On ESG Investing: Heterogeneous Preferences, Information, and Asset Prices

Itay Goldstein, Alexandr Kopytov, Lin Shen, Haotian Xiang

WP 2022

Alex von Hafften

UW-Madison

May 2, 2022

Main Question

- Environmental, social, and governance (ESG) growing in finance

Main Question

- Environmental, social, and governance (ESG) growing in finance
    - In 2014, $6.6 trillion of ESG-related assets under management

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, \$6.6 trillion of ESG-related assets under management
  - In 2020, up to \$17.1 trillion out of \$48.6 trillion total

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, $6.6 trillion of ESG-related assets under management
  - In 2020, up to $17.1 trillion out of $48.6 trillion total

- Classic paradigm:

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, \$6.6 trillion of ESG-related assets under management
  - In 2020, up to \$17.1 trillion out of \$48.6 trillion total
- Classic paradigm:
  - Financial markets aggregate information about fundamentals

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, \$6.6 trillion of ESG-related assets under management
  - In 2020, up to \$17.1 trillion out of \$48.6 trillion total

- Classic paradigm:
  - Financial markets aggregate information about fundamentals
  - Price informativeness $\implies$ cost of capital $\implies$ allocation of capital

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, \$6.6 trillion of ESG-related assets under management
  - In 2020, up to \$17.1 trillion out of \$48.6 trillion total

- Classic paradigm:
  - Financial markets aggregate information about fundamentals
  - Price informativeness $\implies$ cost of capital $\implies$ allocation of capital
  - Assumes uniform objectives across investors

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, \$6.6 trillion of ESG-related assets under management
  - In 2020, up to \$17.1 trillion out of \$48.6 trillion total
- Classic paradigm:
  - Financial markets aggregate information about fundamentals
  - Price informativeness $\implies$ cost of capital $\implies$ allocation of capital
  - Assumes uniform objectives across investors
- Questions:

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, \$6.6 trillion of ESG-related assets under management
  - In 2020, up to \$17.1 trillion out of \$48.6 trillion total
- Classic paradigm:
  - Financial markets aggregate information about fundamentals
  - Price informativeness $\implies$ cost of capital $\implies$ allocation of capital
  - Assumes uniform objectives across investors
- Questions:
  - How do asset prices form when investors value assets differently?

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, $6.6 trillion of ESG-related assets under management
  - In 2020, up to $17.1 trillion out of $48.6 trillion total
- Classic paradigm:
  - Financial markets aggregate information about fundamentals
  - Price informativeness $\implies$ cost of capital $\implies$ allocation of capital
  - Assumes uniform objectives across investors
- Questions:
  - How do asset prices form when investors value assets differently?
  - How to interpret asset prices? What info is incorporated in the price?

Main Question

- Environmental, social, and governance (ESG) growing in finance
  - In 2014, \$6.6 trillion of ESG-related assets under management
  - In 2020, up to \$17.1 trillion out of \$48.6 trillion total
- Classic paradigm:
  - Financial markets aggregate information about fundamentals
  - Price informativeness $\implies$ cost of capital $\implies$ allocation of capital
  - Assumes uniform objectives across investors
- Questions:
  - How do asset prices form when investors value assets differently?
  - How to interpret asset prices? What info is incorporated in the price?
  - What are the implications of recent trends?

Approach

- A noisy rational expectations equilibrium model à la Hellwig (1980)

Approach

- A noisy rational expectations equilibrium model à la Hellwig (1980)
- Asset payoff has two risky payoff components:

Approach

- A noisy rational expectations equilibrium model à la Hellwig (1980)
- Asset payoff has two risky payoff components:
  - Financial cashflow

Approach

- A noisy rational expectations equilibrium model à la Hellwig (1980)
- Asset payoff has two risky payoff components:
  - Financial cashflow
  - ESG component

Approach

- A noisy rational expectations equilibrium model à la Hellwig (1980)
- Asset payoff has two risky payoff components:
  - Financial cashflow
  - ESG component
- Two types of risk-averse investors with heterogenous signals:

Approach

- A noisy rational expectations equilibrium model à la Hellwig (1980)
- Asset payoff has two risky payoff components:
  - Financial cashflow
  - ESG component
- Two types of risk-averse investors with heterogenous signals:
  - Traditional investors (t) care only about financial cashflow

Approach

- A noisy rational expectations equilibrium model à la Hellwig (1980)
- Asset payoff has two risky payoff components:
  - Financial cashflow
  - ESG component
- Two types of risk-averse investors with heterogenous signals:
  - Traditional investors (t) care only about financial cashflow
  - Green investors (g) care about both components

Main Findings

- Green and traditional investors trade differently based on same info

Main Findings

- Green and traditional investors trade differently based on same info
- Multiple equilibria from feedback loop (with low noise):

Main Findings

- Green and traditional investors trade differently based on same info
- Multiple equilibria from feedback loop (with low noise):
  - Type i dominate $\implies$ price is more informative for i $\implies$ i trade more

Main Findings

- Green and traditional investors trade differently based on same info
- Multiple equilibria from feedback loop (with low noise):
  - Type i dominate $\implies$ price is more informative for i $\implies$ i trade more
- Increase in green investor might increase the cost of capital

