

Can investors curb greenwashing?

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Greenwashing: a major issue

Greenwashing: *The practice by which companies claim they are doing more for the environment than they actually are.* (European Commission).



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Screening of websites for 'greenwashing': half of green claims lack evidence

/ Annual screening of company websites (European Commission, 2021): In 42% of cases, the authorities “had reason to believe that the [company’s] claim may be false or deceptive.”

Why greenwashing?

1. At equilibrium, environmentally well-rated companies benefit from lower costs of capital (Pástor et al., 2021; Pedersen et al., 2021; Zerbib, 2022).
 2. The reliability of environmental scores is questionable (Berg et al., 2022):
 - | companies' environmental footprints are challenging to measure accurately,
 - | measurement methods are not standardized.
 3. Companies can benefit from information asymmetry about their true environmental values (Barbalau and Zeni, 2023) and communicate in an ambiguous manner (Fabrizio and Kim, 2019).
-) Companies have the ability and the incentive to overstate their environmental value.

Greenwashing: a major issue

For investors: major obstacle to

- (i) environment-related risk assessment;
- (ii) environmental impact of investments.

Questions:

What are the incentives for companies to greenwash?

When do companies use environmental communication to greenwash?

What role can investors play in influencing greenwashing practices?

What we do

1. We build a dynamic asset pricing equilibrium model with
 - | **Information asymmetry** about companies' **environmental *value***;
 - | **Companies** which can (i) **communicate** and (ii) **reduce their emissions** to influence their **environmental *score***;
 - | A **representative investor** (i) with **pro-environmental preferences** and (ii) who can **penalize** revealed environmental **mistrating** (through the occurrence of controversies).

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2. We extend the model allowing for interaction between companies and solve the resulting game.
3. We validate empirically the environmental communication dynamics of green companies.

Contributions to the literature

Greenwashing and environmental disclosure: Duflo et al. (2013); Duchin et al. (2023); Hoepner et al. (2017); Bingler et al. (2022, 2023) and Flammer (2021); Ilhan et al. (2023); Berg et al. (2022, 2021).

| First theoretical paper linking greenwashing to investment decisions with Chen (2023).

Sustainable asset pricing: Pástor et al. (2021); Pedersen et al. (2021); Zerbib (2022); Bolton and Kacperczyk (2021); De Angelis et al. (2023); Pástor et al. (2022); Zerbib (2022); Cheng et al. (2023); Avramov et al. (2022); Sauzet and Zerbib (2022); Berk and van Binsbergen (2021); Goldstein et al. (2022); Pástor et al. (2022); Ardia et al. (2023); Van der Beck (2023).

| Correction for greenwashing in addition to green premium on expected returns.

Asset pricing and information asymmetry: Grossman and Stiglitz (1980); Admati and Pfleiderer (1986); Hughes (1986); Easley and O'hara (2004); Lambert et al. (2012).

| Asset pricing model with random revelation times.

Impact investing: De Angelis et al. (2023); Hartzmark and Shue (2023); Favilukis et al. (2023); Green and Roth (2024); Oehmke and Opp (2024); Green and Roth (2024); Landier and Lovo (2023); Edmans et al. (2023); Barber et al. (2021); Bonnefon et al. (2022); Heeb et al. (2023).

| Double positive impact of investors: curb greenwashing & foster abatement.

Outline

- 1 A dynamic equilibrium model with corporate greenwashing
- 2 Optimal greenwashing and investor's impact
- 3 Empirical evidence

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- 1 A dynamic equilibrium model with corporate greenwashing
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Market setting

Probability space $(\Omega, \mathcal{F} = (\mathcal{F}_t)_{t \geq 0}, \mathbb{P})$ with **infinite** time horizon.

Assets:

1 risk-free asset with zero interest rate

n firms issuing stocks at quantity normalized to 1, indexed by i

Price process of the risky assets, $S \in \mathbb{R}^n$:

$$dS_t = \mu_t dt + \sigma dB_t,$$

$\mu_t \in \mathbb{R}^n$ vector of expected returns, determined at equilibrium

$\sigma \in \mathbb{R}^{n \times n}$ exogenously specified constant volatility matrix

$B \in \mathbb{R}^n$ a.s. a Brownian motion

Environmental score

Fundamental environmental value of company i :

$$dV_t^i = \underbrace{v_t^i dt}_{\text{Abatement effect}} ; \quad V_0^i = p^i ;$$

with v^i the **emissions reduction (or abatement) effort** of company i .

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Proxy for this value:

Environmental score of company i : $E_0^i = q^i$,

$$dE_t^i = \underbrace{a(V_t^i - E_t^i) dt}_{\text{Rating agency effect}} + \underbrace{(V_t^i - E_t^i) \lambda_t^i dN_t^i}_{\text{Controversy effect}} + \underbrace{c_t^i dt}_{\text{Communication effect}} + \underbrace{z dW_t^i}_{\text{Measurement error}} ;$$

c^i the **environmental communication effort** of company i

λ^i Poisson process, W^i Brownian motion, independent from each other

$\lambda_t^i \in [0; 1]$ *random* fraction of misrating revealed at controversy, $E[\lambda_t^i] := b$.

