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Is the public detection of managers' emission-related actions desirable?

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Summary: We consider the contracting problem between a firm and a manager. The manager provides productive efforts to increase the firm's financial performance and to reduce its carbon emissions. The outcome of these efforts depends on the manager's 'green' ability. The manager is interested in the public perception of his green ability, which affects his future employment opportunities in the managerial job market. We study how the public detection of the manager's emission-related decisions affects optimal contract design. Our results show that a higher detection probability leads the firm to implement stronger explicit incentives for reducing carbon emissions and increasing financial performance. Public scrutiny regarding managerial actions is desirable under two conditions. First, the probability of detecting greenwashing must be higher than the probability of verifying abatement actions. Second, both detection probabilities should not be excessively high.

Keywords: Carbon Emissions; Sustainability; ESG Reporting; Greenwashing; Brownwashing; Career Concerns; Incentive Contracts; Transparency

Ist die öffentliche Aufdeckung emissionsbezogener Managemententscheidungen wünschenswert?

Zusammenfassung: Wir betrachten das Anreizproblem zwischen einem Unternehmen und seinem Manager. Der Manager kann Massnahmen zur Erhöhung des finanziellen Unternehmensergebnisses und zur Reduktion von Treibhausgasemissionen ergreifen. Der Erfolg dieser Massnahmen hängt vom 'grünen' Talent des Managers ab, dessen öffentliche Wahrnehmung seinen Wert am Arbeitsmarkt bestimmt. Wir untersuchen, wie sich die optimale Struktur der Managementvergütung verändert, wenn die Massnahmen des Managers publik werden können. Unsere Ergebnisse zeigen, dass Unternehmen, bei denen die Massnahmen des Managements mit einer höheren Wahrscheinlichkeit publik werden, stärkere explizite Anreize zur Reduktion der Emissionen und zur Steigerung des finanziellen Erfolgs setzen. Ein stärkerer öffentlicher Druck durch erhöhte Transparenz ist unter zwei Bedingungen wünschenswert. Einerseits muss es wahrscheinli-

cher sein, die Massnahmen zur Emissionsreduktion aufzudecken als diejenigen zum Zwecke des Greenwashing. Andererseits darf die Wahrscheinlichkeit, dass beide Aktivitäten publik werden, insgesamt nicht zu hoch ausfallen.

Stichwörter: Treibhausgasemissionen; Nachhaltigkeit; ESG-Berichterstattung; Greenwashing; Brownwashing; Career Concerns; Anreizverträge; Transparenz

1. Introduction

Firms and their managers face considerable pressure to contribute to the ecological transformation of society. Recent regulations require firms to issue reports on their environmental footprint including detailed information about their carbon emissions.[1] On the side of management, there is considerable demand for sustainability-focused executives in the managerial labor market (e.g., Boone & Seto, 2023; Deloitte, 2023; Majumdar, 2024). Managers with the knowledge and skills to contribute to the ecological transformation expect considerable rewards from their future employment opportunities.

Consequently, managers face incentives to signal 'green' ability to the labor market. Such incentives may be desirable because they motivate managers to reduce their firms' carbon emissions. However, managers' career concerns may also induce unproductive greenwashing activities that are not in the interests of their employers. For example, managers use their discretion in preparing carbon reports to disseminate favorable information without reducing the actual carbon emissions. Widely discussed examples include Shell's and BP's selective reporting and greenwashing (Global Witness, 2023), H&M overstating the sustainability of its Conscious Collection (Ferris et al., 2023), and Coca-Cola making ambitious claims about plastic neutrality and recycling efforts that do not significantly reduce its overall plastic production or environmental impact (Ermini et al., 2021). Such greenwashing activities waste resources without increasing firms' financial performance or reducing their environmental footprint.

Given that managers have considerable discretion in preparing carbon reports, there is public scrutiny regarding firms' carbon-related actions. Environmental organizations and activists question firm disclosures and conduct their own research to verify firms' abatement actions or identify their greenwashing activities. Such measures increase transparency and are desirable from an information perspective. However, it is unclear how they affect executive compensation design and contract efficiency.

We use a principal-agent model to study how public information on managers' emission-related actions affects firms' carbon emissions and optimal contract design. A representative firm owner hires a risk-neutral manager to run the firm's operations. The owner has intrinsic preferences for reducing carbon emissions and compensates the manager based on the firm's financial report and its carbon report. The contract in our model solves a multi-task problem. First, the manager provides productive effort, which increases the firm's financial performance but causes higher carbon emissions. Second, the manager can reduce the firm's carbon emissions via costly abatement actions. Third, the manag-

1 A recent example is the European Union's Corporate Sustainability Reporting Directive (CSRD), which mandates large and listed companies to disclose their management of social and environmental challenges. In the United States, the Securities and Exchange Commission (SEC) has proposed rules to enhance and standardize climate-related disclosures, including greenhouse gas emissions and climate risks.

er can engage in greenwashing activities that alter the realization of the carbon report without changing the firm's actual emissions. Compensating the manager for the carbon report motivates desirable abatement actions but is costly to the owner because it induces unproductive greenwashing.

The firm's actual carbon emissions depend on the manager's abatement actions and his 'green' ability. The knowledge and skills in implementing new technologies and leading the green transformation differ across managers and are typically not observable by outsiders. As a consequence, potential employers use firm disclosures to learn about a manager's ability. The manager in our model anticipates potential rents from signaling high ability to the labor market. He uses his actions to deflate the firm's carbon report and to induce favorable beliefs about his ability. The firm owner considers the manager's implicit career concerns when designing the compensation contract and adjusts the contractual incentives accordingly.

