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).

→ 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 **misrating** (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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2. Optimal greenwashing and investor's impact
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Market setting

Probability space $(\Omega, \mathbb{F} = (\mathcal{F}_t)_{t \geq 0}, \mathbb{P})$ 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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Environmental score of company i: $\quad E_0^i = q^i,$

$$dE_t^i = \underbrace{a(V_t^i - E_t^i)dt}_{\text{Rating agency effect}} + \underbrace{(V_{t-}^i - E_{t-}^i)\Theta_t^i dN_t^i}_{\text{Controversy effect}} + \underbrace{c_t^i dt}_{\text{Communication effect}} + \underbrace{zdW_t^i}_{\text{Measurement error}},$$

- c^i the **environmental communication effort** of company i
- N^i Poisson process, W^i Brownian motion, independent from each other
- $\Theta_t^i \in [0,1]$ *random* fraction of misrating revealed at controversy, $\mathbb{E}[\Theta_t^i] := b$.

Misrating proxy

Communication effort c^i

- allows the company to influence its score ($c > 0$, < 0, or $= 0$)
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$\Rightarrow$ use of **controversies history** which reveal a random fraction of the ongoing misrating (through jumps of N^i).

Misrating proxy:

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

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.

$$\sup_{\omega \in \mathbb{A}^\omega} \mathbb{E}\left[\int_0^\infty e^{-rt} \left\{ \underbrace{\omega_t' dS_t - \frac{\gamma}{2} \langle \omega' dS \rangle_t}_{\text{Mean-variance criterion}} + \underbrace{\omega_t' (\beta E_t - \alpha M_t) dt}_{\text{Non-pecuniary preferences}} \right\} \right]$$

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, $-\alpha M_t$

$\Rightarrow$ 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

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

- 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

Equivalent program with asset prices

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Optimal portfolio and equilibrium expected returns

Proposition

The optimal asset allocation of the investor is the pointwise solution

$$\omega_t^* = \frac{1}{\gamma}\Sigma^{-1}(\mu_t + \beta E_t - \alpha M_t),$$

and the equilibrium expected return is

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

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

αM_t : Additional correction for greenwashing companies.

Proof

Companies' program with explicit objective

Knowing equilibrium expected returns, companies' program becomes:

$$\inf_{(r^i,c^i)\in\mathbb{A}} \mathbb{E}\left[\int_0^\infty e^{-\delta t}\left(\gamma\boldsymbol{\Sigma 1}_n - \beta E_t^i + \alpha M_t^i + \frac{\kappa_r^i}{2}(r_t^i)^2 + \frac{\kappa_c^i}{2}(c_t^i)^2\right) dt\right].$$

Under the following constraints:

$$\begin{cases} dE_t^i = a(V_t^i - E_t^i)dt + (V_{t-}^i - E_{t-}^i)\Theta_t^i dN_t^i + c_t^i dt + zdW_t^i, \quad E_0^i = q^i, \\ dV_t^i = v_t^i dt, \quad V_0^i = p^i, \\ dM_t^i = -\rho M_t^i dt + (E_t^i - E_{t-}^i)^2 dN_t^i, \quad M_0^i = u^i, \end{cases}$$

$$\mathbb{A} := \left\{(c,v)\in\mathbb{R}^2, \mathbb{F}-\text{prog. meas.} : \mathbb{E}[\int_0^\infty e^{-\delta^I\wedge\delta t}\left(|c_t|^2 + |v_t|^2\right) dt] < \infty\right\}$$

$\Rightarrow$ 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), $\frac{\kappa_r^i}{2}(v_t^i)^2 + \frac{\kappa_c^i}{2}(c_t^i)^2$.