Misrating proxy

Communication effort c^i

allows the company to influence its score ($c > 0$, < 0 , or $= 0$)

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Misrating proxy

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) Aware of this possibility, the investor tries to penalize **misrating** $E_t^i - V_t^i$.

BUT Only source of **information**: $(E_t^i)_t$ (the investor does not observe env. value V_t^i)

) use of **controversies history** which reveal a random fraction of the ongoing misrating (through jumps of N^i).

Misrating proxy:

$$dM_t^i = \underbrace{\rho M_t^i dt}_{\text{Forgetting rate}} + \underbrace{(E_t^i - E_t^i)^2 dN_t^i}_{\text{Square of misrating revealed by controversies}}, \quad M_0^i = u^i$$

Formal definition of greenwashing

Greenwashing

Company i is *greenwashing* at time t if:

- (i) it is not underrated, that is, $E_t^i \geq V_t^i$,
- (ii) its environmental communication is positive, $c_t^i > 0$,
- (iii) it communicates more than it abates, $c_t^i > v_t^i$.

When the company is greenwashing, its *greenwashing effort* is defined as

$$c_t^i - v_t^i.$$

) *Greenwashing* is any communication effort that aims at **creating** or **increasing** a **positive gap** between the **environmental score** and the **fundamental environmental value**, when the company is accurately rated or already overrated.

Investor's program

Notations: all variables are $\in \mathbb{R}^n$ in this slide.

$$\sup_{\omega \in \mathbb{R}^n} E \left[\int_0^T e^{-rt} \left\{ \underbrace{\omega_t^0 dS_t + \frac{\gamma}{2} h \omega_t^0 dS_t^2}_{\text{Mean-variance criterion}} + \underbrace{\omega_t^0 (\beta E_t + \alpha M_t) dt}_{\text{Non-pecuniary preferences}} \right\} \right]$$

Mean-variance criterion (Standard, e.g., Bouchard et al., 2018)

Non-pecuniary preferences:

Pro-environmental preferences, βE_t (e.g., Pástor et al., 2021; Zerbib, 2022)

Penalty on revealed misrating, αM_t

) Expected returns $\mu_t \in \mathbb{R}^n$ determined at equilibrium

Company i 's program

Notations: the exponent i indicates the i -th component of a vector.

Objective: Trade-off between reducing its **cost of capital** μ^i and the **quadratic costs** of environmental efforts

$$\inf_{(r^i; c^i)_{2A}} \mathbb{E} \left[\int_0^T e^{-\rho t} \left(\mu_t^i + \frac{\kappa_v^i}{2} (v_t^i)^2 + \frac{\kappa_c^i}{2} (c_t^i)^2 \right) dt \right],$$

μ_t^i : expected returns of company i determined at equilibrium

$\frac{\kappa_v^i}{2} (v_t^i)^2$: quadratic costs of abatement effort, v_t^i

$\frac{\kappa_c^i}{2} (c_t^i)^2$: quadratic costs of communication effort, c_t^i

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Optimal portfolio and equilibrium expected returns

Proposition

The optimal asset allocation of the investor is the pointwise solution

$$\omega_t = \frac{1}{\gamma} \mathbf{1}' (\mu_t + \beta E_t - \alpha M_t),$$

and the equilibrium expected return is

$$\mu_t = \gamma \mathbf{1}_n - \beta E_t + \alpha M_t.$$

βE_t : Green premium on expected returns (Pástor et al., 2021; Zerbib, 2022).

αM_t : Additional correction for greenwashing companies.

Companies' program with explicit objective

Knowing equilibrium expected returns, companies' program becomes:

$$\inf_{(r^i; c^i) \geq A} \mathbb{E} \left[\int_0^T e^{-\int_0^t r^i ds} \left(\mathbf{1}_n \quad E_t^i + M_t^i + \frac{r^i}{2} (V_t^i)^2 + \frac{c^i}{2} (C_t^i)^2 \right) dt \right]:$$

Under the following constraints:

$$\begin{cases} dE_t^i = a(V_t^i - E_t^i) dt + (V_t^i - E_t^i) \sigma^i dN_t^i + c^i dt + z dW_t^i; & E_0^i = q^i; \\ dV_t^i = v^i dt; & V_0^i = p^i; \\ dM_t^i = M_t^i dt + (E_t^i - E_t^i)^2 dN_t^i; & M_0^i = u^i; \end{cases}$$

$$A := \left\{ (c; v) \geq \mathbb{R}^2; F \text{ prog. meas. : } \mathbb{E} \left[\int_0^T e^{-\int_0^t r^i ds} (j_{c,t}^2 + j_{v,t}^2) dt \right] < 1 \right\}$$

) Each company looks for r^i and c^i that maximize its environmental score, E^i , controlling for its misrating proxy, M^i , and costs of environmental action (abatement and communication), $\frac{r^i}{2} (V_t^i)^2 + \frac{c^i}{2} (C_t^i)^2$.