Within this setting, we study public detection of the manager's emission-related actions. With positive probability, outsiders learn either the manager's abatement action, his greenwashing activity, or both. Importantly, if outsiders observe one of the manager's actions, this action fails to influence public beliefs about his ability. The manager anticipates that his efforts are less likely to change the public perception of his ability and reduces his efforts accordingly. We find that public detection affects the relative desirability of abatement actions and greenwashing as two alternative means to influcence the public beliefs. If outsiders are more likely to learn the manager's abatement actions, greenwashing is more effective in influencing public beliefs than abatement actions. In contrast, if outsiders are more likely to detect the firm's greenwashing activities, the manager curbs his greenwashing and relies on abatement actions to manipulate public beliefs.

We conclude that public detection affects the manager's effort allocation. This can be desirable if outsiders are more likely to learn the manager's greenwashing activity than his abatement actions. In this case, the manager's career concerns motivate abatement actions but discourage greenwashing. For a moderate detection probability, this allows the owner to induce the same level of carbon reductions at a lower cost which improves contract efficiency. However, if the detection probability exceeds a threshold level, the manager's career concerns motivate inefficiently high abatement actions, forcing the owner to mute the contractual incentives tied to the carbon report. We show that the optimal contract induces brownwashing. The manager faces incentives to inflate the carbon report by his reporting choices, which is equally costly for the owner.[2] In this case, further increases in the likelihood of public detection are detrimental to the firm owner.

The results of this study are relevant to three strands of literature. First, we contribute to the literature on ESG disclosures and optimal incentive contracts. Prior studies such as Bonham & Riggs-Cragun (2024) and Chaigneau & Sahuguet (2024) provide a foundation for understanding how contractual adjustments can motivate managers towards achieving ESG goals. Bonham & Riggs-Cragun (2024) discuss the general motivational aspects of contracts and examine the impact of taxation and regulation on firm behavior. In contrast, we delve into how contracts are optimized under different scenarios of public detection, providing a more nuanced view of managerial incentives linked to emission-related ac-

2 The term 'brownwashing' refers to the empirically documented phenomenon that firms understate their accomplishments in reducing carbon emissions (e.g., Kim & Lyon, 2015; Montgomery & Robertson, 2022).

tions. Chaigneau & Sahuguet (2024) explore executive compensation in motivating ESG activities. They study how discrepancies in ESG preferences between boards and investors influence the optimal choice of performance measures and managers' ESG investments. In particular, their results highlight the role of stock prices and ESG scores as contractual performance measures. Our study shows how managers' career concerns complement explicit incentive contracts in aligning their ESG-related decisions with firms' environmental goals.

Second, we add to the literature on optimal incentive contracts in multi-task agency relationships (e.g., Feltham & Xie, 1994; Datar et al., 2001; Pfaff & Pfeiffer, 2001; Pfaff, 2004). Feltham & Xie (1994) and Datar et al. (2001) study settings where firms are restricted in controlling managers' various decisions. If a firm cannot use separate performance measures for different actions, it may be unable to induce a desirable effort allocation which results in a cost for the firm. We build on a multi-task agency model to develop our arguments. Compensating managers based on carbon reports motivates both desirable abatement actions and undesirable greenwashing. We show that the public detection of these actions may relax this multi-task problem if managers are interested in the public beliefs about their green ability.

Third, we add to the literature on managerial career concerns and their interplay with optimal incentive contracts (Fama, 1982; Holmström, 1982; Gibbons & Murphy, 1992). Related work considers the effects of additional disclosure requirements and performance measure aggregation (Autrey et al., 2007 and 2010; Arya & Mittendorf, 2011). Autrey et al. (2007) study how noisy, non-contractible information about firm performance affects incentive contract design and contract efficiency. In contrast to their analysis, we consider a multi-task problem with a manager who can use his reporting discretion to manipulate firm disclosures (see Feller & Schäfer, 2024; Friedman et al., 2024). With positive probability, outsiders learn the manager's effort choices without noise, which leads to novel economic insights. Our results complement the findings of Autrey et al. (2007).

2. Model setup

2.1 Production technology and information environment

We consider the contractual relationship between a representative firm owner ('she') and the firm's manager ('he') who operates the firm on her behalf. The firm's financial performance, x, and carbon emissions, y, are given by

$$x = e \quad \text{and} \quad y = \alpha \cdot x - (a + \theta)$$

where $e > 0$ denotes the manager's productive effort. Productive effort not only increases the firm's financial performance but also the firm's carbon emissions. The factor $\alpha \in (0,1)$ measures the carbon intensity of the firm's business model in the sense that higher financial performance is accompanied by a larger carbon footprint. Aside from his productive effort, the manager can reduce the firm's carbon emissions. The total carbon reduction, $a + \theta$, is the sum of two components. The first component, a, reflects the abatement actions in the respective period that are personally costly to the manager. The manager exerts effort to change the firm's existing productions and implement new investments

to reduce carbon emissions.[3] The second component, θ, represents the manager's 'green' ability. To effectively reduce carbon emissions, managers must be aware of potential externalities caused by a firm's operations. The implementation of more sustainable operations requires knowledge not only about the firm's production but also about technological alternatives. Managers differ in their awareness of firm externalities and their skills to estimate the emissions caused by complex production systems. Accordingly, θ captures such unobservable managerial abilities that cannot be communicated in a credible way. We assume that the manager's ability is the realization of a normally distributed random variable $\widetilde{\theta} \sim N\left(0, \sigma_\theta^2\right)$.[4]

The firm provides public reports about its financial performance and carbon emissions in line with prevailing regulatory requirements. The financial report, r_x, and carbon report, r_y, are noisy and potentially biased signals about x and y, respectively,

$$r_x = x + \varepsilon_x \quad \text{and} \quad r_y = y - m + \varepsilon_y,$$

where ε_x and ε_y represent uncorrelated noise terms and are realizations of normally distributed random variables, $\widetilde{\varepsilon}_x \sim N(0, \sigma_x^2)$ and $\widetilde{\varepsilon}_y \sim N(0, \sigma_y^2)$. For instance, ε_x reflects inaccuracies caused by imprecise financial reporting standards, and ε_y results from errors in estimating the firm's indirect carbon emissions. We assume that the manager can manipulate the carbon report to capture current debates about sustainability reporting and 'greenwashing.' He chooses a greenwashing activity m that reduces the carbon report without affecting the firm's emissions. For instance, the manager uses his discretion in recording and classifying indirect carbon emissions which allows him to present a more favorable carbon report to the public. Misrepresenting the firm's carbon emissions is effort- and time-consuming and causes private costs for the manager.