Optimal strategies

Proposition (Optimal strategies)

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

$$c_t^{i,*} = \frac{1}{\kappa_c^i}\left(B^i - A^i(E_t^{i,*} - V_t^{i,*})\right),$$
$$v_t^{i,*} = \frac{1}{\kappa_v^i}\left(\frac{\beta}{\delta} - B^i + A^i(E_t^{i,*} - V_t^{i,*})\right),$$

where

$$B^i = \frac{\beta(1 + \frac{A^i}{\delta\kappa_v^i})}{\delta + a + b\lambda^i + \frac{2A^i}{\bar{\kappa}^i}}, \qquad A^i = \frac{\bar{\kappa}^i}{4}R^i\left(\sqrt{1 + \frac{16}{\bar{\kappa}^i}\frac{T^i}{(R^i)^2}} - 1\right)$$
$$T^i = \frac{2\lambda^i b^2 \boldsymbol{\alpha}}{(1+b)(\delta+\rho)}, \quad R^i = \delta + 2a + \frac{2\lambda^i b}{1+b}, \quad \bar{\kappa}^i = \frac{2}{\frac{1}{\kappa_v^i} + \frac{1}{\kappa_c^i}}$$

with $E^{i,*}$, $V^{i,*}$ state variables when the optimal strategies $c^{i,*}$, $v^{i,*}$ are employed, $A^i, B^i \geq 0$ and $\frac{\beta}{\delta} - B^i \geq 0$.

Proof

Optimal greenwashing effort when $\beta > 0$, $\alpha > 0$

Proposition (Greenwashing effort)

If the following condition $(*)$ is satisfied,

$$\frac{\kappa_v^i}{\kappa_c^i} > \frac{a + b\lambda^i}{\delta}, \qquad (*)$$

company i greenwashes if, and only if,

$$0 \leq E_t^{i,*} - V_t^{i,*} < \frac{1}{\frac{2}{\bar{\kappa}^i}A^i} G_{max}^i, \qquad G_{max}^i = \frac{2}{\bar{\kappa}^i} B^i - \frac{\beta}{\delta \kappa_v^i}.$$

When it greenwashes, its greenwashing effort is as follows:

$$c_t^{i,*} - v_t^{i,*} = G_{max}^i - \frac{2}{\bar{\kappa}^i} A^i (E_t^{i,*} - V_t^{i,*})$$

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

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

$\Rightarrow$ Companies greenwash to maintain their environmental score at a certain level above their environmental value

Impact of investor's preferences and penalty

- β Sensitivity of pro-environmental preferences of the investor
- α Investor's penalty on revealed misrating

Proposition (Investor's impact on greenwashing)

When condition $(*)$ is satisfied, the maximal greenwashing effort, G^i_{max}, 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, $\frac{1}{\kappa^i_r}\left(\frac{\beta}{\delta} - B^i\right)$, increases linearly in β, and, when condition $(*)$ is satisfied, increases in a concave way in α.

$\Rightarrow$ 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

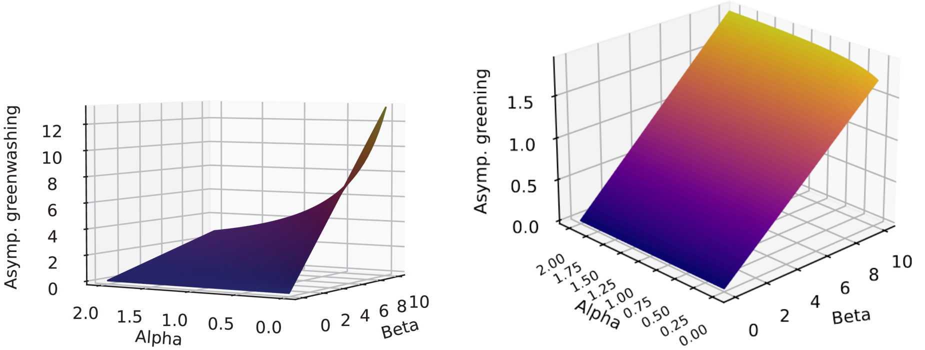

Figure: **Average greenwashing and abatement as a function of β and α.** Asymptotic expected optimal greenwashing ($\lim_{t\to\infty} \mathbb{E}[c_t^* - v_t^*]$; left) and abatement ($\lim_{t\to\infty} \mathbb{E}[v_t^*]$; right) as a function of the pro-environmental sensitivity, β, and the misrating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

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

Calibration, which verifies condition $(*)$, and $\kappa_v/\kappa_c = 50$.