Optimal strategies

Proposition (Optimal strategies)

The optimal environmental communication effort, $c^{i;}$, and abatement effort, $v^{i;}$, of company i are as follows:

$$c_t^{i;} = \frac{1}{i^c} \left(B^i \quad A^i(E_t^{i;} \quad V_t^{i;}) \right);$$

$$v_t^{i;} = \frac{1}{i^v} \left(- \quad B^i + A^i(E_t^{i;} \quad V_t^{i;}) \right);$$

where

$$B^i = \frac{(1 + \frac{A^i}{i^v})}{+ a + b \quad i + \frac{2A^i}{T}}; \quad A^i = \frac{i}{4} R^i \left(\sqrt{1 + \frac{16}{i} \frac{T^i}{(R^i)^2}} \quad 1 \right)$$

$$T^i = \frac{2 \quad i b^2}{(1 + b)(\quad +)}; \quad R^i = \quad + 2a + \frac{2 \quad i b}{1 + b}; \quad i = \frac{2}{\frac{1}{T} + \frac{1}{i^c}}$$

with $E^{i;}$; $V^{i;}$ state variables when the optimal strategies $c^{i;}$; $v^{i;}$ are employed, $A^i; B^i \geq 0$ and $- \quad B^i \leq 0$.

Optimal greenwashing effort when $\frac{v^i}{c^i} > 0$; $\frac{v^i}{c^i} > 0$

Proposition (Greenwashing effort)

If the following condition () is satisfied,

$$\frac{v^i}{c^i} > \frac{a + b^i}{c^i}; \quad ()$$

company i greenwashes if, and only if,

$$0 < E_t^{i;} < V_t^{i;} < \frac{1}{\frac{2}{c^i} A^i} G_{max}^i; \quad G_{max}^i = \frac{2}{c^i} B^i \frac{v^i}{c^i}$$

When it greenwashes, its greenwashing effort is as follows:

$$c_t^{i;} < v_t^{i;} = G_{max}^i \frac{2}{c^i} A^i (E_t^{i;} < V_t^{i;})$$

When condition () is not satisfied, company i never greenwashes.

NB: $a + b^i$ Revelation intensity (inverse: degree of **information asymmetry**).

) Companies greenwash to maintain their environmental score at a certain level above their environmental value

Impact of investor's preferences and penalty

Sensitivity of pro-environmental preferences of the investor

Investor's penalty on revealed misrating

Proposition (Investor's impact on greenwashing)

When condition () is satisfied, the maximal greenwashing effort, G_{max}^i , increases linearly in β and decreases in a convex way in α .

Proposition (Investor's impact on abatement)

The constant part in the abatement effort, $\frac{1}{r} \left(- B^i \right)$, increases linearly in β , and, when condition () is satisfied, increases in a concave way in α .

) Adds to the impact investing literature (Landier and Lovo, 2023; Green and Roth, 2024; Pástor et al., 2022; De Angelis et al., 2023; Oehmke and Opp, 2024).

Impact of investors on greenwashing and abatement

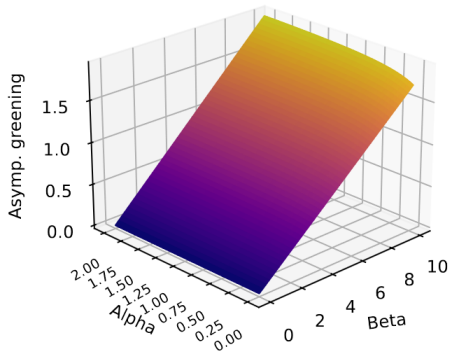
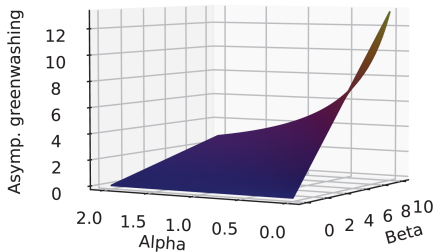


Figure: Average greenwashing and abatement as a function of α and β . Asymptotic expected optimal greenwashing ($\lim_{t \rightarrow \infty} E[C_t - v_t]$; left) and abatement ($\lim_{t \rightarrow \infty} E[v_t]$; right) as a function of the pro-environmental sensitivity, α , and the misrating penalty, β .

- Greenwashing and abatement efforts increase linearly with green preferences α ;
- Penalty β strongly deters greenwashing, and encourages abatement.

Calibration, which verifies condition (), and $v = c = 50$.