2.2 Preferences and the owner's problem

The manager's private costs for his productive and unproductive actions are given by

$$C(e, a, m) = \tfrac{1}{2} \cdot \left(e^2 + a^2 + c \cdot m^2\right),$$

where $c > 0$ denotes the marginal costs of greenwashing. The owner designs a linear incentive contract based on the financial and carbon reports to induce the desired actions.[5] The manager's compensation is given by

$$s\left(r_x, r_y\right) = s_0 + s_x \cdot r_x + s_y \cdot r_y,$$

where s_0 denotes his fixed wage, and s_x and s_y are the incentive rates tied to financial and carbon reports. In addition to his compensation, $s\left(r_x, r_y\right)$, the manager considers

3 It is reasonable to assume that the implementation of abatement actions is a time and effort consuming process and causes private costs to the manager. The firm has to compensate the manager for his efforts and, thus, indirectly incurs the costs of implementing abatement actions. Considering additional costs on the side of the firm would not change our results qualitatively.

4 In line with the career concerns literature, we assume that the effects of managerial ability and abatement actions are additively separable (see Holmström, 1982; Gibbons & Murphy, 1992).

5 We assume that the actual financial performance x and carbon emissions y cannot be used as contractual performance measures—for instance, because they are unverifiable or not realized before the manager retires.

the long-term consequences of his actions. We assume that the manager expects future rents that are proportional to the labor market beliefs about his green ability θ. This assumption is in line with the empirical observation that there is considerable demand for sustainability-focused executives in the managerial labor market (e.g., Boone & Seto, 2023; Deloitte, 2023; Majumdar, 2024). Arguably, executives who demonstrate their skills as green managers increase their future employment opportunities and expect higher rents. We therefore assume that the manager is interested in the public beliefs about his ability $E\left[\widetilde{\theta}\middle|\Omega\right]$, where Ω denotes the set of all publicly available information. Overall, the manager's objective is to maximize his payoff $U = s\left(r_x, r_y\right) + \delta \cdot E\left[\widetilde{\theta}\middle|\Omega\right] - C(e,a,m)$, where $\delta > 0$ is the relative weight assigned to the public beliefs about his ability. We interpret δ as a measure of labor market pressure.[6]

We assume that both the firm owner and the manager are risk neutral. The owner's contracting problem has the following form:

$$\max_{e,\,a,\,m,\,s_0,\,s_x,\,s_y} \quad \Pi = E\left[x - \gamma \cdot \widetilde{y} - s(\widetilde{r}_x, \widetilde{r}_y)\right]$$

$$\text{s.t.} \quad (e,a,m) \in \operatorname{argmax} \quad EU = E\left[s\left(\widetilde{r}_x, \widetilde{r}_y\right) + \delta \cdot E\left[\widetilde{\theta}\middle|\widetilde{\Omega}\right]\right] - C(e,a,m) \tag{IC}$$

$$EU = E\left[s\left(\widetilde{r}_x, \widetilde{r}_y\right) + \delta \cdot E\left[\widetilde{\theta}\middle|\widetilde{\Omega}\right]\right] - C(e,a,m) \geq 0. \tag{IR}$$

The owner's objective function Π is the expected outcome $x - \gamma \cdot y$ net of compensation costs $s\left(r_x, r_y\right)$. Higher emissions y are costly, for instance, because carbon emissions trigger negative cash flows in future periods or the owner has an intrinsic preference for reducing emissions. The parameter $\gamma \in [0,1]$ represents the importance of carbon emissions to the owner relative to financial performance.[7]

The owner maximizes her expected payoff Π considering two constraints. The incentive constraint (IC) accounts for the fact that the manager chooses his unobservable actions to maximize his expected utility EU. According to the individual rationality constraint (IR), the manager agrees to the owner's contract offer if his expected utility EU exceeds a reservation wage that is normalized to zero without loss of generality.

2.3 Detection of emission-related actions

We assume that there is public scrutiny about the manager's choices. With probability $\pi \in [0,1]$, public detection is successful, and the market learns a subset of the manager's actions. Conditional on successful detection, the public learns the manager's abatement action a with probability $\psi_a \in [0,1]$, the greenwashing activity m with probability $\psi_m \in [0,1-\psi_a]$, and both actions (a,m) with probability $1-\psi_a-\psi_m$. Figure 1 illustrates how the public detection of the manager's emission-related action affects the set of publicly available information Ω. Public beliefs about the manager's green ability take the form

6 For a similar model assumption, see Autrey et al. (2007).

7 We adopt the standard assumption that the owner is interested in the actual firm performance. As a consequence, she does not benefit from the manager's endeavors to influence market beliefs.

$$E\left[\widetilde{\theta}\,\middle|\,\Omega\right] = \beta_0 + \beta_y \cdot r_y, \quad \text{where } \beta_y = -\frac{\sigma_\theta^2}{\sigma_\theta^2 + \sigma_y^2}. \tag{1}$$

They do not depend on the financial report r_x because it is not sensitive to carbon reductions. In contrast, a higher carbon report r_y indicates fewer carbon reductions and lower green ability of the manager. Accordingly, the slope β_y is negative, and the market beliefs are decreasing in r_y. The market reaction β_y is strong if the carbon report is more useful in learning about green ability. This is the case if there is high prior uncertainty about ability, σ_θ^2, and low reporting noise, σ_y^2. We define $s_\theta = \delta \cdot \beta_y$ as the manager's implicit incentives related to the carbon report. The manager faces stronger implicit incentives if his future rents are more sensitive to the public beliefs, i.e., for higher values of δ, and if there is a stronger market reaction, i.e., for more negative values of β_y.