Main Findings

- Green and traditional investors trade differently based on same info
- Multiple equilibria from feedback loop (with low noise):
  - Type i dominate $\implies$ price is more informative for i $\implies$ i trade more
- Increase in green investor might increase the cost of capital
  - More g investors $\implies$ price comoves more with ESG component $\implies$ price less informative about cash flows and noisier to t investors

Main Findings

- Green and traditional investors trade differently based on same info
- Multiple equilibria from feedback loop (with low noise):
  - Type i dominate $\implies$ price is more informative for i $\implies$ i trade more
- Increase in green investor might increase the cost of capital
  - More g investors $\implies$ price comoves more with ESG component $\implies$ price less informative about cash flows and noisier to t investors
- Improved ESG information might indirectly increase cost of capital

Main Findings

- Green and traditional investors trade differently based on same info
- Multiple equilibria from feedback loop (with low noise):
  - Type i dominate $\implies$ price is more informative for i $\implies$ i trade more
- Increase in green investor might increase the cost of capital
  - More g investors $\implies$ price comoves more with ESG component $\implies$ price less informative about cash flows and noisier to t investors
- Improved ESG information might indirectly increase cost of capital
  - All investors benefit directly from better ESG info, but g investors more

Main Findings

- Green and traditional investors trade differently based on same info
- Multiple equilibria from feedback loop (with low noise):
  - Type i dominate $\implies$ price is more informative for i $\implies$ i trade more
- Increase in green investor might increase the cost of capital
  - More g investors $\implies$ price comoves more with ESG component $\implies$ price less informative about cash flows and noisier to t investors
- Improved ESG information might indirectly increase cost of capital
  - All investors benefit directly from better ESG info, but g investors more
  - g investors trade more $\implies$ price less informative to t investors

Outline

1. Introduction
2. **Simplified Model**
3. Other Findings
4. Conclusion and Discussion

Environment - Assets

- Unlimited supply of risk-free asset

Environment - Assets

- Unlimited supply of risk-free asset
  - Payoff and price normalized to one

Environment - Assets

- Unlimited supply of risk-free asset
  - Payoff and price normalized to one
- Unit supply of risky asset, “stock”

Environment - Assets

- Unlimited supply of risk-free asset
  - Payoff and price normalized to one
- Unit supply of risky asset, “stock”
  - $\tilde{z}$ is monetary factor in payoff and $\tilde{\delta}$ is non-monetary factor in payoff

$$\tilde{z}, \tilde{\delta} \sim_{iid} N(0, \tau^{-1})$$

Environment - Assets

- Unlimited supply of risk-free asset
  - Payoff and price normalized to one
- Unit supply of risky asset, "stock"
  - $\tilde{z}$ is monetary factor in payoff and $\tilde{\delta}$ is non-monetary factor in payoff

$$\tilde{z}, \tilde{\delta} \sim_{iid} N(0, \tau^{-1})$$

  - Price $\tilde{p}$ is determined by market clearing

Environment - Market Participants

- Rational investors trade on signals and learn from price

Environment - Market Participants

- Rational investors trade on signals and learn from price
  - Traditional ($\beta_z^t = 1$ and $\beta_\delta^t = 0$) and green ($\beta_z^g = 0$ and $\beta_\delta^g = 1$)

Environment - Market Participants

- Rational investors trade on signals and learn from price
  - Traditional ($\beta_z^t = 1$ and $\beta_\delta^t = 0$) and green ($\beta_z^g = 0$ and $\beta_\delta^g = 1$)
  - Mass of each group is $\frac{m}{2}$

Environment - Market Participants

- Rational investors trade on signals and learn from price
  - Traditional ($\beta_z^t = 1$ and $\beta_\delta^t = 0$) and green ($\beta_z^g = 0$ and $\beta_\delta^g = 1$)
  - Mass of each group is $\frac{m}{2}$
  - Investor i of type j holding d_j^i shares has CARA expected utility

$$E\{-\exp(-\gamma[W_0^i + d_j^i(\tilde{v}_j - \tilde{q}])\}$$

where $\tilde{v}_j = \beta_z^j \tilde{z} + \beta_\delta^j \tilde{\delta}$ is per-unit payoff

Environment - Market Participants

- Rational investors trade on signals and learn from price
  - Traditional ($\beta_z^t = 1$ and $\beta_\delta^t = 0$) and green ($\beta_z^g = 0$ and $\beta_\delta^g = 1$)
  - Mass of each group is $\frac{m}{2}$
  - Investor i of type j holding d_j^i shares has CARA expected utility

$$E\{-\exp(-\gamma[W_0^i + d_j^i(\tilde{v}_j - \tilde{q}])\}$$

    where $\tilde{v}_j = \beta_z^j \tilde{z} + \beta_\delta^j \tilde{\delta}$ is per-unit payoff
  - Each investor receives private signals about each factor

$$\tilde{s}_z^i \sim_{iid} N(\tilde{z}, \tau_s^{-1}), \tilde{s}_\delta^i \sim_{iid} N(\tilde{\delta}, \tau_s^{-1})$$

