, i.e., what managers know about upstream operations, with supply chain transparency, i.e., information that is disclosed to the public, including consumers and investors about upstream operations and argue that supply chain visibility is necessarily for transparency. In our usage of the term, we further restrict the high visibility case to the situation in which the supply chain is visible to the manager, yet the manager is unable to communicate this information to the market without first acquiring evidence.

optimal for the firm's effort to remain unobservable to the market, and for the disclosure of evidence to be voluntary, thereby encouraging the firm to acquire evidence. The rationale behind this approach is as follows: if the firm is expected to gather evidence, the market views a lack of disclosure with skepticism. This skepticism arises because it is impossible to discern whether the firm has failed to acquire evidence or is concealing unfavorable evidence. To avoid such skepticism, the firm conducts investigations and discloses the findings. Furthermore, no other combination of mandates is able to incentivize evidence acquisition when the firm lacks knowledge about its supply chain. If the policymaker mandates disclosure of effort, by exerting no effort, the firm is able to convince the market that the absence of disclosure is due to a lack of investigation altogether. Similarly, if the policymaker mandates disclosure of evidence, the firm can assure the market that there is indeed nothing to disclose when it does not disclose. In both cases, the absence of disclosure is not interpreted negatively by the market. This means that the firm has no incentives to acquire evidence.

In the case with high visibility, the firm has full knowledge of its supply chain. Through investigation, the firm obtains evidence only, which it can use to prove its supplier's impacts to the market. In such case, it is optimal to mandate the disclosure of both effort and evidence obtained. The rationale behind this approach is as follows: a firm can signal its private information through the chosen effort level. Without mandating the disclosure of effort, which enables the market to monitor evidence acquisition, this signaling mechanism is impossible. Similarly, in the absence of mandatory disclosure of evidence, firms with high impacts can imitate firms with low impacts by putting extensive effort without the risk of being exposed, making full separation of high- and low-impact firms impossible in equilibrium.

We further consider an extension in which the firm can credibly reveal its effort to the market. In this case, information regarding effort, like evidence, is hard. We show that even in this case, our main results hold, albeit in a weaker sense, i.e., the original optimal policy is still optimal, but not uniquely so.

To the best of our knowledge, this paper is the first to compare supply chains with low

and high visibility and examine the policy implications on disclosure mandates as well as to consider disclosure mandate on two dimensions, i.e., the effort to acquire evidence and the decision to disclose acquired evidence. We demonstrate that the difference in visibility is crucial in determining the optimal intervention.

2 Literature review

Our paper belongs to the literature on quality disclosure and certification. An overview of the theoretical literature is given by Milgrom (2008) while Dranove and Jin (2010) review the empirical literature. Early seminal works of this literature include Grossman (1981) and Milgrom (1981), who study the implications of voluntary disclosure of verifiable information in markets and show that information is fully disclosed in equilibrium. Dye (1985) and Jung and Kwon (1988) show that uncertainty about the sender’s information endowment precludes full disclosure.⁷ In these models, mandating disclosure can only increase market information.

Several papers show that this conclusion no longer holds when the sender’s information is endogenized and regulations may backfire. This is because even though disclosure requirement increases information revelation, it discourages the sender from acquiring it (Matthews and Postlewaite 1985; Polinsky and Shavell 2012; Shavell 1994). Weksler and Zik (2023) generalize this result to privately informed firms. In the context of supply chain management, Kalanci and Plambeck (2020) consider how disclosure mandates affect a manager’s decision to learn about the supplier’s impacts and his effort to reduce them, and show that disclosure mandates might result in higher expected impacts. Kalanci et al. (2016) provide support for this thesis using consumer choice experiments.

Similarly, Milgrom (2008), Henry (2009), Felgenhauer and Loerke (2017), Wong and Yang (2018) and Herresthal (2022) show that disclosure of effort to acquire evidence can likewise undermine the sender’s incentives to acquire information and hurt the receiver. In the context of supply chain management, Cho et al. (2019) consider a mandate for the

⁷Not all the papers we cite in this section apply the disclosure model in a supply chain context. Therefore, we sometimes also use the term “sender” more generally to refer to the firm and “receiver” to refer to the market.

downstream firm to disclose its policy regarding auditing for child labor and show that this can backfire by enabling the downstream firm to choose not to audit and thus allowing the upstream firm to employ child labor. In these papers, the sender is uninformed. Our analysis suggests that the optimal regulation under private information could be drastically different.

Che and Kartik (2009), Kartik, Lee and Suen (2017), DeMarzo, Kremer and Skrzypacz (2018) and Wong and Yang (2021) also study models of voluntary disclosure with endogenous evidence acquisition but have different focuses. Che and Kartik (2009) show that difference between the decision maker's belief and the expert's belief can incentivize the expert to acquire information. Kartik, Lee and Suen (2017) study how the presence of multiple senders affects information acquisition in the disclosure model. Wong and Yang (2021) consider a dynamic version of their model. DeMarzo, Kremer and Skrzypacz (2018) study a model in which the seller can choose from a set of tests and show that the simple pass/fail tests are likely to dominate the market.