Greenwashing and transparency parameters

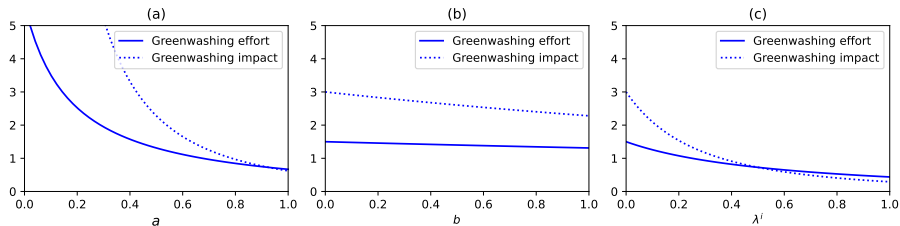


Figure: Greenwashing and transparency parameters when $\alpha = 0$. The maximum greenwashing effort, G_{max}^i , (solid lines), and greenwashing impact, $\lim_{t \rightarrow \infty} E[E_t^i - V_t^i]$, (dotted lines), as a function of transparency parameters a ; b ; λ^i , when the investor's penalty, α , is null.

1. Without investor's penalty on misrating ($\alpha = 0$):

- | The rating agency's efficiency, a , strongly deters greenwashing effort & impact.
- | Controversy frequency, b , and portion of misrating revealed, λ^i , are also dissuasive but with a smaller magnitude.

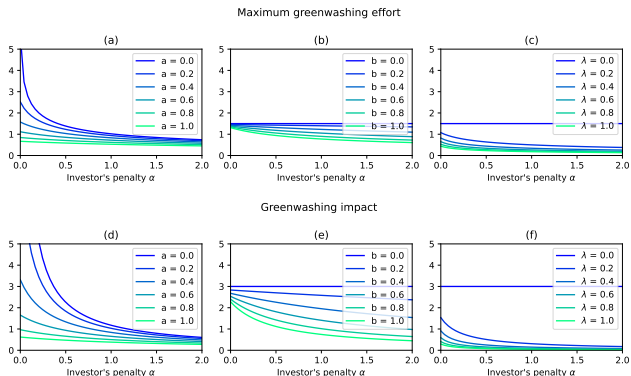


Figure: Greenwashing and penalty for various transparency parameters. The maximum greenwashing effort, G_{max}^i , and greenwashing impact, $\lim_{t \rightarrow \infty} E[E_t^i - V_t^i]$, as a function of the investor's penalty, α , for different values of transparency parameters a ; b ; λ .

2. With investor's penalty on misrating ($\alpha > 0$):

- | The effect of a replaces rather than cumulates with the penalty.
- | The existence of controversies ($\lambda > 0$; $b > 0$) is necessary to have an impact, and the magnitude of λ ; b amplify the impact of the penalty.

Greenwashing and technological change

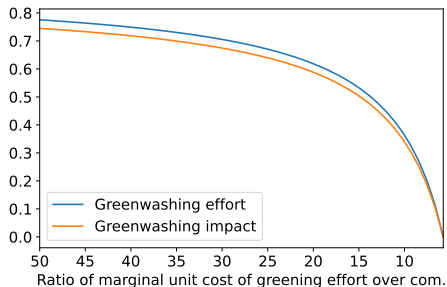


Figure: Greenwashing and technological change. Maximum greenwashing effort, G_{max}^i , and impact, $\lim_{t \rightarrow \infty} E[E_t^i - V_t^i]$, as function of the ratio of marginal unit costs of abatement and communication $\frac{c}{r}$. Consistently with Proposition 3.3, greenwashing is zero when the threshold represented by condition () is hit.

⇒ Curbing greenwashing through green technological change would require a sustained and pronounced R&D effort to bring down $\frac{c}{r}$ before being effective on greenwashing effort and impact.

What if environmental scores were normalized?

Extension of the investor's program:

$$\sup_{\omega \in \mathcal{A}} E \left[\int_0^T e^{-rt} \left\{ \underbrace{\omega_t^0 dS_t + \frac{\gamma}{2} h \omega_t^0 dS i_t}_{\text{Mean-variance criterion}} + \underbrace{\omega_t^0 \left(\beta \frac{E_t}{h(\frac{1}{n} \sum_i E_t^i)} - \alpha M_t \right) dt}_{\text{Non-pecuniary preferences}} \right\} \right],$$

h a regular function approximating identity on \mathbb{R}_+ .

Two interpretations:

Investors practice a “best-in-class” strategy.

Rating agencies standardize environmental scores.

Method and results

Resolution approach of the n -player game:

approximate with the mean field limit ($n \rightarrow \infty$),

show that there exists a unique Nash equilibrium in the equivalent mean field game.

Main results:

1. **Qualitatively**, optimal abatement, communication and greenwashing efforts follow the **same pattern as in the baseline case**
2. However, **all efforts are lower** at the Nash equilibrium, as cross-sectional comparison decreases the incentive to get high environmental ratings.

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Empirical analysis

Challenge: No robust, exhaustive, and dynamic data on companies' emission abatement.) Unreliable test for greenwashing

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However, we build a proxy for environmental communication effort, \hat{c}_t^i , and:

1. analyze its strength;
2. test the dynamics of the model:

$$c_t^{i;} = \frac{1}{\kappa_c^i} \left(B^i \quad A^i(E_t^{i;} \quad V_t^{i;}) \right)$$

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Monthly data from Covalence:

an environmental reputation score, $Rep \in [0, 100]$;

an environmental controversy score, $Con \in [0, 100]$;

an environmental performance score, $E \in [0, 100]$.