Greenwashing and transparency parameters

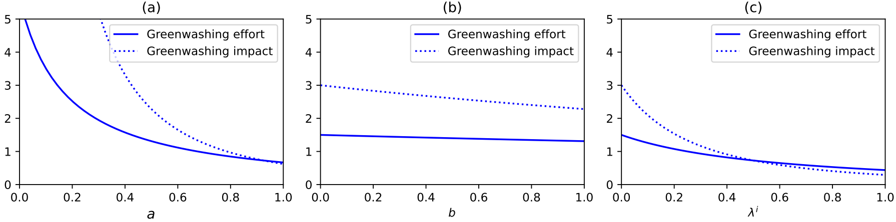

Figure: **Greenwashing and transparency parameters when $\alpha = 0$.** The maximum greenwashing effort, G^i_{max}, (solid lines), and greenwashing impact, $\lim_{t\to\infty} \mathbb{E}[E^{i,*}_t - V^{i,*}_t]$, (dotted lines), as a function of transparency parameters a, b, λ^i, when the investor's penalty, 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, $\boldsymbol{\lambda}^i$, and portion of misrating revealed, ***b***, are also dissuasive but with a smaller magnitude.

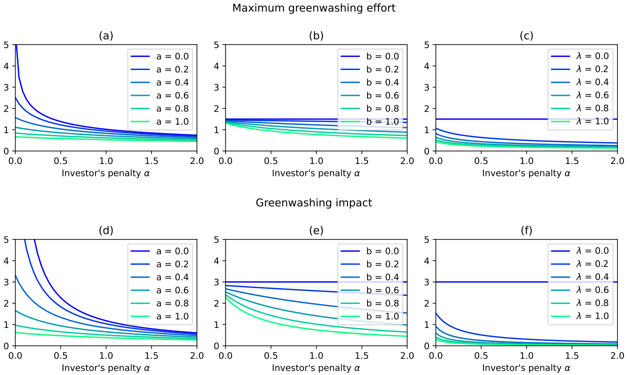

Figure: **Greenwashing and penalty α for various transparency parameters.** The maximum greenwashing effort, G^i_{max}, and greenwashing impact, $\lim_{t\to\infty} \mathbb{E}[E^{i,*}_t - V^{i,*}_t]$, as a function of the investor's penalty, α, for different values of transparency parameters a, b, λ^i.

2. With investor's penalty on misrating ($\alpha > 0$):
   - The effect of ***a*** *replaces* rather than *cumulates* with the penalty α.
   - The existence of controversies ($\boldsymbol{\lambda}^i > 0$, $\boldsymbol{b} > 0$) is *necessary* for α to have an impact, and the magnitude of $\boldsymbol{\lambda}^i$, ***b*** *amplify* the impact of the penalty α.

Greenwashing and technological change

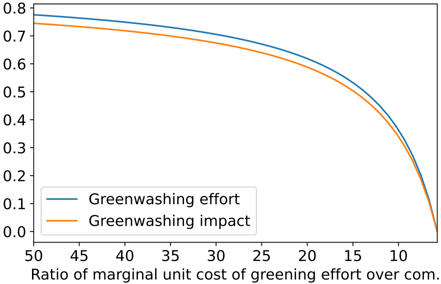

Figure: **Greenwashing and technological change.** Maximum greenwashing effort, G^i_{max}, and impact, $\lim_{t\to\infty} \mathbb{E}[E^{i,*}_t - V^{i,*}_t]$, as function of the ratio of marginal unit costs of abatement and communication κ^i_r/κ^i_c. Consistently with Proposition 3.3, greenwashing is zero when the threshold represented by condition $(*)$ is hit.