Our paper is also related to the literature on certification initiated by Lizzeri (1999). Two papers have pointed out that sellers' certification decisions itself can signal private information. Marinovic and Sridhar (2015) show that if a seller makes the certification decision before observing the certifier's assessment, favorable disclosures are more informative than unfavorable disclosures as they signal the seller's positive private information. Stahl and Strausz (2017) show that, because of the possibility of signaling through certification decision, seller-induced certification leads to more market transparency than buyer-induced certification. In the high visibility environment of our model, the firm's decision to exert effort can signal information in a similar way. However, our focus is on how disclosure mandate of *evidence* can help enable such a signaling mechanism, which has not been pointed out in the literature before.

The rest of the paper is organized as follows. Section 3 introduces the model. Section 4 studies the low visibility case while Section 5 studies the high visibility case. Section 6 considers an extension of the model in which the firm can credibly reveal its effort to the market. Section 7 concludes. The appendix contains omitted proofs.

3 Model

Consider a firm, whose suppliers' production process causes some social and environmental impacts. The market values firms with lower impacts, a firm's valuation gets higher when its perceived impacts are lower.

Denote the impact level by θ , which is distributed according to some prior distribution F . We assume that F is strictly increasing and admits a probability density function f on $[0, 1]$. We denote the associated random variable by $\tilde{\theta}$.

The game has two stages. In stage I, the evidence acquisition stage, the firm can launch an investigation of its suppliers' production process to obtain evidence about its impact level. The firm can choose the scope of the investigation, and a more thorough investigation costs more. Denote the cost of investigation by $c \in \mathbb{R}_+$. When the firm spends c in investigation, it obtains evidence with probability $p(c)$. The function $p(c)$ is twice-continuously differentiable and for all $c \in \mathbb{R}_+$, $p'(c) > 0$, $p''(c) < 0$. Moreover, $p(0) = 0$ and $p(c)$ satisfies the Inada conditions, i.e., $\lim_{c \rightarrow 0} p'(c) = \infty$ and $\lim_{c \rightarrow \infty} p'(c) = 0$.⁸ Therefore, no evidence is obtained when $c = 0$, and it is infinitely costly to obtain the evidence for certain.

In stage II, the evidence disclosure stage, the firm chooses whether to disclose obtained evidence in case the investigation is successful and disclosure is not mandatory (see later for details). If evidence is disclosed, the evidence constitutes a conclusive proof of the realized value of $\tilde{\theta}$. Given the disclosure or the lack of disclosure, the firm's valuation is determined by the market, and the valuation is an exogenous value $v > 1$ minus the expected value of θ given all the information available. The firm's objective is to maximize its expected market value net of investigation costs. If disclosure is mandatory, the firm must disclose evidence it possesses.

Firm's information. We consider two information environments. In the low visibility environment, the firm is uninformed about the impact level θ at the outset of game. In the high visibility environment, the firm knows the impact level θ . The difference in prior

⁸Notice that the second Inada condition is implied by monotonicity, concavity and boundedness.

knowledge of the impact θ implies that the firm’s strategy in the evidence acquisition stage is different in the two environments. When the firm is uninformed, the firm’s evidence acquisition strategy is a distribution over effort levels. When the firm is informed, the firm’s evidence acquisition strategy is a mapping from the impact levels to distributions over effort levels.

Policy regimes. There are two dimensions of information disclosure on which a policymaker can intervene. One dimension of information disclosure is disclosure of the evidence acquisition effort. The other dimension of information disclosure is disclosure of the acquired evidence. The policymaker can decide whether the market observes the firm’s effort (overt investigation) or not (covert investigation). The policymaker can also decide whether disclosure of evidence is mandatory or voluntary. Therefore, we consider the following four policy regimes: 1) overt investigation with mandatory disclosure, 2) overt investigation with voluntary disclosure, 3) covert investigation with mandatory disclosure, and 4) covert investigation with voluntary disclosure. We assume that the objective of the policymaker is to maximize the amount of information revealed to the market in equilibrium.⁹ If a policy regime admits multiple equilibria, we measure market information by the most informative equilibrium. Our main results do not depend on the particular informativeness criterion used to measure market information. They hold as long as the informativeness criterion is an extension of Blackwell’s order.¹⁰

4 Uninformed firm: low supply chain visibility

In this section, we provide the equilibrium characterizations in the low visibility environment, where the firm is not informed about its impact level before evidence acquisition,

⁹We focus on the amount of information revealed to the market because information could have an intrinsic value to the consumers (see Section 2.1 of DeMarzo, Kremer and Skrzypacz (2018), for example, for an alternative way to interpret our model so that better information improves the allocation of a good to the consumers) and it facilitates the society to monitor the firms and to put more pressure on the firms to reduce impacts (Doshi et al., 2013). Of course, market information is just a proxy of the actual improvement in welfare. The exact mechanism behind this is beyond the scope of the current paper.