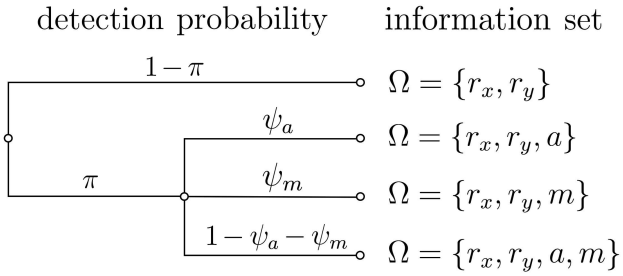

Fig. 1: Public detection probabilities

Note that the carbon report r_y depends on the manager's actions, which are unrelated to his green ability. The constant β_0 in Equation (1) therefore removes the effect of the manager's actions from the market beliefs. Depending on the detection results, β_0 reflects the actual effort levels or outsiders' conjectures $\widehat{e}$, $\widehat{a}$, and $\widehat{m}$:

$$\beta_0 = \begin{cases} -\beta_y \cdot (\alpha \cdot \widehat{e} - \widehat{a} - \widehat{m}) \text{ if } \Omega = \{r_x, r_y\} \\ -\beta_y \cdot (\alpha \cdot \widehat{e} - a - \widehat{m}) \text{ if } \Omega = \{r_x, r_y, a\} \\ -\beta_y \cdot (\alpha \cdot \widehat{e} - \widehat{a} - m) \text{ if } \Omega = \{r_x, r_y, m\} \\ -\beta_y \cdot (\alpha \cdot \widehat{e} - a - m) \text{ if } \Omega = \{r_x, r_y, a, m\} \end{cases}. \tag{2}$$

Figure 2 summarizes the timeline of the model.

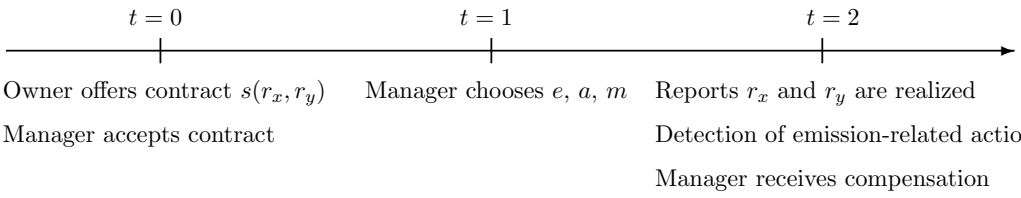

Fig. 2: Timeline of events

2.4 First-best solution

The first-best solution is obtained if the owner can perfectly control the manager's actions. In this hypothetical case, the owner implements the first-best actions $e^{FB} = 1 - \alpha \cdot \gamma$ and $a^{FB} = \gamma$ irrespective of public detection. A higher intrinsic preference for carbon reductions, γ, renders the carbon-inducing productive decision less valuable, $de^{FB}/d\gamma < 0$, but increases the first-best level of the abatement action, $da^{FB}/d\gamma > 0$. The owner prevents greenwashing, $m^{FB} = 0$, because manipulation increases the compensation costs but does not add firm value. The owner's expected payoff in the first-best case is given by

$$\Pi^{FB} = \tfrac{1}{2} \cdot (1 - \alpha \cdot \gamma)^2 + \tfrac{1}{2} \cdot \gamma^2,$$

where $\frac{1}{2} \cdot (1 - \alpha \cdot \gamma)^2$ is the contribution of the manager's productive effort and $\frac{1}{2} \cdot \gamma^2$ is the payoff resulting from abatement actions.

3. Model analysis

3.1 Benchmark: No detection of emission-related actions

As a benchmark for our main analysis, we study the case in which the public cannot detect the emission-related actions, $\pi = 0$. We first consider the manager's decisions at time $t = 1$. When choosing his productive effort e, abatement action a, and greenwashing m, the manager anticipates the effects on his compensation and the beliefs about his green ability. The public beliefs $E\left[\tilde{\theta} \middle| r_x, r_y\right] = \beta_0 + \beta_y \cdot r_y$ depend on the manager's actions only via the carbon report r_y. External parties cannot assess whether a lower report results from the manager's green ability, θ, or from his costly actions, e, a, and m. They attribute a lower report to the manager's ability, which provides a rationale for signal jamming. The manager faces incentives to deflate the carbon report with his actions to achieve a more favorable assessment of his green ability. The manager's effort choices are given by

$$e = S_e, \quad a = S_{am}, \quad \text{and} \quad m = \tfrac{1}{c} \cdot S_{am},$$

where

$$S_e = s_x + \alpha \cdot (s_y + s_\theta) \quad \text{and} \quad S_{am} = -(s_y + s_\theta), \tag{3}$$

are the marginal benefits from the manager's productive effort and emission-related decisions, respectively. These benefits reflect the manager's explicit contractual incentives and the implicit incentives induced by changes in the market beliefs.

In the benchmark case, the manager expects the same marginal benefits from abatement actions and greenwashing. Both decisions uniformly reduce the carbon report which affects the manager's utility for two reasons. First, it changes the manager's explicit compensation claims with a marginal effect of s_y. Second, it influences market beliefs about the manager's green ability and, thus, the manager's expected future rents in the job market with a marginal effect of s_θ. The total benefits of reporting lower carbon emissions are given by $S_{am} = -(s_y + s_\theta)$. The negative sign reflects that the manager benefits from reducing the report.

The marginal benefit of the manager's productive effort, S_e, summarizes its effects on the manager's compensation via the financial and carbon reports. On the one hand, higher effort boosts the firm's financial performance and increases the manager's compensation by s_x. On the other hand, extending the firm's operations induces higher carbon emissions. Given the carbon intensity α, this effect causes a cost of $\alpha \cdot S_{am}$ for the manager. The total effect of productive effort amounts to $S_e = s_x - \alpha \cdot S_{am} = s_x + \alpha \cdot (s_y + s_\theta)$.