$\Rightarrow$ Curbing greenwashing through green technological change would require a sustained and pronounced R&D effort to bring down κ^i_r before being effective on greenwashing effort and impact.

What if environmental scores were normalized?

Extension of the investor's program:

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

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 ($n \to \infty$),
- 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. $\Rightarrow$ 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:

$$c_t^{i,*} = \frac{1}{\kappa_c^i}\left(B^i - A^i(E_t^{i,*} - V_t^{i,*})\right)$$

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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*

  $\Rightarrow$ Analyze $\hat{c}_t^i$

- **Step 2**: Test the dynamics of environmental communication effort

  $\Rightarrow$ Test the equilibrium equation based on $\hat{c}_t^i$

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

Recall, we want to test:

$$c_t^{i,*} = \frac{1}{\kappa_c^i}\left(B^i - A^i(E_t^{i,*} - V_t^{i,*})\right)$$

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

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To address simultaneity issues, we estimate:

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

where $\Delta E_t^{i,*}$ is the prediction of the following regression:

$$\Delta E_t^i = \alpha_4^i + \beta_4 E_{t-2}^i + \varepsilon_{4,t}^i.$$

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

$\Rightarrow$ 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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Bibliography I

Admati, A. R. and Pfleiderer, P. (1986). A monopolistic market for information. *Journal of Economic Theory*, 39(2):400–438.

Ardia, D., Bluteau, K., Boudt, K., and Inghelbrecht, K. (2023). Climate change concerns and the performance of green vs. brown stocks. *Management Science*, 69(12):7607–7632.

Avramov, D., Cheng, S., Lioui, A., and Tarelli, A. (2022). Sustainable investing with ESG rating uncertainty. *Journal of Financial Economics*, 145(2):642–664.

Barbalau, A. and Zeni, F. (2023). The optimal design of green securities. *Working*, Paper.

Barber, B. M., Morse, A., and Yasuda, A. (2021). Impact investing. *Journal of Financial Economics*, 139(1):162–185.

Berg, F., Fabisik, C., and Sautner, Z. (2021). Is history repeating itself? The (un)predictable past of ESG ratings. *Working*, Paper.

Berg, F., Koelbel, J. F., and Rigobon, R. (2022). Aggregate confusion: The divergence of ESG ratings. *Review of Finance*, 26(6):1315–1344.

Berk, J. B. and van Binsbergen, J. H. (2021). The impact of impact investing. *Working*, Paper.

Bingler, J., Kraus, M., Leippold, M., and Webersinke, N. (2022). Cheap talk in corporate climate commitments: The effectiveness of climate initiatives. *Swiss Finance Institute Research Paper*, (22-54).

Bingler, J., Kraus, M., Leippold, M., and Webersinke, N. (2023). How cheap talk in climate disclosures relates to climate initiatives, corporate emissions, and reputation risk. *Working*, Paper.

Bibliography II

Bolton, P. and Kacperczyk, M. T. (2021). Do investors care about carbon risk? *Journal of Financial Economics*, 142(2):517–549.

Bonnefon, J.-F., Landier, A., Sastry, P. R., and Thesmar, D. (2022). The moral preferences of investors: Experimental evidence. *Working*, Paper.

Bouchard, B., Fukasawa, M., Herdegen, M., and Muhle-Karbe, J. (2018). Equilibrium returns with transaction costs. *Finance and Stochastics*, 22:569–601.

Chen, H. (2023). Talk or walk the talk? the real impact of ESG investing. *The Real Impact of ESG Investing (May 19, 2023)*.

Cheng, G., Jondeau, E., Mojon, B., and Vayanos, D. (2023). The impact of green investors on stock prices. *Working*, Paper.

De Angelis, T., Tankov, P., and Zerbib, O. D. (2023). Climate impact investing. *Management Science*, 69(12):7669–7692.

Duchin, R., Gao, J., and Xu, Q. (2023). Sustainability or greenwashing: Evidence from the asset market for industrial pollution. *Working*, Paper.