Sample: 3,769 global companies between December 2015 and December 2022: 145,508 firm month observations.

Empirical Method

We build a two-step method:

Step 1: Build a proxy for the environmental communication effort, out of *Rep* and *Con*

) Analyze \hat{C}_t^i

Step 2: Test the dynamics of environmental communication effort

) Test the equilibrium equation based on \hat{C}_t^i

Method: Step 2 (Dynamics of env. comm. effort)

Recall, we want to test:

$$c_t^{i_j} = \frac{1}{\kappa_c^i} \left(B^i \quad A^i (E_t^{i_j} \quad V_t^{i_j}) \right)$$

Challenge: V_t^i is **unobservable** and probably correlated with E_t^i .

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Idea: we can test the **time derivative** (first diff.) of c_t^j by making the reasonable assumption that the V_t^j is **highly inert from one month to the next**.

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Idea: we can test the **time derivative** (first diff.) of c_t^i by making the reasonable assumption that the V_t^i is **highly inert from one month to the next**.

To address simultaneity issues, we estimate:

$$\hat{c}_t^i = \alpha_3^i + \iota_{3;t} + \beta_3 \quad E_t^i + \varepsilon_{3;t}^i,$$

where E_t^i is the prediction of the following regression:

$$E_t^i = \frac{1}{4} + \frac{1}{4} E_{t-2}^i + \eta_{4;t}^i$$

Summary of results from the empirics

Conclusions about environmental communication:

1. Companies have implemented a **quasi-structural *positive* envir. com.** policy
 2. **Counter-cyclical dynamic of the envir. com.**, as highlighted by the model
-) Supported by the low marginal unit cost of communication and the asymmetry of information (Barbalau and Zeni, 2023), the **greenwashing** option, at least part of the time, is the most likely.

Conclusion

Investors' pro-environmental preferences incentivize companies to greenwash

- | Impeding further abatement efforts

Investors can curb greenwashing practices by penalizing misrating revealed by controversies

- | This, in turn, encourages abatement

Policymakers can also curb greenwashing and increase abatement:

- (i) regulations strengthening **transparency**
- (ii) support for environmental **technological innovation**

These results are qualitatively **robust** to the introduction of an **interaction** between companies; however, **standardization of environmental ratings** seems **detrimental to abatement efforts**.

Empirical results suggest that companies tend to **greenwash significantly**.

Thank you!

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Companies' program in terms of asset prices

Company i 's program is equivalent to the following:

$$\sup_{(r^i; c^i) \geq A} \mathbb{E} \left[\int_0^T e^{-\delta t} \left(\delta(S_0^i - S_t^i) - \frac{\kappa_r^i}{2} (r_t^i)^2 - \frac{\kappa_c^i}{2} (c_t^i)^2 \right) dt \right],$$

with S_0^i the initial price of the asset issued by company i .

Equilibrium expected returns: Sketch of the proof

Definition (Equilibrium expected returns)

so that:

the investor implements her optimal investing strategy θ_t ,

market clears: $\theta_t^i = 1$.

Proof.

Define the candidate optimal strategy $\theta_t := \frac{1}{M_t} (\theta_t + E_t M_t)$.

The investor's program can be rewritten as

$$\sup_{\theta \in \mathcal{A}} \mathbb{E} \left[\int_0^T e^{-\int_0^t r_s ds} \left\{ \frac{1}{2} (\theta_t - \theta_t^0)^2 + \frac{1}{2} \theta_t^0 \theta_t \right\} dt \right]:$$

) The optimal portfolio choice of the investor is thus the pointwise solution θ_t .

In addition, writing $\mathbf{1}_n$ a vector of ones of size n , market clearing condition writes:

$$\theta_t = \mathbf{1}_n:$$

Equilibrium expected returns are therefore $r_t = \frac{1}{M_t} (E_t M_t)$:

Sketch of the proof

1. Show that, at optimum, optimal strategies verify the following: ${}^t c_t^i + {}^t r_t^i = -$.
2. Reduce the dimension of the problem by a change of variable:
 - ▶ State variables: $(E; V; M) \rightarrow (X; M); \quad X := E - V$ (overrating)
 - ▶ Controls: $(c; r) \rightarrow u; \quad u := c - r$ (greenwashing effort)
 - ▶ Equivalent program:

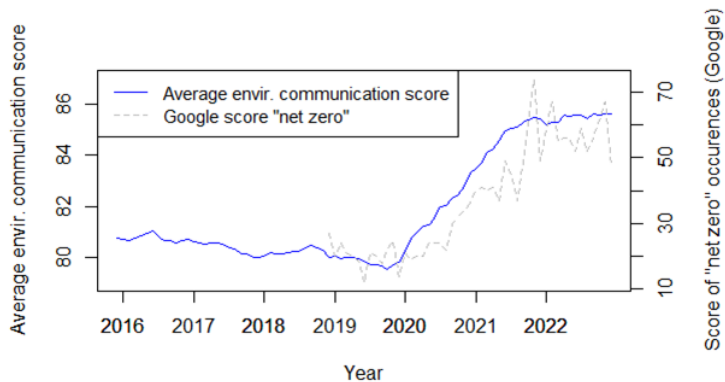
$$\sup_{\substack{c, r; \\ (r; c) \geq \bar{A}}} E \left[\int_0^T e^{-\rho t} \left(X_t^x - M_t^u - \frac{1}{4} \left(u + \frac{1}{r} \right)^2 \right) dt \right]:$$