The owner considers the manager's decisions in her contract offer. The optimal contract, the equilibrium actions, and the owner's expected payoff in the benchmark setting without public detection are summarized in Lemma 1.[8]

Lemma 1 *In the absence of public detection, the optimal incentive rates,*

$$s_x^* = 1 - \alpha \cdot \tfrac{1}{1+c} \cdot \gamma \quad \textit{and} \quad s_y^* = -\tfrac{c}{1+c} \cdot \gamma - s_\theta,$$

induce managerial actions

$$e^* = e^{FB},\ a^* = a^{FB} - \tfrac{1}{1+c} \cdot \gamma, \quad \textit{and} \quad m^* = \tfrac{1}{1+c} \cdot \gamma.$$

The owner's expected payoff amounts to

$$\Pi^* = \tfrac{1}{2} \cdot (1 - \alpha \cdot \gamma)^2 + \tfrac{1}{2} \cdot \tfrac{c}{1+c} \cdot \gamma^2.$$

The owner faces trade offs that are well known from multi-task agency models (e.g., Feltham & Xie, 1994; Datar et al., 2001). She controls three actions with two performance measures which implies a loss of control. The problem becomes most apparent from the manager's emission-related actions a and m, which alter the firm's carbon report r_y but do not affect the financial report r_x. For $\gamma > 0$, the owner cares about the firm's carbon emissions and prefers to induce strictly positive abatement actions, $a > 0$, by choosing $s_y < -\delta \cdot \beta_y$. However, this also motivates unproductive greenwashing by the manager who chooses $m > m^{FB} = 0$ and must be compensated for the manipulation costs. Since the owner cannot implement both decisions at their first-best level, she trades off carbon reductions from abatement actions and the additional compensation costs from greenwashing. In equilibrium, she accepts some manipulation, $m^* > 0$, to induce a positive but inefficiently low level of abatement actions, $0 < a^* < a^{FB}$. On aggregate, the deviation from the first-best solution does not affect the expected level of the carbon report because $a^* + m^* = a^{FB} + m^{FB}$.

Note that the multi-task problem does not affect the manager's choice of productive effort. Because both the financial report, r_x, and the carbon report, r_y, are sensitive to the productive effort, the owner chooses s_y^* to induce the optimal emission-related actions, a^* and m^*, and uses the incentive rate s_x^* to implement the first-best productive effort $e^* = e^{FB}$. Accordingly, the agency costs $AC^* = \Pi^{FB} - \Pi^*$ result from the owner's trade off between motivating carbon reductions and preventing greenwashing:

$$AC^* = \tfrac{1}{2} \cdot \tfrac{1}{1+c} \cdot \gamma^2.$$

8 The superscript $*$ denotes the benchmark solution with undetectable managerial actions.

The agency costs increase in the owner's preferences for carbon reductions, $dAC^*/d\gamma > 0$. If the owner cares only about financial performance, $\gamma = 0$, there is no benefit from inducing abatement actions, and she implements the first-best solution by eliminating the incentives related to the carbon report, $s_x^* = 1$, $s_y^* = -s_\theta$. Moreover, the agency costs decrease in the manager's marginal costs of greenwashing because higher costs c relax the multi-task problem. If manipulating the carbon report is costlier for the manager, the owner can induce higher abatement actions with less greenwashing, $da^*/dc > 0$, $dm^*/dc < 0$, which reduces agency costs, i.e., $dAC^*/dc < 0$.

Notably, the manager's actions in the benchmark setting, e^*, a^*, and m^*, do not depend on market pressure δ or the market reaction to the carbon report β_y. This result is intuitive because the external labor market has no superior information. Public beliefs about the manager's green ability $E\left[\tilde{\theta}\middle|\Omega\right]$ rely only on the carbon report r_y. Accordingly, Equation (3) shows that the manager's career concerns have the same effect as a higher contractual incentive rate s_y. The owner anticipates uncontrollable career concerns and reduces the contractual incentives s_y by s_θ to balance the manager's total incentives. She thereby prevents potential incentive distortions caused by the manager's career concerns. Given this observation, the results in Lemma 1 can be established in a model without managerial career concerns ($\delta = 0$).

3.2 Detection of emission-related actions

Next, we study a setting in which the public detects the manager's emission-related actions with positive probability, $\pi > 0$. Learning the abatement actions or the level of greenwashing allows the labor market to remove the effects of a and m from the carbon report. Outsiders receive a debiased signal $\bar{r}_y$ about the manager's ability, θ. Following this logic, the pricing function in Equation (1) can be interpreted as a two-step procedure. In the first step, the market uses its information about the emission-related actions to determine a debiased report $\bar{r}_y$ about the manager's green ability:

$$\bar{r}_y = r_y + 1_{a \in \Omega} \cdot a + 1_{m \in \Omega} \cdot m,$$

where $1_{a \in \Omega}, 1_{m \in \Omega} \in \{0,1\}$ are indicator variables that take the value of one if the respective activity is detected and zero if it remains undetected. In the second step, the market forms beliefs about the manager's green ability based on the debiased report, $E\left[\tilde{\theta}\middle|\bar{r}_y\right]$.