Environment - Market Participants

- Rational investors trade on signals and learn from price
  - Traditional ($\beta_z^t = 1$ and $\beta_\delta^t = 0$) and green ($\beta_z^g = 0$ and $\beta_\delta^g = 1$)
  - Mass of each group is $\frac{m}{2}$
  - Investor i of type j holding d_j^i shares has CARA expected utility

$$E\{-\exp(-\gamma[W_0^i + d_j^i(\tilde{v}_j - \tilde{q}])\}$$

    where $\tilde{v}_j = \beta_z^j \tilde{z} + \beta_\delta^j \tilde{\delta}$ is per-unit payoff
  - Each investor receives private signals about each factor

$$\tilde{s}_z^i \sim_{iid} N(\tilde{z}, \tau_s^{-1}), \tilde{s}_\delta^i \sim_{iid} N(\tilde{\delta}, \tau_s^{-1})$$

  - Define info set $\mathcal{F}_i \equiv \{\tilde{s}_z^i, \tilde{s}_\delta^i, \tilde{p}\}$ of investor i

Environment - Market Participants

- Rational investors trade on signals and learn from price
  - Traditional ($\beta_z^t = 1$ and $\beta_\delta^t = 0$) and green ($\beta_z^g = 0$ and $\beta_\delta^g = 1$)
  - Mass of each group is $\frac{m}{2}$
  - Investor i of type j holding d_j^i shares has CARA expected utility

$$E\{-\exp(-\gamma[W_0^i + d_j^i(\tilde{v}_j - \tilde{q}]))\}$$

    where $\tilde{v}_j = \beta_z^j \tilde{z} + \beta_\delta^j \tilde{\delta}$ is per-unit payoff
  - Each investor receives private signals about each factor

$$\tilde{s}_z^i \sim_{iid} N(\tilde{z}, \tau_s^{-1}), \tilde{s}_\delta^i \sim_{iid} N(\tilde{\delta}, \tau_s^{-1})$$

  - Define info set $\mathcal{F}_i \equiv \{\tilde{s}_z^i, \tilde{s}_\delta^i, \tilde{p}\}$ of investor i

- Noise traders

Environment - Market Participants

- Rational investors trade on signals and learn from price
  - Traditional ($\beta_z^t = 1$ and $\beta_\delta^t = 0$) and green ($\beta_z^g = 0$ and $\beta_\delta^g = 1$)
  - Mass of each group is $\frac{m}{2}$
  - Investor i of type j holding d_j^i shares has CARA expected utility

$$E\{-\exp(-\gamma[W_0^i + d_j^i(\tilde{v}_j - \tilde{q}])\}$$

    where $\tilde{v}_j = \beta_z^j \tilde{z} + \beta_\delta^j \tilde{\delta}$ is per-unit payoff
  - Each investor receives private signals about each factor

$$\tilde{s}_z^i \sim_{iid} N(\tilde{z}, \tau_s^{-1}), \tilde{s}_\delta^i \sim_{iid} N(\tilde{\delta}, \tau_s^{-1})$$

  - Define info set $\mathcal{F}_i \equiv \{\tilde{s}_z^i, \tilde{s}_\delta^i, \tilde{p}\}$ of investor i

- Noise traders
  - Demand is $\tilde{N}(0, \tau_n^{-1})$

Market Clearing

- Market clearing

$$\underbrace{D_t(\tilde{z}, \tilde{\delta}, \tilde{p})}_{\equiv \int_{i \in \mathcal{T}_t} d_t^i(\mathcal{F}_i) di} + \underbrace{D_g(\tilde{z}, \tilde{\delta}, \tilde{p})}_{\equiv \int_{i \in \mathcal{T}_g} d_g^i(\mathcal{F}_i) di} + \tilde{n} = 1$$

Market Clearing

- Market clearing

$$\underbrace{D_t(\tilde{z},\tilde{\delta},\tilde{p})}_{\equiv\int_{i\in\mathcal{T}_t} d_t^i(\mathcal{F}_i)di} + \underbrace{D_g(\tilde{z},\tilde{\delta},\tilde{p})}_{\equiv\int_{i\in\mathcal{T}_g} d_g^i(\mathcal{F}_i)di} + \tilde{n} = 1$$

- Focus on equilibria with linear prices

$$\begin{aligned}\tilde{p} &= p_0 + p_z\tilde{z} + p_\delta\tilde{\delta} + p_n\tilde{n} \\ &= p_0 + p_n(\xi_z\tilde{z} + \xi_\delta\tilde{\delta} + \tilde{n})\end{aligned}$$

where $\xi_z \equiv \frac{q_z}{q_n}$ and $\xi_\delta \equiv \frac{q_\delta}{q_n}$ is normalized price coefficeint

Trading Intensity

- CARA utility $\implies$ traditional investor demand

$$d_t(\mathcal{F}) = \frac{1}{\gamma}\frac{E[\tilde{z}|\mathcal{F}] - \tilde{p}}{V[\tilde{z}|\mathcal{F}]}$$

where

$$E[\tilde{z}|\mathcal{F}] = \underbrace{\tilde{s}_z \frac{\tau_s}{\tau_s + \tau}}_{\text{inference from private signal}} + \underbrace{\frac{\xi_z \frac{1}{\tau + \tau_s}[\tilde{p}/p_n - (p_0/p_n + \xi_z \tilde{s}_z \frac{\tau_s}{\tau_s + \tau} + \xi_\delta \tilde{s}_\delta \frac{\tau_s}{\tau_s + \tau})]}{\xi_z^2 \frac{1}{\tau + \tau_s} + \xi_\delta^2 \frac{1}{\tau + \tau_s} + \frac{1}{\tau_n}}}_{\text{inference from the price}}$$