3. Solve the equivalent program with **one-dimensional** control variable. HJB equation:

$$\max_{u \in \mathbb{R}} \left\{ x - u - \frac{1}{4} \left(u + \frac{1}{r} \right)^2 + v + \frac{\partial v}{\partial x} (ax + b) - \frac{\partial v}{\partial u} u + \frac{\rho v}{2} - \frac{\partial^2 v}{\partial x^2} + \left[v(x(1-b); u + b^2 x^2) - v(x; u) \right] \right\} = 0:$$

4. Deduce optimal strategies in the optimal problem using equality stated in 1.

Estimation: Step 1 (Environmental communication)

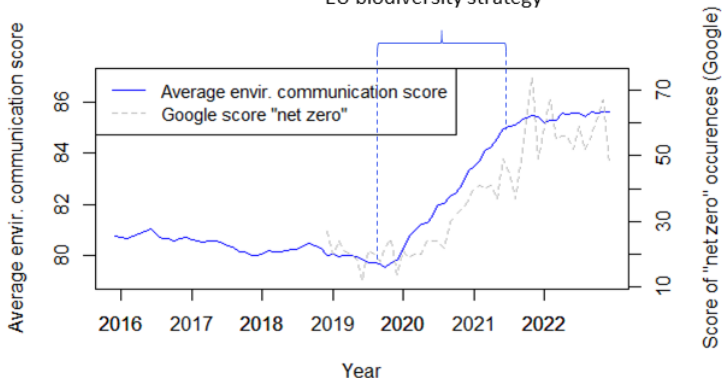


Estimation: Step 1 (Environmental communication)

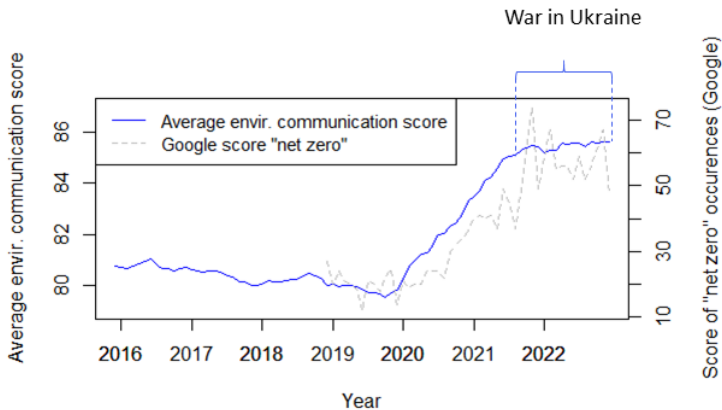
Key environmental regulations worldwide.

E.g., EU:

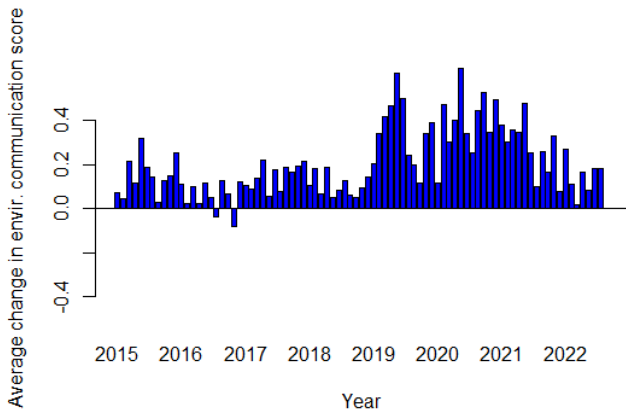
- EU Green Deal, regulations on binding annual emission reductions,
- circular economy,
- sustainable finance,
- EU biodiversity strategy



Estimation: Step 1 (Environmental communication)



Estimation: Step 1 (Environmental comm effort, \hat{c}_t^i)



) **98.8%** of the average monthly environmental communication over the period is positive.