The public detection of emission-related actions affects the manager's implicit incentives to deflate the carbon report. The debiased report $\bar{r}_y$ is not sensitive to emission-related actions that are publicly known. For instance, if the market learns both the manager's abatement actions a and greenwashing m, the debiased report, $\bar{r}_y = \alpha \cdot x - \theta + \varepsilon_y$, cannot be manipulated by the manager's emission-related actions. Signal jamming fails with positive probability, and, accordingly, the manager expects lower marginal benefits from his emission-related actions. For a given contract, the manager chooses

$$e = S_e, \quad a = S_a, \quad \text{and} \quad m = \tfrac{1}{c} \cdot S_m,$$

where

$$S_e = s_x + \alpha \cdot (s_y + \delta \cdot \beta_y),$$
$$S_a = -(s_y + (1 - Pr[a \in \Omega]) \cdot s_\theta), \quad S_m = -(s_y + (1 - Pr[m \in \Omega]) \cdot s_\theta). \tag{4}$$

A comparison with Equation (3) shows that the marginal benefits from the manager's abatement actions, S_a, and greenwashing, S_m, are lower than those in the benchmark setting, S_{am}, and are no longer identical for both activities. If the public detects the manager's abatement actions or greenwashing with positive probability, $Pr[a \in \Omega] > 0$ or $Pr[m \in \Omega] > 0$, signal jamming is less effective. The manager faces lower implicit incentives to reduce the carbon report than in the benchmark setting and reduces his efforts accordingly. The marginal benefits from abatement and greenwashing are not identical (i.e., $S_a \neq S_m$) whenever the probability of verifying abatement actions differs from the probability of detecting greenwashing, $\psi_a \neq \psi_m$. For instance, greenwashing is more effective in influencing the public beliefs, $S_m > S_a$, if abatement actions are detected more frequently, i.e., if $\psi_a > \psi_m$.

This has important implications for the managerial actions that can be implemented by the owner. In the benchmark setting, Equation (3) shows that the ratio of the emission-related actions, $a/m = c$, is constant and depends neither on the owner's contract choice nor on the market reaction to the carbon report. The reason is that the manager's emissions-related actions a and m affect affect both his compensation $s(r_x, r_y)$ and market beliefs about his green ability $E[\tilde{\theta} | r_x, r_y]$ only via the performance measure r_y. Thus, the sensitivity of the carbon report r_y to a and m determines the optimal effort allocation. Since both actions have the same marginal effect on the expected carbon report, $dE[\tilde{r}_y]/da = dE[\tilde{r}_y]/dm = -1$, the marginal benefits are identical and given by S_{am}.

This result no longer holds if the manager's emission-related actions are detectable. While the manager's compensation still depends on the verifiable carbon report r_y, the beliefs about his ability are based on the debiased report $\bar{r}_y$. Whenever abatement actions and greenwashing differ in their detection probability, $\psi_a \neq \psi_m$, the expected debiased report is not equally sensitive to a and m, i.e., $dE[\bar{r}_y]/da \neq dE[\bar{r}_y]/dm$.[9] As a consequence, the manager's career concerns and his compensation induce different effort allocations:

$$\frac{a}{m} = c \cdot \frac{s_y + (1 - Pr[a \in \Omega]) \cdot s_\theta}{s_y + (1 - Pr[m \in \Omega]) \cdot s_\theta}. \tag{5}$$

If the probability of detecting greenwashing is higher than the probability of verifying abatement actions (i.e., $Pr[m \in \Omega] > Pr[a \in \Omega]$), we find $a/m > c$ for sufficiently low levels of s_y. Compared to the benchmark setting, the owner can induce the same level of a with less greenwashing. If public scrutiny is more likely to reveal abatement actions (i.e., $Pr[m \in \Omega] < Pr[a \in \Omega]$), greenwashing is more attractive to the manager, and it is

9 Following the terminology used in the literature on multi-task agency problems, we conclude that r_y and $\bar{r}_y$ are linear independent measures of the manager's actions whenever $\psi_a \neq \psi_m$ (Feltham & Xie, 1994). If the owner could use the public beliefs $E[\tilde{\theta} | \bar{r}_y]$ as an additional contractual performance measure, she would be able to induce the first-best solution. However, public beliefs are unverifiable by their very nature.

costlier for the owner to induce a positive level of a. Lemma 2 characterizes the optimal contract and the owner's expected payoff.[10]

Lemma 2 *If emission-related actions are detected with positive probability, the owner's optimal incentive rates*

$$s_x^\dagger = s_x^* - \alpha \cdot \Lambda \cdot s_\theta \quad \textit{and} \quad s_y^\dagger = s_y^* + \Lambda \cdot s_\theta$$

induce managerial actions

$$e^\dagger = e^*, \quad a^\dagger = a^* + \lambda \cdot \tfrac{1}{1+c} \cdot s_\theta, \quad \textit{and} \quad m^\dagger = m^* - \lambda \cdot \tfrac{1}{1+c} \cdot s_\theta,$$

which yields the following expected payoff:

$$\Pi^\dagger = \Pi^* + \tfrac{1}{2} \cdot \tfrac{1}{1+c} \cdot \left(\gamma^2 - (\gamma - \lambda \cdot s_\theta)^2\right),$$

where $\Lambda = \pi \cdot \left(1 - \left(\tfrac{1}{1+c} \cdot \psi_a + \tfrac{c}{1+c} \cdot \psi_m\right)\right)$ *and* $\lambda = \pi \cdot (\psi_a - \psi_m)$.

A closer analysis of the optimal contract shows some structural insights. Since the public detection of emission-related actions reduces the manager's implicit incentives to deflate the carbon report, the owner implements stronger explicit incentives to reduce carbon emissions, $s_y^\dagger < s_y^*$. Note that this adjustment also discourages the provision of productive effort since productive effort increases carbon emissions. To maintain the first-best productive effort choice, the owner must increase the manager's incentives based on the firm's financial report, $s_x^\dagger > s_x^*$.

Proposition 1 *With higher likelihood of public detection* π*, the owner increases both incentives to reduce carbon emissions and incentives to boost financial performance*, $ds_y^\dagger/d\pi < 0$ and $ds_x^\dagger/d\pi > 0$.

While a higher likelihood of detection has clear implications for the optimal contract choice, its effects on the owner's expected payoff are ambiguous.