Trading Intensity

- CARA utility $\implies$ traditional investor demand

$$d_t(\mathcal{F}) = \frac{1}{\gamma}\frac{E[\tilde{z}|\mathcal{F}] - \tilde{p}}{V[\tilde{z}|\mathcal{F}]}$$

where

$$E[\tilde{z}|\mathcal{F}] = \underbrace{\tilde{s}_z \frac{\tau_s}{\tau_s + \tau}}_{\text{inference from private signal}} + \underbrace{\frac{\xi_z \frac{1}{\tau+\tau_s}[\tilde{p}/p_n - (p_0/p_n + \xi_z \tilde{s}_z \frac{\tau_s}{\tau_s+\tau} + \xi_\delta \tilde{s}_\delta \frac{\tau_s}{\tau_s+\tau})]}{\xi_z^2 \frac{1}{\tau+\tau_s} + \xi_\delta^2 \frac{1}{\tau+\tau_s} + \frac{1}{\tau_n}}}_{\text{inference from the price}}$$

- $\tilde{s}_\delta$ is not informative about $\tilde{z}$, but has price inference effect

Trading Intensity

- *Trading intensity* is the change in demand given change in signal

Trading Intensity

- *Trading intensity* is the change in demand given change in signal

- For traditional investor,

$$i_t^z \equiv \frac{\partial d^t}{\partial \tilde{s}_z} = \frac{\tau_s}{\gamma} > 0$$

$$i_t^\delta \equiv \frac{\partial d^t}{\partial \tilde{s}_\delta} = -\frac{\tau_s}{\gamma} \frac{\overbrace{\xi_\delta \xi_z}^{\text{Strength of inference}}}{\underbrace{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}}_{\text{price noisiness}}} < 0$$

Trading Intensity

- *Trading intensity* is the change in demand given change in signal

- For traditional investor,

$$i_t^z \equiv \frac{\partial d^t}{\partial \tilde{s}_z} = \frac{\tau_s}{\gamma} > 0$$

$$i_t^\delta \equiv \frac{\partial d^t}{\partial \tilde{s}_\delta} = -\frac{\tau_s}{\gamma} \frac{\overbrace{\xi_\delta \xi_z}^{\text{Strength of inference}}}{\underbrace{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}}_{\text{price noisiness}}} < 0$$

- Opposite for green investor $i_g^z < 0$ and $i_g^\delta > 0$

Trading Intensity

- *Trading intensity* is the change in demand given change in signal

- For traditional investor,

$$i_t^z \equiv \frac{\partial d^t}{\partial \tilde{s}_z} = \frac{\tau_s}{\gamma} > 0$$

$$i_t^\delta \equiv \frac{\partial d^t}{\partial \tilde{s}_\delta} = -\frac{\tau_s}{\gamma} \frac{\overbrace{\xi_\delta \xi_z}^{\text{Strength of inference}}}{\underbrace{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}}_{\text{price noisiness}}} < 0$$

- Opposite for green investor $i_g^z < 0$ and $i_g^\delta > 0$

- Constant trading intensity for signal about valued factor

Feedback Loop

- How actively do investor trade on signals about non-valued factor?

$$\frac{i_t^{\delta}}{i_g^{z}} = \frac{\xi_z^2 + \frac{\tau + \tau_s}{\tau_n}}{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}} = \frac{PI_t}{PI_g}$$

where $PI_j \equiv [V(\tilde{v}_j | \mathcal{F})]^{-1}$ is the *price informativeness* for type j

Feedback Loop

- How actively do investor trade on signals about non-valued factor?

$$\frac{i_t^\delta}{i_g^z} = \frac{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}} = \frac{PI_t}{PI_g}$$

  where $PI_j \equiv [V(\tilde{v}_j|\mathcal{F})]^{-1}$ is the *price informativeness* for type j

- Feedback loop

Feedback Loop

- How actively do investor trade on signals about non-valued factor?

$$\frac{i_t^\delta}{i_g^z} = \frac{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}} = \frac{PI_t}{PI_g}$$

where $PI_j \equiv [V(\tilde{v}_j|\mathcal{F})]^{-1}$ is the *price informativeness* for type j

- Feedback loop
  - $\frac{PI_t}{PI_g}$ is high $\implies$ traditional investors dominate trading $\implies$ price is informative about $\tilde{z}$ but not $\tilde{\delta}$ $\implies$ $\frac{PI_t}{PI_g}$ is high

Feedback Loop

- How actively do investor trade on signals about non-valued factor?

$$\frac{i_t^\delta}{i_g^z} = \frac{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}} = \frac{PI_t}{PI_g}$$

where $PI_j \equiv [V(\tilde{v}_j|\mathcal{F})]^{-1}$ is the *price informativeness* for type j