¹⁰One such informativeness criterion that is commonly used in the literature is the expected precision of the market belief, which measures how much the posterior mean of the market belief deviates from the truth. For a given equilibrium, if the unconditional distribution of the equilibrium posterior market belief $\tilde{\pi}$ is given by G , market information under the expected precision criterion is defined as $I = -\mathbb{E}_G[\mathbb{E}_{\tilde{\pi}}(\mathbb{E}_{\tilde{\pi}}[\hat{\theta}] - \hat{\theta})^2]$.

and compare market information across the four policy regimes.

First, we show that when investigation is overt, the firm finds it optimal not to obtain evidence, regardless of the evidence disclosure mandate.

Lemma 1 *Suppose the firm is uninformed. If investigation is overt, then the firm does not attempt to acquire evidence in equilibrium, i.e., $c^* = 0$.*

Proof. By the law of iterated expectations, in any equilibrium, the ex ante expected value of the market valuation must be $v - \mathbb{E}[\tilde{\theta}]$. Since investigation effort is observed by the market, if the firm chooses not to acquire evidence, the market expects no evidence from the firm and the firm's market valuation remains at $v - \mathbb{E}[\tilde{\theta}]$. This means that the firm's payoff is maximized by choosing $c = 0$ and any other choice of effort gives the firm a strictly lower payoff. ■

The intuition behind Lemma 1 is that by conducting an investigation, the firm may find good news or bad news. Good news leads to higher valuation while bad news leads to lower valuation. On average, these effects cancel out. The firm thus is better off not to acquire evidence.¹¹

Next, we show that when investigation is covert and evidence disclosure is mandatory, the firm likewise would not exert any effort to obtain evidence.

Lemma 2 *Suppose the firm is uninformed. If investigation is covert and evidence disclosure is mandatory, then the firm does not attempt to acquire evidence in equilibrium, i.e., $c^* = 0$.*

Proof. Suppose to the contrary that there exists an equilibrium in which the firm exerts positive effort with positive probability. Then with positive probability the firm obtains evidence and has to disclose it. Since the probability of obtaining evidence is independent of the state, the expected impact level in this case must be $\mathbb{E}[\tilde{\theta}]$. With complementary probability, the firm gets no evidence. Independence implies that in this case the market belief remains at $\mathbb{E}[\tilde{\theta}]$. Therefore, the firm's expected payoff is thus $v - \mathbb{E}[\tilde{\theta}] - c$. On the

¹¹A similar argument has been used by Kamenica and Gentzkow (2011) to show that a sender cannot benefit from persuasion when his payoff is a concave function of the expected state.

other hand, deviating to $c = 0$ results in a payoff of $v - \mathbb{E}[\tilde{\theta}]$. Thus, the firm is strictly better off exerting no effort. ■

Similar to Lemma 1, Lemma 2 shows that the firm cannot improve its expected payoff by exerting effort and, as a result, is better off exerting no effort. However, it should be noted that while these two lemmas appear to be similar, they rely on very different arguments. The proof of Lemma 1 uses only the law of iterated expectations to show that the firm cannot benefit from acquiring evidence. Therefore, it holds regardless of the joint distribution of the state and evidence given effort level. Lemma 2, on the other hand, relies on the fact that the probability of obtaining evidence is independent of the impact level. If, for example, the firm can direct the investigation to good evidence so that the probability of obtaining evidence is positively correlated with the impact level, then the market would revise its belief about the firm's impact level upward upon seeing no disclosure. As a result, the firm has incentive to exert a positive amount of effort. In the next lemma, we show that the possibility of withholding bad evidence in effect creates such a positive correlation between the state and disclosure endogenously.

Lemma 3 *Suppose the firm is uninformed. If investigation is covert and evidence disclosure is voluntary, then the firm exerts a positive amount of effort in equilibrium, i.e., $c^* > 0$.*

The intuition behind this result is straightforward. When investigation is covert and disclosure is voluntary, acquiring evidence has an option value to the firm, that is, the firm can reveal evidence when it is favorable and withhold it when it is not. As a result, the firm exerts non-zero effort in equilibrium. Notice, however, that the same reasoning does not apply when investigation is overt. This is because in that case the market would adjust its expectation according to the firm's effort level. When a firm exerts more effort, the market deems that the firm is more likely to have obtained evidence and the lack of disclosure is punished more severely. This cancels out any potential gain from obtaining favorable evidence and destroys the option value of evidence, resulting in zero evidence acquisition as shown in Lemma 1. Notice also that Lemma 3 does not rule out the possibility of multiple

equilibria. However, it does assert that in any equilibrium, the firm does not randomize over effort levels.