Proposition 2 *Effects of increasing the detection probability on the owner's expected payoff*

i) *For* $\psi_a > \psi_m$*, higher detection probabilities reduce the owner's payoff,* $d\Pi^\dagger/d\pi < 0$.

ii) *For* $\psi_a < \psi_m$*, the owner's payoff is maximized for a detection probability* $\pi^\dagger = \gamma/(s_\theta \cdot (\psi_a - \psi_m))$*. It is increasing in* π *for lower detection probabilities and decreasing in* π *for higher detection probabilities,* $d\Pi^\dagger/d\pi > 0$ *for* $\pi < \pi^\dagger$ *and* $d\Pi^\dagger/d\pi < 0$ *for* $\pi > \pi^\dagger$.

To understand the effects of the detection probability π, it is instructive to distinguish two cases. For $\psi_a > \psi_m$, it is more likely that the market learns the manager's abatement actions, $Pr[a \in \Omega] > Pr[m \in \Omega]$. According to Equation (5), this implies $a/m < c$ irrespective of the owner's contract choice. The manager's implicit incentives cause a distortion of the manager's effort allocation that is detrimental to the owner. Compared to the benchmark setting, inducing a given level of abatement actions is costlier because

10 The superscript † denotes the solution in our main model.

it is accompanied by more greenwashing. The optimal trade off is characterized by lower abatement actions, $a^{\dagger} < a^{*}$, and more greenwashing, $m^{\dagger} > m^{*}$. This inefficiency is more pronounced for a higher likelihood π. If it is more likely that public detection is successful, the difference between the probabilities ψ_a and ψ_m has a stronger effect on the manager's action choices.

For $\psi_a < \psi_m$, public detection can be desirable if the detection probability is sufficiently low, $\pi < \pi^{\dagger}$. The reason for this result is that the owner can motivate the same level of abatement actions with lower manipulation. Therefore, we find that a higher probability π leads to more abatement actions and less greenwashing. For $\pi = \pi^{\dagger}$, the owner is able to induce the first-best actions $a^{\dagger} = \gamma$ and $m^{\dagger} = 0$. Note, however, that further increases of the detection probability beyond $\pi^{\dagger}$ are undesirable. In this case, career concerns induce inefficiently high abatement effort, and the owner rewards the manager for a *higher* carbon report to limit his incentives, $s_y > 0$. As a consequence, the manager benefits from overstating the firm's carbon emissions. He chooses negative levels of m, which can be interpreted as brownwashing. Such brownwashing activities are unproductive and equally costly for the owner. For $\pi > \pi^{\dagger}$, further increases in the detection probability aggravate this inefficiency. Note that the region $\left[\pi^{\dagger}, 1\right]$ exists only if the owner's preferences for carbon reductions, γ, are low and the manager faces strong implicit incentives, s_θ. Otherwise, it holds that $\pi^{\dagger} \geq 1$, and a higher detection probability is always desirable.

The public detection of emission-related actions is beneficial to the owner if her expected payoff exceeds the expected payoff in the benchmark setting, $\Pi^{\dagger} > \Pi^{*}$. Corollary 1 highlights the conditions for an overall positive effect of public detection.

Corollary 1 *Public detection is strictly beneficial to the owner if the detection of greenwashing is likelier than the detection of abatement actions,* $\psi_m > \psi_a$*, and the detection probability is not too high,* $\pi \in \left(0{,}2 \cdot \pi^{\dagger}\right)$.

The results of Corollary 1 build on the observations of Proposition 2. The detection of emission-related actions can be desirable only if it helps the owner improve the manager's effort allocation. This is the case if the probability for detecting greenwashing activities is higher than the probability of verifying the manager's abatement actions, $\psi_m > \psi_a$. As a consequence, the manager faces stronger implicit incentives to actually reduce the firm's carbon emissions than to manipulate the carbon report. Moreover, the detection probability π must not exceed a threshold value $2 \cdot \pi^{\dagger}$. Otherwise, the optimal provision of abatement actions induces costly brownwashing, and the higher compensation costs outweigh the benefits of public detection.

4. Conclusion

This study explores how public detection of managers' emission-related actions (i.e., abatement actions and greenwashing) influences optimal contract design and agency costs. Public detection of abatement actions and greenwashing reduces managers' incentives to influence public beliefs about their green ability with those actions. This has important implications for firms' optimal incentive provision. Our findings suggest that public detec-

tion mechanisms can be desirable if greenwashing is more likely detected than genuine emission abatement. Moderate levels of detection enhance transparency and enable implementing sustainable practices that are in the firms' best interest. By contrast, excessively high detection probabilities can lead managers to overstate carbon emissions which hinders an optimal incentive provision.

Our study underscores the importance of public detection mechanisms and incentive contracts in promoting corporate environmental responsibility. By balancing implicit career concerns and explicit contractual incentives, firms can align managerial actions with their sustainability goals, leading to higher reductions in carbon emissions and improved environmental outcomes. Our results hint at the desirability of detection mechanisms that are more effective at identifying greenwashing than genuine abatement actions. Such mechanisms can help firms control managers' productive and unproductive actions.

Our results are subject to a number of limitations. Perhaps most importantly, we assume that all parties are risk neutral and neglect risk-incentive trade offs in our analysis of optimal contracts. We simplify the reporting model to focus on managers' emission-related actions. In a more general analysis, the market learns not only about the manager's green ability but also about his ability to increase the firm's financial performance, and the manager can misreport both financial performance and carbon emissions. Moreover, considering correlation between financial performance and carbon emissions might help to generalize our results and could be an interesting avenue for further research.