- Feedback loop
  - $\frac{PI_t}{PI_g}$ is high $\implies$ traditional investors dominate trading $\implies$ price is informative about $\tilde{z}$ but not $\tilde{\delta}$ $\implies$ $\frac{PI_t}{PI_g}$ is high
  - $\frac{PI_t}{PI_g}$ is low $\implies$ green investors dominate trading $\implies$ price is informative about $\tilde{\delta}$ but not $\tilde{z}$ $\implies$ $\frac{PI_t}{PI_g}$ is low

Feedback Loop

- How actively do investor trade on signals about non-valued factor?

$$\frac{i_t^\delta}{i_g^z} = \frac{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}} = \frac{PI_t}{PI_g}$$

where $PI_j \equiv [V(\tilde{v}_j|\mathcal{F})]^{-1}$ is the *price informativeness* for type j

- Feedback loop
  - $\frac{PI_t}{PI_g}$ is high $\implies$ traditional investors dominate trading $\implies$ price is informative about $\tilde{z}$ but not $\tilde{\delta}$ $\implies$ $\frac{PI_t}{PI_g}$ is high
  - $\frac{PI_t}{PI_g}$ is low $\implies$ green investors dominate trading $\implies$ price is informative about $\tilde{\delta}$ but not $\tilde{z}$ $\implies$ $\frac{PI_t}{PI_g}$ is low
- Feedback is strong when noise is small

Feedback Loop

- How actively do investor trade on signals about non-valued factor?

$$\frac{i_t^\delta}{i_g^z} = \frac{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}} = \frac{PI_t}{PI_g}$$

where $PI_j \equiv [V(\tilde{v}_j|\mathcal{F})]^{-1}$ is the *price informativeness* for type j

- Feedback loop
  - $\frac{PI_t}{PI_g}$ is high $\implies$ traditional investors dominate trading $\implies$ price is informative about $\tilde{z}$ but not $\tilde{\delta}$ $\implies$ $\frac{PI_t}{PI_g}$ is high
  - $\frac{PI_t}{PI_g}$ is low $\implies$ green investors dominate trading $\implies$ price is informative about $\tilde{\delta}$ but not $\tilde{z}$ $\implies$ $\frac{PI_t}{PI_g}$ is low

- Feedback is strong when noise is small
  - Large noise $\implies$ $\frac{i_t^\delta}{i_g^z} \to 1$ as $\tau_n^{-1} \to \infty$ $\implies$ uninformative price

Feedback Loop

- How actively do investor trade on signals about non-valued factor?

$$\frac{i_t^\delta}{i_g^z} = \frac{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}} = \frac{PI_t}{PI_g}$$

where $PI_j \equiv [V(\tilde{v}_j|\mathcal{F})]^{-1}$ is the *price informativeness* for type j

- Feedback loop
  - $\frac{PI_t}{PI_g}$ is high $\implies$ traditional investors dominate trading $\implies$ price is informative about $\tilde{z}$ but not $\tilde{\delta}$ $\implies$ $\frac{PI_t}{PI_g}$ is high
  - $\frac{PI_t}{PI_g}$ is low $\implies$ green investors dominate trading $\implies$ price is informative about $\tilde{\delta}$ but not $\tilde{z}$ $\implies$ $\frac{PI_t}{PI_g}$ is low

- Feedback is strong when noise is small
  - Large noise $\implies$ $\frac{i_t^\delta}{i_g^z} \to 1$ as $\tau_n^{-1} \to \infty$ $\implies$ uninformative price
  - Small noise $\implies$ $\frac{i_t^\delta}{i_g^z} \to \frac{\xi_z^2}{\xi_\delta^2}$ as $\tau_n^{-1} \to 0$ $\implies$ strong feedback loop

Multiple Equilibria

- Trading intensity determine price coefficients:

$$\xi_z = \frac{m}{2} i_g^z + \frac{m}{2} i_t^z = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_z^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

$$\xi_\delta = \frac{m}{2} i_g^\delta + \frac{m}{2} i_t^\delta = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

Multiple Equilibria

- Trading intensity determine price coefficients:

$$\xi_z = \frac{m}{2} i_g^z + \frac{m}{2} i_t^z = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_z^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

$$\xi_\delta = \frac{m}{2} i_g^\delta + \frac{m}{2} i_t^\delta = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

- Exists a noise threshold $\hat{\tau}_n = 4(\tau + \tau_s)(\frac{\tau_2}{\gamma} \frac{m}{2})^{-2}$

Multiple Equilibria

- Trading intensity determine price coefficients:

$$\xi_z = \frac{m}{2} i_g^z + \frac{m}{2} i_t^z = \frac{m}{2}\frac{\tau_s}{\gamma}\left[1 - \frac{\xi_z \xi_\delta}{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}\right]$$

$$\xi_\delta = \frac{m}{2} i_g^\delta + \frac{m}{2} i_t^\delta = \frac{m}{2}\frac{\tau_s}{\gamma}\left[1 - \frac{\xi_z \xi_\delta}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}}\right]$$

- Exists a noise threshold $\hat{\tau}_n = 4(\tau + \tau_s)(\frac{\tau_2}{\gamma}\frac{m}{2})^{-2}$
- Large noise $\tau_n^{-1} \geq \hat{\tau}_n^{-1} \implies$ unique equilibrium with $\xi_z = \xi_\delta$