It is clear from Lemmas 1–3 that the policy regime with covert investigation and voluntary evidence disclosure leads to strictly more market information than any other regimes.

Proposition 1 *Suppose the firm is uninformed. The policy regime with covert investigation and voluntary evidence disclosure uniquely maximizes market information.*

Table 1 summarizes the equilibrium effort levels across the four regimes.

	Mandatory evidence disclosure	Voluntary evidence disclosure
Overt investigation	0	0
Covert investigation	0	$c^* > 0$

Table 1: Equilibrium effort in the low visibility case

5 Informed firm: high supply chain visibility

In this section, we compare market information across the four policy regimes in the high visibility environment, where the firm is perfectly informed about its impact level before evidence acquisition. When investigation is overt, we establish that there exists an equilibrium in which the market knows the impact level if and only if disclosure is mandatory. Then we discuss the case when investigation is covert.

When the firm is informed and investigation is overt, the market can make inference about the firm’s private information from the observed effort level. In a pure strategy equilibrium, denote the firm’s equilibrium effort level as a function of its impact level θ by $c^*(\theta)$. When $c^*(\theta)$ is one-to-one, the market can infer the firm’s impact level perfectly. Such an equilibrium is called a fully separating equilibrium in the signaling literature.¹²

¹²Notice that it is without loss of generality for us to assume here that a fully separating equilibrium must also be a pure strategy equilibrium. This is because, if the market infers perfectly that the firm has a particular impact level after observing two different effort levels, then the firm would strictly prefer to choose the lower effort level, which implies that a fully separating equilibrium in mixed strategies is impossible.

Definition 1 *Suppose the firm is perfectly informed and investigation is overt. A pure strategy equilibrium is fully separating if and only if the firm's equilibrium effort level $c^*(\theta)$ is a one-to-one function of its impact level θ .*

Clearly, market information reaches its maximum level in a fully separating equilibrium. We define

Definition 2 *Given an equilibrium, we say that market information is maximal if and only if the market is perfectly informed of the firm's impact level in equilibrium, otherwise, market information is submaximal.*

Moreover, the second Inada condition on the function $p(c)$ implies that the firm will never obtain evidence with probability 1. This means that only in a fully separating equilibrium market information is maximal.

It is well known in the signaling literature that the existence of a fully separating equilibrium depends on the Spence-Mirrlees single-crossing condition.¹³ Let $U(\theta, \vartheta, c)$ be the payoff of the firm when the impact level is θ , the market's belief of its impact level in the absence of evidence is ϑ and the firm incurs cost c . The single-crossing condition is satisfied if $U_3(\theta, \vartheta, c)/U_2(\theta, \vartheta, c)$ is strictly increasing in θ , which implies that indifference curves of firms with different impact levels cross only once. Intuitively, $U_3(\theta, \vartheta, c)$ is the marginal cost of raising the probability of obtaining evidence and $U_2(\theta, \vartheta, c)$ is the marginal cost of raising market's belief of its impact level. When the single-crossing condition is satisfied, the marginal rate of substitution of the two is strictly increasing in the firm's impact level θ . Thus, given any (ϑ, c) , a firm with a lower impact level is more willing to exert effort than a firm with a higher impact level. As a result, low-impact firms are able to separate themselves from high-impact firms in equilibrium.

When disclosure is mandatory, the market's belief of the impact level is θ when evidence is obtained and ϑ otherwise. Thus,

$$U(\theta, \vartheta, c) = v - p(c)\theta - (1 - p(c))\vartheta - c.$$

¹³Mailath (1987) and Mailath and von Thadden (2013) show the existence of a unique separating equilibrium for a broad class of signaling models when the Spence-Mirrlees single-crossing condition is satisfied.

Moreover,

$$\frac{U_3(\theta, \vartheta, c)}{U_2(\theta, \vartheta, c)} = \frac{p'(c)(\theta - \vartheta) + 1}{1 - p(c)},$$

which is strictly increasing in θ . The single-crossing condition is satisfied. Thus, we have

Lemma 4 *Suppose the firm is perfectly informed. If investigation is overt and evidence disclosure is mandatory, then there exists a fully separating equilibrium.*

The single-crossing condition breaks down when evidence disclosure is voluntary. Since a firm with $\theta > \vartheta$ is better off withholding the evidence, the function $U(\theta, \vartheta, c)$ becomes

$$U(\theta, \vartheta, c) = \begin{cases} v - \vartheta - c & \text{if } \theta \geq \vartheta, \\ v - p(c)\theta - (1 - p(c))\vartheta - c & \text{if } \theta < \vartheta. \end{cases}$$

Notice that, for $\theta \geq \vartheta$, the firm's payoff $U(\theta, \vartheta, c)$ does not depend on θ . As a result, the indifference curves of high- and low-impact firms overlap with each other in this region. This means that the single-crossing condition is violated.¹⁴ Since a high-impact firm can pretend to be a low-impact firm at no additional cost, low-impact firms cannot separate themselves fully from high-impact firms. This leads to our next result.