Duflo, E., Greenstone, M., and Ryan, N. (2013). Truth-telling by third-party auditors and the response of polluting firms: Experimental evidence from India. *The Quarterly Journal of Economics*, 128(4):1499–1545.

Easley, D. and O'hara, M. (2004). Information and the cost of capital. *The Journal of Finance*, 59(4):1553–1583.

Bibliography III

Edmans, A., Levit, D., and Schneemeier, J. (2023). Socially responsible divesmtent. *Working*, Paper.

Fabrizio, K. R. and Kim, E.-H. (2019). Reluctant disclosure and transparency: Evidence from environmental disclosures. *Organization Science*, 30(6):1207–1231.

Favilukis, J., Garlappi, L., and Uppal, R. (2023). Evaluating the impact of portfolio mandates. *Working*, Paper.

Flammer, C. (2021). Corporate green bonds. *Journal of Financial Economics*, 142(2):499–516.

Goldstein, I., Kopytov, A., Shen, L., and Xiang, H. (2022). On ESG investing: Heterogeneous preferences, information, and asset prices. *Working*, Paper.

Green, D. and Roth, B. (2024). The allocation of socially responsible capital. *Working*, Paper.

Grossman, S. J. and Stiglitz, J. E. (1980). On the impossibility of informationally efficient markets. *American Economic Review*, 70(3):393–408.

Hartzmark, S. and Shue, K. (2023). Counterproductive sustainable investing: The impact elasticity of brown and green firms. *Working*, Paper.

Heeb, F., Kölbel, J. F., Paetzold, F., and Zeisberger, S. (2023). Do investors care about impact? *Review of Financial Studies*, 36(5):1737–1787.

Hoepner, A. G. F., Dimatteo, S., Schauld, J., Yi, P.-S., and Musolesi, M. (2017). Tweeting About Sustainability: Can Emotional Nowcasting Discourage Greenwashing? ICMA Centre Discussion Papers in Finance icma-dp2017-02, Henley Business School, University of Reading.

Bibliography IV

Hughes, P. J. (1986). Signalling by direct disclosure under asymmetric information. *Journal of Accounting and Economics*, 8(2):119–142.

Ilhan, E., Krueger, P., Sautner, Z., and Starks, L. T. (2023). Climate risk disclosure and institutional investors. *Review of Financial Studies*, 36(7):2617–2650.

Lambert, R. A., Leuz, C., and Verrecchia, R. E. (2012). Information asymmetry, information precision, and the cost of capital. *Review of Finance*, 16(1):1–29.

Landier, A. and Lovo, S. (2023). ESG investing: How to optimize impact? *Working*, Paper.

Oehmke, M. and Opp, M. M. (2024). A theory of socially responsible investment. *Review of Economic Studies,*, forthcoming.

Pástor, L., Stambaugh, R. F., and Taylor, L. A. (2021). Sustainable investing in equilibrium. *Journal of Financial Economics*, 142(2):550–571.

Pedersen, L. H., Fitzgibbons, S., and Pomorski, L. (2021). Responsible investing: The ESG-efficient frontier. *Journal of Financial Economics*, 142(2):572–597.

Pástor, L., Stambaugh, R. F., and Taylor, L. A. (2021). Sustainable investing in equilibrium. *Journal of Financial Economics*, 142(2):550–571.

Pástor, L., Stambaugh, R. F., and Taylor, L. A. (2022). Dissecting green returns. *Journal of Financial Economics*, 146(2):403–424.

Bibliography V

Sauzet, M. and Zerbib, O. D. (2022). When green investors are green consumers. *Working*, Paper.

Van der Beck, P. (2023). Flow-driven ESG returns. *Working*, Paper.

Zerbib, O. D. (2022). A sustainable capital asset pricing model (S-CAPM): Evidence from environmental integration and sin stock exclusion. *Review of Finance*, 26(6):1345–1388.

Companies' program in terms of asset prices

Company i's program is equivalent to the following:

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

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

Back

Equilibrium expected returns: Sketch of the proof

Definition (Equilibrium expected returns)

μ so that:

- the investor implements her optimal investing strategy ω^*,
- market clears: $\forall i, \ \forall t, \ \omega_t^{*,i} = 1$.