Estimation: Step 2 ($\hat{c}_t^i = \frac{i}{3} + 3_{,t} + 3 E_t^i + \epsilon_{3,t}^i$)

Dependent variable: $\Delta \hat{c}_t^i$					
Top brownest companies:					
	10%	20%	30%	40%	50%
$\Delta E_t^{i,*}$	-0.071 (0.051)	-0.164** (0.065)	-0.244*** (0.073)	-0.221*** (0.067)	-0.271*** (0.060)
Firm FE	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes
Observations	18,760	30,711	44,116	56,785	68,276
R ²	0.005	0.006	0.008	0.010	0.013
Adjusted R ²	-0.061	-0.049	-0.041	-0.035	-0.029
F Statistic	0.985	3.525*	5.460**	3.608*	4.949**
Dependent variable: $\Delta \hat{c}_t^i$					
Top brownest companies:					
	60%	70%	80%	90%	Whole sample
$\Delta E_t^{i,*}$	-0.237*** (0.053)	-0.176*** (0.049)	-0.188*** (0.046)	-0.158*** (0.040)	-0.119*** (0.033)
Firm FE	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes
Observations	83,309	97,324	110,206	123,864	145,508
R ²	0.015	0.016	0.017	0.017	0.017
Adjusted R ²	-0.023	-0.019	-0.015	-0.012	-0.008
F Statistic	3.476*	1.756	1.875	1.195	0.661

Note:

*p<0.1; **p<0.05; ***p<0.01

Estimation: Step 2 ($\hat{c}_t^i = \frac{i}{3} + 3_{,t} + 3 E_t^i + \epsilon_{3,t}^i$)

Dependent variable: $\Delta \hat{c}_t^i$					
Top greenest companies:					
	10%	20%	30%	40%	50%
$\Delta E_t^{i,*}$	-0.255*** (0.079)	-0.342*** (0.069)	-0.446*** (0.072)	-0.405*** (0.061)	-0.415*** (0.057)
Firm FE	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes
Observations	21,644	35,302	48,184	62,199	77,232
R ²	0.018	0.019	0.021	0.020	0.020
Adjusted R ²	-0.018	-0.013	-0.010	-0.010	-0.009
F Statistic	4.284**	8.542***	14.584***	11.377***	10.606***
Dependent variable: $\Delta \hat{c}_t^i$					
Top greenest companies:					
	60%	70%	80%	90%	Whole sample
$\Delta E_t^{i,*}$	-0.404*** (0.052)	-0.380*** (0.054)	-0.294*** (0.052)	-0.237*** (0.044)	-0.119*** (0.033)
Firm FE	Yes	Yes	Yes	Yes	Yes
Month FE	Yes	Yes	Yes	Yes	Yes
Observations	88,723	101,392	114,797	126,748	145,508
R ²	0.022	0.022	0.022	0.021	0.017
Adjusted R ²	-0.007	-0.006	-0.006	-0.006	-0.008
F Statistic	8.727***	6.709***	3.513*	2.169	0.661

Note:

*p<0.1; **p<0.05; ***p<0.01

Testing the equation of optimal communication

) Companies, **especially the greenest ones**, use **environmental communication in a counter-cyclical way** with respect to the evolution of their environmental score, in line with the results of the model.

The results are **robust** to:

Controlling for systematic risks and returns. /

Repeating the estimation starting at **different dates**: December 2012, December 2017, December 2019, and December 2021. /

Using 3 environmental **subscores** related to (i) the environmental impacts of the products sold, (ii) the resources used, and (iii) the emissions, effluents, and waste. /

What about greenwashing?

Conclusions about environmental communication:

1. Companies have implemented a **quasi-structural *positive* envir. com.** policy
2. **Counter-cyclical dynamic of the envir. com.**, as highlighted by the model

Three possible interpretations:

1. Companies are **structurally underrated**.
! But no evidence of underrating; in addition evidence that rating agencies tend to be biased in favor of borrowers (Manso, 2013)
 2. Companies use communication to support their **continuous abatement effort**.
! But monthly communication is very likely to be more volatile than environmental value.
 3. Companies **greenwash** at least part of the time.
! Supported by the low MUC of communication and the asymmetry of information (Barbalau and Zeni, 2023).
-) The **greenwashing** option, at least part of the time, is the most likely.

Robustness: Controls

Dependent variable: Δc_t^g					
Top greenest companies:					
	10%	20%	30%	40%	50%
$\Delta E_t^{g,*}$	-0.205 (0.182)	-0.380** (0.178)	-0.261* (0.142)	-0.243** (0.096)	-0.280*** (0.093)
R_{t-1}^g	-0.335 (0.287)	-0.222 (0.245)	-0.002 (0.217)	0.348 (0.241)	0.480** (0.232)
$\beta_{t-1}^{CAPM,g}$	0.005 (0.015)	0.008 (0.014)	-0.013 (0.027)	0.008 (0.013)	-0.009 (0.014)
Firm FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	8,084	12,272	16,003	19,503	23,219
R ²	0.016	0.021	0.023	0.022	0.020
Adjusted R ²	-0.023	-0.012	-0.008	-0.009	-0.009
F Statistic	1.504	3.582	1.748	3.120	5.449
Dependent variable: Δc_t^g					
Top greenest companies:					
	60%	70%	80%	90%	Whole sample
$\Delta E_t^{g,*}$	-0.385*** (0.093)	-0.284*** (0.086)	-0.251*** (0.093)	-0.193*** (0.067)	-0.083* (0.050)
R_{t-1}^g	0.375* (0.220)	0.185 (0.170)	0.316* (0.171)	0.255* (0.153)	0.252** (0.124)
$\beta_{t-1}^{CAPM,g}$	0.005 (0.011)	0.008 (0.011)	-0.011 (0.012)	-0.0002 (0.010)	0.010 (0.007)
Firm FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	25,745	28,779	32,062	35,208	41,252
R ²	0.023	0.022	0.023	0.022	0.016
Adjusted R ²	-0.007	-0.007	-0.006	-0.006	-0.012
F Statistic	5.711	2.722	4.029	2.754	3.014