Lemma 5 *Suppose the firm is perfectly informed. If investigation is overt and evidence disclosure is voluntary, then a fully separating equilibrium does not exist.*

Proof. Suppose to the contrary that a fully separating equilibrium exists. Let $c^*(\theta)$ denote the firm's equilibrium effort level given impact level θ . Since a firm with impact level θ can pretend to be a firm with impact level θ' by exerting effort $c^*(\theta')$ and hiding the obtained evidence, we must have

$$v - \theta - c^*(\theta) \geq v - \theta' - c^*(\theta'), \tag{1}$$

¹⁴Since $U(\theta, \vartheta, c)$ is not differentiable when $\theta = \vartheta$, it automatically fails the Spence-Mirrlees single-crossing condition formulated earlier in the text, which presumes differentiability. However, our discussion here further shows that it also fails a weaker version of the single-crossing condition that does not require differentiability (Edlin and Shannon 1998).

for all $\theta, \theta' \in [0, 1]$. On the other hand, a firm with impact level θ' also has the option to exert effort $c^*(\theta)$ and disclose its true type if it finds evidence. Therefore, for all $\theta, \theta' \in [0, 1]$,

$$v - \theta' - c^*(\theta') \geq v - p(c^*(\theta))\theta' - (1 - p(c^*(\theta)))\theta - c^*(\theta). \quad (2)$$

Combining (1) and (2), we have, for all $\theta, \theta' \in [0, 1]$,

$$p(c^*(\theta))(\theta' - \theta) \geq 0$$

which dictates that $p(c^*(\theta)) = 0$ for all $\theta \in [0, 1]$, contradicting the assumed existence of a fully separating equilibrium. ■

Next, we move to the two policy regimes with covert investigation.

Lemma 6 *Suppose the firm is perfectly informed. When investigation is covert, mandatory and voluntary disclosure of evidence lead to an identical level of market information that is submaximal.*¹⁵

Lemma 6 shows that when investigation is covert, the evidence disclosure policy has no effect on how much information is revealed to the market. The reason is fairly simple. Since the firm is perfectly informed about its impact level θ , it perfectly foresees whether evidence will be useful in the disclosure stage. Therefore, if the firm is willing to acquire evidence, it must be willing to reveal it. This means that disclosure mandate has no bite and the set of equilibrium outcomes is the same under both disclosure policies, which in turn implies that market information under the two policy regimes is the same.

Combining the results in Lemmas 4-6, we have

Proposition 2 *Suppose the firm is perfectly informed. The policy regime with overt investigation and mandatory evidence disclosure uniquely maximizes market information.*

Table 2 summarizes the main results of this section.

¹⁵Recall that when there are multiple equilibria, we measure market information by the most informative equilibrium.

	Mandatory evidence disclosure	Voluntary evidence disclosure
Overt investigation	Maximal market information	Submaximal market information
Covert investigation	Same submaximal market information	

Table 2: Market information in the high visibility case

6 Verifiable disclosure of effort

In this section, we extend our baseline model to allow the firm to reveal its choice of effort to the market when investigation is covert. We show that this changes the equilibria of our model in a significant way. Nevertheless, we show that even in this case, our main results hold, but only in a weak sense, namely, the information-maximizing policy regime in the baseline model continues to maximize market information under the alternative assumption, albeit no longer uniquely so. In both the low and high visibility scenarios, there is at least one other policy regime that results in the same level of market information.

Formally, when investigation is covert, we introduce an effort disclosure stage after the decision to acquire evidence and before the firm obtains evidence. In this stage, the firm can choose whether to reveal its previous choice of effort to the market or not. One way to interpret this is that after exerting effort, the firm obtain a piece of evidence that can serve as proof of its effort and chooses whether to disclose it to the market or not.

We first consider the low visibility case when the firm is uninformed. We show that in this case the ability to credibly reveal effort effectively makes effort observable to the market.

Lemma 7 *Suppose the firm is uninformed and investigation is covert, but the firm can credibly reveal its effort to the market. Then the firm exerts no effort in equilibrium, regardless of the evidence disclosure mandate.*

Proof. The logic behind this result is similar to Lemma 1, which assumes that investigation is overt. By the law of iterated expectations, in any equilibrium, the ex ante expected value

of the market valuation must be $v - \mathbb{E}[\tilde{\theta}]$. If the firm can credibly reveal its effort, it can achieve its maximum payoff simply by exerting no effort and then revealing it. Therefore, in any equilibrium, the firm must not exert any effort. ■

Combining Lemmas 1 and 7, we conclude that in this case, all policy regimes lead to no evidence acquisition. This is summarized in Table 3.