Proof.

- Define the candidate optimal strategy $\omega_t^* := \frac{1}{\gamma}\Sigma^{-1}(\mu_t + \beta E_t - \alpha M_t)$.
- The investor's program can be rewritten as

$$\sup_{\omega \in \mathbb{A}^\omega} \mathbb{E}\left[\int_0^\infty e^{-\delta^I t}\left\{-\frac{\gamma}{2}(\omega_t - \omega_t^*)'\Sigma(\omega_t - \omega_t^*) + \frac{\gamma}{2}\omega_t^{*\prime}\Sigma\omega_t^*\right\} dt\right].$$

$\Rightarrow$ The optimal portfolio choice of the investor is thus the pointwise solution ω_t^*.

- In addition, writing $\mathbf{1}_n$ a vector of ones of size n, market clearing condition writes: $\forall t, \ \omega_t^* = \mathbf{1}_n$.
- Equilibrium expected returns are therefore $\mu_t = \gamma\Sigma\mathbf{1}_n - \beta E_t + \alpha M_t$.

Back

Sketch of the proof

1. Show that, at optimum, optimal strategies verify the following: $\kappa_c^i c_t^{i,*} + \kappa_r^i r_t^{i,*} = \frac{\beta}{\delta}$.
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: $(c, r) \Rightarrow \xi$, $\quad \xi := c - r$ (greenwashing effort)
   - Equivalent program:

$$\sup_{\substack{\xi = c - r, \\ (r,c) \in \mathbb{A}}} \mathbb{E}\left[\int_0^\infty e^{-\delta t}\left(\beta X_t^x - \alpha M_t^u - \frac{\bar{\kappa}}{4}\left(\xi_t + \frac{\beta}{\delta \kappa_r}\right)^2\right) dt\right].$$

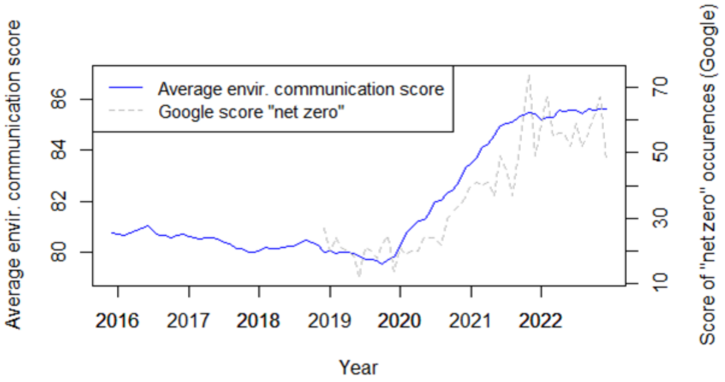
3. Solve the equivalent program with **one-dimensional** control variable. HJB equation:

$$\max_{\xi \in \mathbb{R}} \left\{ \beta x - \alpha u - \frac{\bar{\kappa}}{4}\left(\xi + \frac{\beta}{\delta \kappa_r}\right)^2 - \delta v + \frac{\partial v}{\partial x}(-ax + \xi) - \frac{\partial v}{\partial u}\rho u + \frac{z^2}{2}\frac{\partial^2 v}{\partial x^2} + \lambda\left[v(x(1-b), u + b^2 x^2) - v(x,u)\right]\right\} = 0.$$

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

Back

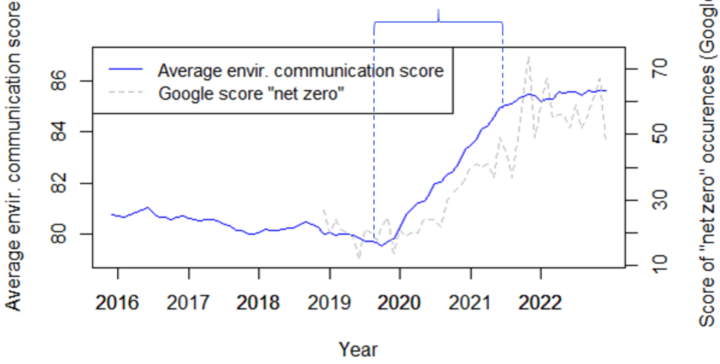
Estimation: Step 1 (Environmental communication)