Multiple Equilibria

- Trading intensity determine price coefficients:

$$\xi_z = \frac{m}{2} i_g^z + \frac{m}{2} i_t^z = \frac{m}{2}\frac{\tau_s}{\gamma}\left[1 - \frac{\xi_z \xi_\delta}{\xi_z^2 + \frac{\tau+\tau_s}{\tau_n}}\right]$$

$$\xi_\delta = \frac{m}{2} i_g^\delta + \frac{m}{2} i_t^\delta = \frac{m}{2}\frac{\tau_s}{\gamma}\left[1 - \frac{\xi_z \xi_\delta}{\xi_\delta^2 + \frac{\tau+\tau_s}{\tau_n}}\right]$$

- Exists a noise threshold $\hat{\tau}_n = 4(\tau + \tau_s)(\frac{\tau_2}{\gamma}\frac{m}{2})^{-2}$

- Large noise $\tau_n^{-1} \geq \hat{\tau}_n^{-1} \implies$ unique equilibrium with $\xi_z = \xi_\delta$

- Small noise $\tau_n^{-1} < \hat{\tau}_n^{-1} \implies$ three equilibria

Multiple Equilibria

- Trading intensity determine price coefficients:

$$\xi_z = \frac{m}{2} i_g^z + \frac{m}{2} i_t^z = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_z^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

$$\xi_\delta = \frac{m}{2} i_g^\delta + \frac{m}{2} i_t^\delta = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

- Exists a noise threshold $\hat{\tau}_n = 4(\tau + \tau_s)(\frac{\tau_2}{\gamma}\frac{m}{2})^{-2}$
- Large noise $\tau_n^{-1} \geq \hat{\tau}_n^{-1} \implies$ unique equilibrium with $\xi_z = \xi_\delta$
- Small noise $\tau_n^{-1} < \hat{\tau}_n^{-1} \implies$ three equilibria
    - Stable T-equilibrium with $\xi_z > \xi_\delta$ and $PI_t > PI_g$

Multiple Equilibria

- Trading intensity determine price coefficients:

$$\xi_z = \frac{m}{2} i_g^z + \frac{m}{2} i_t^z = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_z^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

$$\xi_\delta = \frac{m}{2} i_g^\delta + \frac{m}{2} i_t^\delta = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

- Exists a noise threshold $\hat{\tau}_n = 4(\tau + \tau_s)(\frac{\tau_2}{\gamma} \frac{m}{2})^{-2}$
- Large noise $\tau_n^{-1} \geq \hat{\tau}_n^{-1} \implies$ unique equilibrium with $\xi_z = \xi_\delta$
- Small noise $\tau_n^{-1} < \hat{\tau}_n^{-1} \implies$ three equilibria
  - Stable T-equilibrium with $\xi_z > \xi_\delta$ and $PI_t > PI_g$
  - Stable G-equilibrium with $\xi_z < \xi_\delta$ and $PI_t < PI_g$

Multiple Equilibria

- Trading intensity determine price coefficients:

$$\xi_z = \frac{m}{2} i_g^z + \frac{m}{2} i_t^z = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_z^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

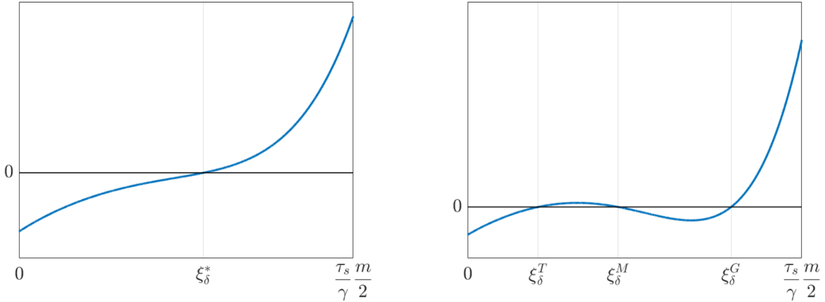
$$\xi_\delta = \frac{m}{2} i_g^\delta + \frac{m}{2} i_t^\delta = \frac{m}{2} \frac{\tau_s}{\gamma} \left[1 - \frac{\xi_z \xi_\delta}{\xi_\delta^2 + \frac{\tau + \tau_s}{\tau_n}} \right]$$

- Exists a noise threshold $\hat{\tau}_n = 4(\tau + \tau_s)(\frac{\tau_2}{\gamma} \frac{m}{2})^{-2}$
- Large noise $\tau_n^{-1} \geq \hat{\tau}_n^{-1} \implies$ unique equilibrium with $\xi_z = \xi_\delta$
- Small noise $\tau_n^{-1} < \hat{\tau}_n^{-1} \implies$ three equilibria
  - Stable T-equilibrium with $\xi_z > \xi_\delta$ and $PI_t > PI_g$
  - Stable G-equilibrium with $\xi_z < \xi_\delta$ and $PI_t < PI_g$
  - Unstable M-equilibrium with $\xi_z = \xi_\delta$ and $PI_t = PI_g$