	Mandatory evidence disclosure	Voluntary evidence disclosure
Overt investigation	0	0
Covert investigation	0	0

Table 3: Equilibrium effort in the low visibility case with verifiable disclosure of effort

From Table 3, it is clear that:

Proposition 3 *Suppose the firm is uninformed and the firm can credibly reveal its effort to the market when investigation is covert. The policy regime with covert investigation and voluntary evidence disclosure maximizes market information.*

Comparing Propositions 1 and 3, we see that covert investigation and voluntary evidence disclosure no longer constitute the unique policy that maximizes market information. In fact, in this case, the policy regime is irrelevant for market information.

Next, we move to the high visibility case when the firm is perfectly informed. We are interested in whether the maximal market information can be achieved when investigation is covert. Our next lemma shows that this is possible when evidence disclosure is mandatory.

Lemma 8 *Suppose the firm is perfectly informed and investigation is covert, but the firm can credibly reveal its effort to the market. There exists an equilibrium in which market information is maximal if and only if evidence disclosure is mandatory.*

Proof. In order to have maximal market information, the firm must choose a different effort level for each impact level and then reveal it to the market. By Lemma 5, this cannot be a part of the equilibrium when evidence disclosure is voluntary. When evidence

disclosure is mandatory, the market can punish hidden effort through the most pessimistic belief about the impact level. This means that the firm would always find it optimal to reveal its effort. We then use the construction in Lemma 4 to construct an equilibrium in which market information is maximal. ■

Table 4 summarizes the results in the high visibility case with verifiable disclosure of effort.

	Mandatory evidence disclosure	Voluntary evidence disclosure
Overt investigation	Maximal market information	Submaximal market information
Covert investigation		Submaximal market information

Table 4: Market information in the high visibility case with verifiable disclosure of effort

From Table 4, it is clear that:

Proposition 4 *Suppose the firm is perfectly informed and the firm can credibly reveal its effort to the market when investigation is covert. The policy regime with overt investigation and mandatory evidence disclosure maximizes market information.*

Taken together, Propositions 1–4 show that, regardless whether the firm is able to credibly disclose its effort level, the policy regime with covert investigation and voluntary evidence disclosure is optimal in the low visibility case, and the policy regime with overt investigation and mandatory evidence disclosure is optimal in the high visibility case. This shows the robustness of the optimal policies with respect to the nature of information regarding effort.

7 Conclusion

In this paper, we study a model of evidence acquisition and disclosure in a supply chain setting. We find that the optimal disclosure mandate depends crucially on supply chain visibility prior to evidence acquisition. When visibility is low, it is optimal to impose

no disclosure requirements to incentivize evidence acquisition, while stringent disclosure mandates help to facilitate information transmission when visibility is high. Our results provide a rationale for varying regulatory approaches in markets with different levels of supply chain visibility. Additionally, it sheds light on the growing demand for supply chain transparency as visibility improves in recent years.

References

- [1] Budler, M., Quiroga, B. F., & Trkman, P. (2024). A review of supply chain transparency research: Antecedents, technologies, types, and outcomes. *Journal of Business Logistics*, 45(1), e12368.
- [2] Che, Y. K., & Kartik, N. (2009). Opinions as incentives. *Journal of Political Economy*, 117(5), 815–860.
- [3] Cho, S. H., Fang, X., Tayur, S., & Xu, Y. (2019). Combating child labor: Incentives and information disclosure in global supply chains. *Manufacturing & Service Operations Management*, 21(3), 692-711.
- [4] Crawford, V. P., & Sobel, J. (1982). Strategic information transmission. *Econometrica*, 50(6), 1431–1451.
- [5] DeMarzo, P. M., Kremer, I., & Skrzypacz, A. (2019). Test design and minimum standards. *American Economic Review*, 109(6), 2173–2207.
- [6] Doshi, A. R., Dowell, G. W., & Toffel, M. W. (2013). How firms respond to mandatory information disclosure. *Strategic Management Journal*, 34(10), 1209-1231.
- [7] Dranove, D., & Jin, G. Z. (2010). Quality disclosure and certification: Theory and practice. *Journal of Economic Literature*, 48(4), 935-963.
- [8] Dye, R. A. (1985). Disclosure of nonproprietary information. *Journal of Accounting Research*, 23(1), 123–145.