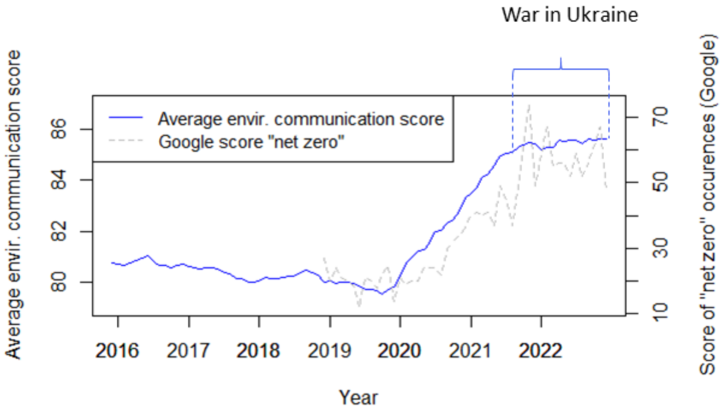
Estimation: Step 1 (Environmental communication)

Key environmental regulations worldwide.
E.g., EU:

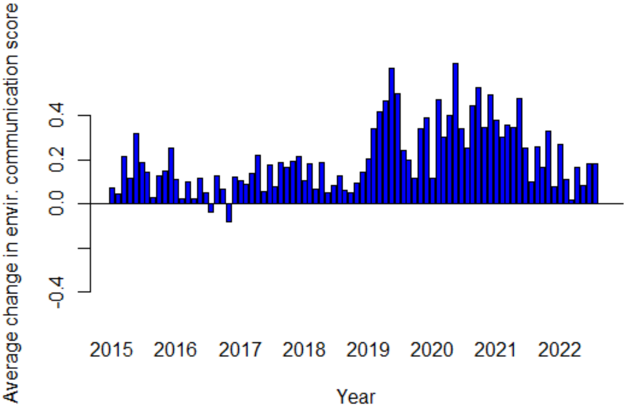
- EU Green Deal, regulations on binding annual emission reductions,
- circular economy,
- sustainable finance,
- EU biodiversity strategy



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 ($\Delta \hat{c}_t^i = \alpha_3^i + \iota_{3,t} + \beta_3 \Delta E_t^{i,*} + \varepsilon_{3,t}^i$)

	Dependent variable: $\Delta \hat{c}_t^i$				
	Top brownest companies:				
	10%	20%	30%	40%	50%
$\Delta E_t^{i,*}$	−0.071	−0.164**	−0.244***	−0.221***	−0.271***
	(0.051)	(0.065)	(0.073)	(0.067)	(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***	−0.176***	−0.188***	−0.158***	−0.119***
	(0.053)	(0.049)	(0.046)	(0.040)	(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 ($\Delta \hat{c}_t^i = \alpha_3^i + \iota_{3,t} + \beta_3 \Delta E_t^{i,*} + \varepsilon_{3,t}^i$)

	Dependent variable: $\Delta \hat{c}_t^i$				
	Top greenest companies:				
	10%	20%	30%	40%	50%
$\Delta E_t^{i,*}$	-0.255^{***}	-0.342^{***}	-0.446^{***}	-0.405^{***}	-0.415^{***}
	(0.079)	(0.069)	(0.072)	(0.061)	(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^{***}	-0.380^{***}	-0.294^{***}	-0.237^{***}	-0.119^{***}
	(0.052)	(0.054)	(0.052)	(0.044)	(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:

- **Controling 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: $\Delta\hat{c}_t^i$				
	Top greenest companies:				
	10%	20%	30%	40%	50%
$\Delta E_t^{i,*}$	−0.205	−0.380**	−0.261*	−0.243**	−0.280***
	(0.182)	(0.178)	(0.142)	(0.096)	(0.093)
R_{t-1}^i	−0.335	−0.222	−0.002	0.348	0.480**
	(0.287)	(0.245)	(0.217)	(0.241)	(0.232)
$\beta_{t-1}^{CAPM,i}$	0.005	0.008	−0.013	0.008	−0.009
	(0.015)	(0.014)	(0.027)	(0.013)	(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: $\Delta\hat{c}_t^i$				
	Top greenest companies:				
	60%	70%	80%	90%	Whole sample
$\Delta E_t^{i,*}$	−0.385***	−0.284***	−0.251***	−0.193***	−0.083*
	(0.093)	(0.086)	(0.093)	(0.067)	(0.050)
R_{t-1}^i	0.375*	0.185	0.316*	0.255*	0.252**
	(0.220)	(0.170)	(0.171)	(0.153)	(0.124)
$\beta_{t-1}^{CAPM,i}$	0.005	0.008	−0.011	−0.0002	0.010
	(0.011)	(0.011)	(0.012)	(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

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Robustness: Period

	Dependent variable: $\Delta\hat{c}_t^i$			
	50% brownest companies			
	Since 2012	Since 2017	Since 2019	Since 2021
$\Delta E_t^{i,*}$	−0.271***	−0.226***	−0.220***	−0.237***
	(0.060)	(0.057)	(0.072)	(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: $\Delta\hat{c}_t^i$			
	50% greenest companies			
	Since 2012	Since 2017	Since 2019	Since 2021
$\Delta E_t^{i,*}$	−0.415***	−0.457***	−0.449***	−0.353***
	(0.057)	(0.061)	(0.065)	(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

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Robustness: Subscores

	Dependent variable: $\Delta\hat{c}_t^i$		
	50% brownest companies		
	(1)	(2)	(3)
$\Delta E_t^{Imp,i,*}$	−0.142***		
	(0.046)		
$\Delta E_t^{Res,i,*}$		−0.180***	
		(0.047)	
$\Delta E_t^{Emi,i,*}$			−0.204***
			(0.051)
Firm FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observations	68,276	68,276	68,276
R^2	0.006	0.005	0.015
Adjusted R^2	−0.036	−0.037	−0.027
F Statistic	2.087	3.580*	3.978**

	Dependent variable: $\Delta\hat{c}_t^i$		
	50% greenest companies		
	(1)	(2)	(3)
$\Delta E_t^{Imp,i,*}$	−0.269***		
	(0.042)		
$\Delta E_t^{Res,i,*}$		−0.252***	
		(0.038)	
$\Delta E_t^{Emi,i,*}$			−0.225***
			(0.036)
Firm FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Observations	77,232	77,232	77,232
R^2	0.013	0.009	0.014
Adjusted R^2	−0.016	−0.020	−0.016
F Statistic	5.953**	8.354***	8.135***

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

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Directional marginal benefits

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

$$c^\epsilon_s := c_s + \epsilon \delta c_s, \qquad r^\epsilon_s := r_s + \epsilon \delta r.$$

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

$$J(c, r) := \mathbb{E}\left[\int_0^\infty e^{-\delta t}\left\{-\gamma \Sigma \mathbf{1}_n + \beta E^{c,r}_t - \boldsymbol{\alpha} M^{c,r}_t\right\} dt\right],$$

Then, the expected marginal benefits of communication and abatement along directions δc and δr are defined respectively as the directional (Gateaux) derivatives of J in these two directions:

$$\lim_{\epsilon \to 0} \frac{1}{\epsilon}\left(J(c + \epsilon \delta c, r) - J(c, r)\right), \qquad \lim_{\epsilon \to 0} \frac{1}{\epsilon}\left(J(c, r + \epsilon \delta r) - J(c, r)\right).$$

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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:

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

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

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

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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

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