Appendix

Proof of Lemma 1

Using the marginal benefits defined in Equation (3), we find

$$EU = s_0 + \delta \cdot \beta_0 + S_e \cdot e + S_{am} \cdot (a + m) - \tfrac{1}{2} \cdot \left(e^2 + a^2 + c \cdot m^2\right).$$

Optimization for the manager's actions yields $e = S_e$, $a = S_{am}$, and $m = \frac{1}{c} \cdot S_{am}$. The owner implements incentives at minimal cost. She chooses a fixed wage s_0 such that the individual rationality constraint binds. Because $E\left[E\left[\tilde{\theta} \middle| \tilde{r}_x, \tilde{r}_y\right]\right] = 0$ in equilibrium, we can rearrange the individual rationality constraint to:

$$E\left[s(\tilde{r}_x, \tilde{r}_y)\right] = C(e, a, m).$$

Substituting the expected compensation from the individual rationality constraint and the incentive constraints into the owner's objective function yields:

$$\Pi = (1 - \alpha \cdot \gamma) \cdot S_e + \gamma \cdot S_{am} - \tfrac{1}{2} \cdot \left(S_e^2 + \tfrac{1+c}{c} \cdot S_{am}^2\right).$$

For given β_0 and β_y, the owner controls S_e and S_{am} by her choices of s_x and s_y. Optimization yields

$$S_e = 1 - \alpha \cdot \gamma \quad \text{and} \quad S_{am} = \tfrac{c}{1+c} \cdot \gamma.$$

The owner implements optimal incentives by choosing the incentive rates

$$s_x^* = S_e - \alpha \cdot \left(s_y + s_\theta\right) = 1 - \alpha \cdot \tfrac{1}{1+c} \cdot \gamma \quad \text{and} \quad s_y^* = S_{am} - s_\theta = -\tfrac{c}{1+c} \cdot \gamma - s_\theta.$$

Substituting these expressions into the incentive constraints and the owner's expected payoff yields the results in Lemma 1.

Proof of Lemma 2

Using the functional form of beliefs about the manager's green ability in Equations (1) and (2), the manager's utility reads

$$EU = s_0^D + S_e \cdot e + S_a \cdot a + S_m \cdot m - \frac{1}{2} \cdot \left(e^2 + a^2 + c \cdot m^2\right)$$

with

$$s_0^D = s_0 - \left(\alpha \cdot \widehat{e} - \left(1 - Pr[a \in \Omega]\right) \cdot \widehat{a} - \left(1 - Pr[m \in \Omega]\right) \cdot \widehat{m}\right) \cdot s_\theta$$

and S_e, S_a and S_m according to Equation (4). Optimization for the manager's actions yields $e = S_e$, $a = S_a$, and $m = \frac{1}{c} \cdot S_m$. Note that the owner controls S_e by varying s_x and jointly controls S_a and S_m by her choice of s_y. As she cannot control the latter incentives independently, we express S_m in terms of S_a:

$$S_m = S_a - \pi \cdot (\psi_a - \psi_m) \cdot s_\theta.$$

Substituting these results and the binding individual rational constraint, $E\left[s(\widetilde{r}_x, \widetilde{r}_y)\right] = C(e, a, m)$, into the owner's objective function yields:

$$\begin{aligned}\Pi \;=\;& (1 - \alpha \cdot \gamma) \cdot S_e + \gamma \cdot S_a \\ & - \tfrac{1}{2} \cdot \left(S_e^2 + \tfrac{1+c}{c} \cdot S_a^2 + 2 \cdot \tfrac{1}{c} \cdot S_a \cdot (\psi_a - \psi_m) \cdot \pi \cdot s_\theta + \tfrac{1}{c} \cdot (\psi_a - \psi_m)^2 \cdot \pi^2 \cdot s_\theta^2\right).\end{aligned}$$

Optimization yields

$$S_e = 1 - \alpha \cdot \gamma \quad \text{and} \quad S_a = \tfrac{c}{1+c} \cdot \gamma + \pi \cdot (\psi_a - \psi_m) \cdot \tfrac{1}{1+c} \cdot s_\theta,$$

which implies

$$S_m = \tfrac{c}{1+c} \cdot \gamma - \pi \cdot (\psi_a - \psi_m) \cdot \tfrac{c}{1+c} \cdot s_\theta.$$

Substituting these expressions into the incentive constraints and the owner's expected payoff yields the results in Lemma 2.

Proof of Proposition 1

Taking the first-order derivative of the optimal incentive rates w.r.t. π yields

$$\tfrac{ds_y^\dagger}{d\pi} = \tfrac{d\Lambda}{d\pi} \cdot s_\theta \quad \text{and} \quad \tfrac{ds_x^\dagger}{d\pi} = -\alpha \cdot \tfrac{d\Lambda}{d\pi} \cdot s_\theta.$$

Because $\alpha > 0$ and $s_\theta < 0$, Proposition 1 follows from the fact that

$$\tfrac{d\Lambda}{d\pi} = \left(1 - \left(\tfrac{1}{1+c} \cdot \psi_a + \tfrac{c}{1+c} \cdot \psi_m\right)\right) > 0.$$

Proof of Proposition 2

Taking the first-order derivative of the owner's expected payoff w.r.t. π yields

$$\tfrac{d\Pi^\dagger}{d\pi} = \tfrac{1}{1+c} \cdot (\psi_a - \psi_m) \cdot s_\theta \cdot [\gamma - \pi \cdot (\psi_a - \psi_m) \cdot s_\theta].$$

For $\psi_a > \psi_m$, we find $(\psi_a - \psi_m) \cdot s_\theta < 0$ and $\gamma - \pi \cdot (\psi_a - \psi_m) \cdot s_\theta > 0$ such that $d\Pi^\dagger / d\pi < 0$. For $\psi_a < \psi_m$, we have $(\psi_a - \psi_m) \cdot s_\theta > 0$. Therefore, we find that $d\Pi^\dagger / d\pi > 0$ if and only if

$$\gamma - \pi \cdot (\psi_a - \psi_m) \cdot s_\theta > 0 \quad \Leftrightarrow \quad \pi < \frac{\gamma}{(\psi_a - \psi_m) \cdot s_\theta} \equiv \pi^\dagger.$$

Continuity guarantees that the owner's expected payoff is maximized at $\pi = \pi^\dagger$.

Proof of Corollary 1

Comparing the owner's expected payoffs in the benchmark analysis and in the main model yields:

$$\Pi^\dagger - \Pi^* > 0 \quad \Leftrightarrow \quad \psi_a < \psi_m \wedge \pi < 2 \cdot \pi^\dagger.$$

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