- [9] Edlin, A. S., & Shannon, C. (1998). Strict single crossing and the strict Spence-Mirrlees condition: a comment on monotone comparative statics. *Econometrica*, 66(6), 1417-1425.
- [10] Grossman, S. J. (1981). The informational role of warranties and private disclosure about product quality. *The Journal of Law and Economics*, 24(3), 461-483.
- [11] Henry, E. (2009). Strategic disclosure of research results: The cost of proving your honesty. *The Economic Journal*, 119(539), 1036-1064.
- [12] Herresthal, C. (2022). Hidden testing and selective disclosure of evidence. *Journal of Economic Theory*, 200, 105402.
- [13] Hilke, A., Hubert, R., Pauthier, A., & Raynaud, J. 2021. Taking Climate-related Disclosure to the Next Level: Minimum Requirements for Financial Institutions. Institute for Climate Economics. https://www.i4ce.org/wp-core/wp-content/uploads/2021/05/I4CE-ILB_2021_Taking-climate-related-disclosure-to-the-next-level.pdf
- [14] Jung, W. O., & Kwon, Y. K. (1988). Disclosure when the market is unsure of information endowment of managers. *Journal of Accounting research*, 26(1), 146-153.
- [15] Kalkanici, B., Ang, E., & Plambeck, E.L. (2016). Strategic Disclosure of Social and Environmental Impacts in a Supply Chain. In: Atasu, A. (eds) *Environmentally Responsible Supply Chains*. Springer.
- [16] Kalkanici, B., & Plambeck, E. L. (2020). Managing supplier social and environmental impacts with voluntary versus mandatory disclosure to investors. *Management Science*, 66(8), 3311-3328.
- [17] Kamenica, E., & Gentzkow, M. (2011). Bayesian persuasion. *American Economic Review*, 101(6), 2590-2615.
- [18] Kartik, N., Lee, F. X., & Suen, W. (2017). Investment in concealable information by biased experts. *The RAND Journal of Economics*, 48(1), 24-43.

- [19] KPMG. (2013). Competitive Advantage: Enhancing Supply Chain Networks for Efficiency and Innovation. Global Manufacturing Outlook. <https://assets.kpmg/content/dam/kpmg/pdf/2013/07/Global-Manufacturing-Outlook-O-201307.pdf>
- [20] Kraft, T., Valdés, L., & Zheng, Y. (2018). Supply chain visibility and social responsibility: Investigating consumers' behaviors and motives. *Manufacturing & Service Operations Management*, 20(4), 617-636.
- [21] GEODIS. (2017). Supply Chain Worldwide Survey. <https://geodis.com/de/en/newsroom/communiqués-de-presse/geodis-unveils-its-2017-supply-chain-worldwide-survey>
- [22] Lizzeri, A. (1999). Information revelation and certification intermediaries. *The RAND Journal of Economics*, 30(2), 214–231.
- [23] Mailath, G. J. (1987). Incentive compatibility in signaling games with a continuum of types. *Econometrica*, 55(6), 1349–1365.
- [24] Mailath, G. J., & Von Thadden, E. L. (2013). Incentive compatibility and differentiability: New results and classic applications. *Journal of Economic Theory*, 148(5), 1841–1861.
- [25] Marinovic, I., & Sridhar, S. S. (2015). Discretionary disclosures using a certifier. *Journal of Accounting and Economics*, 59(1), 25–40.
- [26] Matthews, S., & Postlewaite, A. (1985). Quality testing and disclosure. *The RAND Journal of Economics*, 16(3), 328–340.
- [27] Milgrom, P. R. (1981). Good news and bad news: Representation theorems and applications. *The Bell Journal of Economics*, 12(2), 380–391.
- [28] Milgrom, P. (2008). What the seller won't tell you: Persuasion and disclosure in markets. *Journal of Economic Perspectives*, 22(2), 115–131.

- [29] Polinsky, A. M., & Shavell, S. (2012). Mandatory versus voluntary disclosure of product risks. *The Journal of Law, Economics, & Organization*, 28(2), 360–379.
- [30] Pucker, K. P. (2021) Overselling sustainability reporting. *Harvard Business Review*.
- [31] Sarbanes-Oxley Act (2002) Pub. L. 107-204, United States Statutes at Large. 116 STAT. 745 (July 30): Section 802(a).
- [32] Securities and Exchange Commission. (2012). SEC Conflict Minerals Final Rule. <http://www.sec.gov/rules/final/2012/34-67716.pdf>
- [33] Shavell, S. (1994). Acquisition and disclosure of information prior to sale. *The RAND Journal of Economics*, 25(1), 20–36.
- [34] Stahl, K., & Strausz, R. (2017). Certification and market transparency. *The Review of Economic Studies*, 84(4), 1842–1868.
- [35] Teschl, G. (2012). *Ordinary differential equations and dynamical systems*. American Mathematical Society.
- [36] Weksler, R., & Zik, B. (2023). Disclosure in Markets for Ratings. *American Economic Journal: Microeconomics*, 15(3), 501-526.
- [37] Wong, T. N., & Yang, L. L. (2018). When does monitoring hurt? Endogenous information acquisition in a game of persuasion. *Economics letters*, 163, 186–189.
- [38] Wong, T. N., & Yang, L. L. (2021). Dynamic expert incentives in teams. *Games and Economic Behavior*, 125, 27–47.