Note:

*p<0.1; **p<0.05; ***p<0.01

Robustness: Period

Dependent variable: $\Delta \tilde{c}_t^i$				
50% brownest companies				
	Since 2012	Since 2017	Since 2019	Since 2021
$\Delta E_t^{i,*}$	-0.271*** (0.060)	-0.226*** (0.057)	-0.220*** (0.072)	-0.237*** (0.087)
Firm FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	68,276	57,626	43,107	19,098
R ²	0.013	0.014	0.019	0.022
Adjusted R ²	-0.029	-0.034	-0.042	-0.093
F Statistic	4.949**	3.497*	3.420*	4.817**
Dependent variable: $\Delta \tilde{c}_t^i$				
50% greenest companies				
	Since 2012	Since 2017	Since 2019	Since 2021
$\Delta E_t^{i,*}$	-0.415*** (0.057)	-0.457*** (0.061)	-0.449*** (0.065)	-0.353*** (0.069)
Firm FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes
Observations	77,232	64,719	48,000	20,768
R ²	0.020	0.022	0.026	0.029
Adjusted R ²	-0.009	-0.012	-0.020	-0.075
F Statistic	10.606***	13.629***	18.549***	9.557***

Note: *p<0.1; **p<0.05; ***p<0.01

Robustness: Subscores

	Dependent variable: $\Delta \hat{c}_t^i$			Dependent variable: $\Delta \hat{c}_t^i$		
	50% brownest companies			50% greenest companies		
	(1)	(2)	(3)	(1)	(2)	(3)
$\Delta E_t^{Imp,i,*}$	-0.142*** (0.046)			$\Delta E_t^{Imp,i,*}$	-0.269*** (0.042)	
$\Delta E_t^{Res,i,*}$		-0.180*** (0.047)		$\Delta E_t^{Res,i,*}$	-0.252*** (0.038)	
$\Delta E_t^{Emi,i,*}$			-0.204*** (0.051)	$\Delta E_t^{Emi,i,*}$		-0.225*** (0.036)
Firm FE	Yes	Yes	Yes	Firm FE	Yes	Yes
Time FE	Yes	Yes	Yes	Time FE	Yes	Yes
Observations	68,276	68,276	68,276	Observations	77,232	77,232
R ²	0.006	0.005	0.015	R ²	0.013	0.009
Adjusted R ²	-0.036	-0.037	-0.027	Adjusted R ²	-0.016	-0.020
F Statistic	2.087	3.580*	3.978**	F Statistic	5.953**	8.354***

Note:

*p<0.1; **p<0.05; ***p<0.01

Directional marginal benefits

Let $\delta > 0$. For a pair of communication and abatement strategies $c; r \in A$ and a pair of test functions $\tilde{c}; \tilde{r} \in A$, let us define the associated pair of modified strategies:

$$C_s := C_s + \tilde{c}_s; \quad r_s := r_s + \tilde{r}_s$$

Define the functional $J(c; r)$ as the expected discounted integral of the cost of capital:

$$J(c; r) := E \left[\int_0^T e^{-\delta t} \{ \mathbf{1}_n + E_t^{c;r} M_t^{c;r} \} dt \right];$$

Then, the expected marginal benefits of communication and abatement along directions \tilde{c} and \tilde{r} are defined respectively as the directional (Gateaux) derivatives of J in these two directions:

$$\lim_{\lambda \rightarrow 0} \frac{1}{\lambda} (J(c + \lambda \tilde{c}; r) - J(c; r)); \quad \lim_{\lambda \rightarrow 0} \frac{1}{\lambda} (J(c; r + \lambda \tilde{r}) - J(c; r)):$$

Marginal benefits of emissions reduction and communication

The directional marginal benefits (Gâteaux derivatives) are linear, and can be expressed through Frechet derivatives D_t^c and D_t^r :

$$\lim_{\epsilon \rightarrow 0} \frac{1}{\epsilon} (J(c + \epsilon \delta c, r) - J(c, r)) = \mathbb{E} \left[\int_0^T e^{-\rho t} {}^t D_t^c J(c, r) \delta c_t dt \right],$$

$$\lim_{\epsilon \rightarrow 0} \frac{1}{\epsilon} (J(c, r + \epsilon \delta r) - J(c, r)) = \mathbb{E} \left[\int_0^T e^{-\rho t} {}^t D_t^r J(c, r) \delta r_t dt \right].$$

The derivatives D_t^c and D_t^r shall be called marginal benefits of increasing communication or abatement at a given time t .

Reference calibration

Table: Calibration.

Parameter	Value
a	0.4
b	1
λ	8.5%
κ_C	1
κ_r	50
β	1
α	1
ρ	0.1
δ	0.1
z	0.2