Multiple Equilibria

(A) Unique equilibrium, $\tau_n < \tau_n^*$

(B) Multiple equilibria, $\tau_n > \tau_n^*$



Unique equilibrium with small noise and multiple equilibria with large noise

Outline

1 Introduction

2 Simplified Model

3 Other Findings

4 Conclusion and Discussion

Baseline Model

- Generalization:

Baseline Model

- Generalization:
  - Allow green investors to care about both components of payoff

Baseline Model

- Generalization:
  - Allow green investors to care about both components of payoff
  - Unequal masses of investors

Baseline Model

- Generalization:
  - Allow green investors to care about both components of payoff
  - Unequal masses of investors
  - Index equilibria by signal precision

Baseline Model

- Generalization:
  - Allow green investors to care about both components of payoff
  - Unequal masses of investors
  - Index equilibria by signal precision
  - Dependence between $\tilde{\delta}$ and $\tilde{z}$

Baseline Model

- Generalization:
  - Allow green investors to care about both components of payoff
  - Unequal masses of investors
  - Index equilibria by signal precision
  - Dependence between $\tilde{\delta}$ and $\tilde{z}$

- Consider the cost of capital:

$$CoC = E[\tilde{z} - \tilde{p}] = \frac{\gamma}{m_t PI_t + m_g PI_g}$$

Baseline Model

- Generalization:
  - Allow green investors to care about both components of payoff
  - Unequal masses of investors
  - Index equilibria by signal precision
  - Dependence between $\tilde{\delta}$ and $\tilde{z}$

- Consider the cost of capital:

$$CoC = E[\tilde{z} - \tilde{p}] = \frac{\gamma}{m_t PI_t + m_g PI_g}$$

- How does cost of capital change with more green investors?

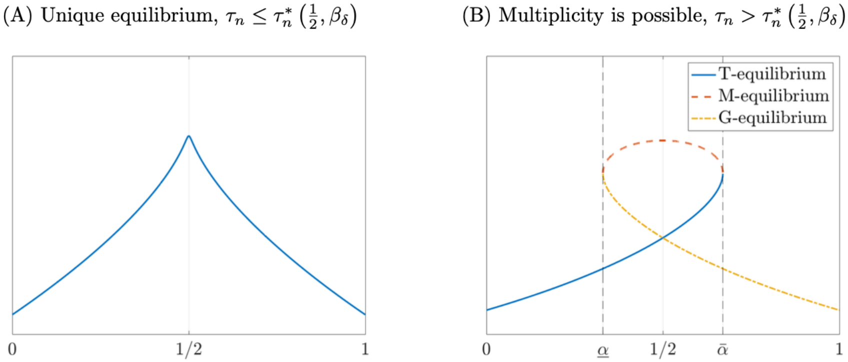
Baseline Model

- Generalization:
  - Allow green investors to care about both components of payoff
  - Unequal masses of investors
  - Index equilibria by signal precision
  - Dependence between $\tilde{\delta}$ and $\tilde{z}$
- Consider the cost of capital:

$$CoC = E[\tilde{z} - \tilde{p}] = \frac{\gamma}{m_t PI_t + m_g PI_g}$$

- How does cost of capital change with more green investors?
- How does cost of capital change with better info about $\tilde{\delta}$?

Cost of Capital with More Green Investors

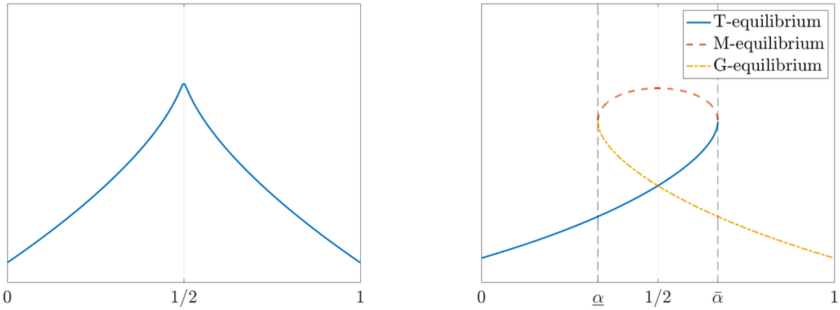


- α is fraction of green investors

Cost of Capital with More Green Investors

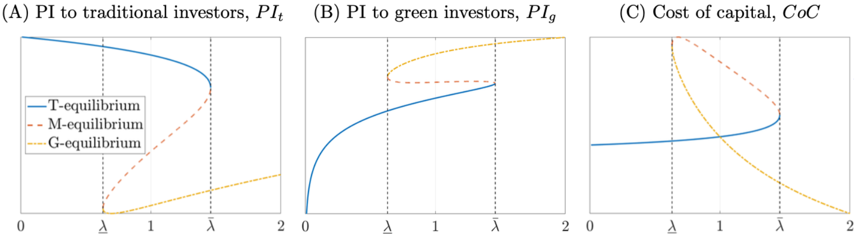
(A) Unique equilibrium, $\tau_n \leq \tau_n^* \left(\frac{1}{2}, \beta_\delta\right)$

(B) Multiplicity is possible, $\tau_n > \tau_n^* \left(\frac{1}{2}, \beta_\delta\right)$