Appendix

Proof of Lemma 3. Suppose that the equilibrium distribution over effort is σ^* . Let p^* be the expected probability that the firm obtains evidence, i.e., $p^* = \int_0^\infty p(c)d\sigma^*(c)$, and θ^* be the threshold defined by

$$\theta^* = \frac{1 - p^*}{1 - p^* + p(1 - F(\theta^*))} \mathbb{E}[\tilde{\theta}] + \frac{p^*(1 - F(\theta^*))}{1 - p + p^*(1 - F(\theta^*))} \mathbb{E}[\tilde{\theta} | \theta > \theta^*], \quad (3)$$

which is the market's expectation of the impact level of a firm that does not disclose in equilibrium. By the intermediate value theorem, θ^* satisfying (3) exists.

In equilibrium, the firm discloses the acquired evidence if and only if the payoff of disclosure is greater than that of no disclosure. i.e., $\theta \leq \theta^*$, and the expected increase in the firm's payoff in this case is $\theta^* - \mathbb{E}[\tilde{\theta}|\tilde{\theta} \leq \theta^*]$. Therefore, the necessary condition for c^* to be in the support of σ^* is

$$p'(c^*)F(\theta^*) \left(\theta^* - \mathbb{E}[\tilde{\theta}|\tilde{\theta} \leq \theta^*] \right) - 1 = 0. \quad (4)$$

The sufficient condition is

$$p''(c^*)F(\theta^*) \left(\theta^* - \mathbb{E}[\tilde{\theta}|\tilde{\theta} \leq \theta^*] \right) < 0,$$

which holds since $\theta^* \geq \mathbb{E}[\tilde{\theta}] > 0$, so $F(\theta^*) > 0$ and $\theta^* > \mathbb{E}[\tilde{\theta}|\tilde{\theta} \leq \theta^*]$ and $p''(c) < 0$ by assumption. Note that (4) implies that the support of σ^* is a singleton. Since $\lim_{c \rightarrow 0} p'(c) \rightarrow \infty$, $c^* = 0$ violates (4), and therefore cannot be the equilibrium choice of effort. Hence, if an equilibrium exists, it must feature a strictly positive amount of effort. To see that an equilibrium exists, note that, as $c^* \rightarrow 0$, the left-hand side of (4) tends to infinity. As $c^* \rightarrow \infty$, the left-hand side of (4) tends to 0. By the intermediate value theorem, there exists a c^* that satisfies (4). ■

Proof of Lemma 4. Suppose a fully separating equilibrium exists, and let $V(\theta)$ be the equilibrium payoff of a firm with impact level θ in such an equilibrium and $c(\theta)$ be the corresponding equilibrium choice of effort. Then, incentive compatibility implies

$$V(\theta) = \max_{\theta' \in [0,1]} \{v - p(c(\theta'))\theta - (1 - p(c(\theta')))\theta' - c(\theta')\}. \quad (5)$$

Taking the derivative of (5), we find that a fully separating equilibrium must satisfy the differential equation

$$c'(\theta) = -(1 - p(c)), \quad (6)$$

with the initial condition $c(1) = 0$, if $c(\theta)$ is differentiable. Since $p(c)$ is continuous, by Peano's theorem (see Teschl (2012), Theorem 2.19), a solution to (6) exists.

We next establish that the solution is indeed an equilibrium by verifying that the firm has no profitable global deviations. By the envelope theorem, we have,

$$V(\theta) = V(0) - \int_0^\theta p(c(z)) dz. \quad (7)$$

The condition for no profitable global deviations is

$$v - p(c(\theta))\theta - (1 - p(c(\theta)))\theta - c(\theta) \geq v - p(c(\theta'))\theta - (1 - p(c(\theta')))\theta' - c(\theta'),$$

which, using (7), can be restated as

$$- \int_{\theta'}^\theta p(c(z)) dz \geq -p(c(\theta'))(\theta - \theta'),$$

which is satisfied, as $c(\theta)$ is decreasing by (6). ■

Proof of Lemma 6. Suppose evidence disclosure is voluntary. Let θ^* denote the market's expected impact level conditional on no disclosure in equilibrium. In the disclosure stage, the firm's optimal choice is to disclose if and only if $\theta \leq \theta^*$. Therefore, if the firm's impact level is higher than θ^* , it is never optimal to exert any effort in the evidence acquisition stage. Since the firm only acquires evidence if $\theta \leq \theta^*$, it always discloses the evidence in equilibrium. As a result, the disclosure mandate has no impact on the firm's behavior. This means that the equilibrium effort and thus the amount of information revealed must be identical under the two regimes. ■