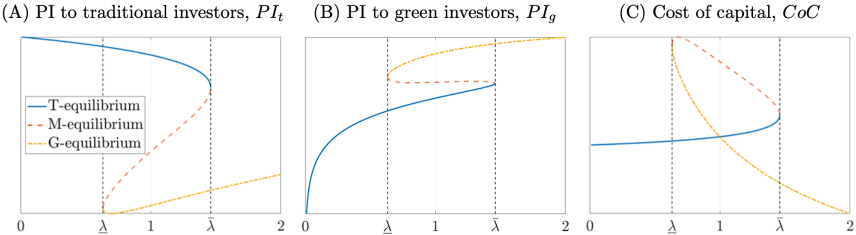
- α is fraction of green investors
- Cost of capital is highest when investor base is balanced

Cost of Capital with More Precise ESG Signals



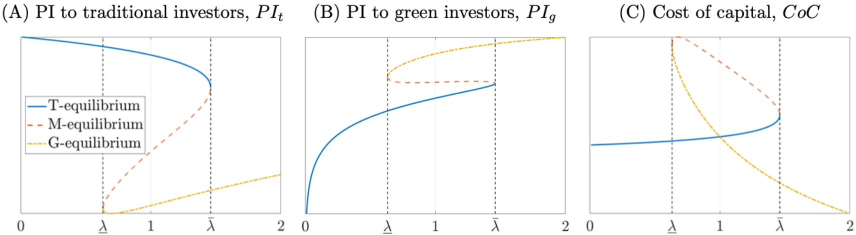
- λ indexes precision of signals about δ (high λ is more precision)

Cost of Capital with More Precise ESG Signals



- λ indexes precision of signals about δ (high λ is more precision)
- Direct effect: $\lambda \uparrow \implies PI_t \uparrow$ and $PI_g \uparrow\uparrow\uparrow$

Cost of Capital with More Precise ESG Signals



- λ indexes precision of signals about δ (high λ is more precision)
- Direct effect: $\lambda \uparrow \implies PI_t \uparrow$ and $PI_g \uparrow\uparrow\uparrow$
- Indirect effect: $\lambda \uparrow \implies i_g^\delta \uparrow \implies PI_t \downarrow$

Outline

1. Introduction
2. Simplified Model
3. Other Findings
4. Conclusion and Discussion

Conclusion

- REE model with investors with heterogenous valuations

Conclusion

- REE model with investors with heterogenous valuations
  - Contribution: Combine (1) heterogeneous preferences over multiple fundamentals and (2) info sets with signals about all fundamentals

Conclusion

- REE model with investors with heterogenous valuations
  - Contribution: Combine (1) heterogeneous preferences over multiple fundamentals and (2) info sets with signals about all fundamentals

- Show how investor base matters $\Longrightarrow$ May reconcile mixed evidence on green premium/discount

Conclusion

- REE model with investors with heterogenous valuations
  - Contribution: Combine (1) heterogeneous preferences over multiple fundamentals and (2) info sets with signals about all fundamentals
- Show how investor base matters $\Longrightarrow$ May reconcile mixed evidence on green premium/discount
- Novel channel for better ESG-disclosures to backfire

Discussion - Green Investor Preferences

- In the paper, green investors prefer for ESG factor is like consumption

Discussion - Green Investor Preferences

- In the paper, green investors prefer for ESG factor is like consumption
- Unclear if this form of preferences is consistent with other research

Discussion - Green Investor Preferences

- In the paper, green investors prefer for ESG factor is like consumption
- Unclear if this form of preferences is consistent with other research
- Using an experimental approach, Heeb et al (2021) find that green investors have a higher WTP for a sustainable investment, but their WTP does not grow with the social impact of the investment

Discussion - Endogenous Information Acquisition

- In the paper, signals are exogenous processes

Discussion - Endogenous Information Acquisition

- In the paper, signals are exogenous processes
- In appendix, they do allow for correlated signals

Discussion - Endogenous Information Acquisition

- In the paper, signals are exogenous processes
- In appendix, they do allow for correlated signals
- How would endogenous information acquisition affect results?

Discussion - Endogenous Information Acquisition

- In the paper, signals are exogenous processes
- In appendix, they do allow for correlated signals
- How would endogenous information acquisition affect results?
- Green investors have direct incentive to discover info about ESG

Discussion - Endogenous Information Acquisition

- In the paper, signals are exogenous processes
- In appendix, they do allow for correlated signals
- How would endogenous information acquisition affect results?
- Green investors have direct incentive to discover info about ESG
- But do traditional investors really have private signals about ESG?

Discussion - Endogenous Information Acquisition

- In the paper, signals are exogenous processes
- In appendix, they do allow for correlated signals
- How would endogenous information acquisition affect results?
- Green investors have direct incentive to discover info about ESG
- But do traditional investors really have private signals about ESG?
- Seems less plausible that traditional investors seek to acquire information about ESG impacts to better trade against green investors

Discussion - Other

- Testing this model's implications is challenging due to issues measuring ESG impacts (i.e. Allcott et al 2021, Berg et al 2021)

Discussion - Other

- Testing this model's implications is challenging due to issues measuring ESG impacts (i.e. Allcott et al 2021, Berg et al 2021)
- More detailed ESG disclosures themselves may increase $\tilde{\delta}$. Kreuger et al (2021) found that firms who were required to disclose more detailed information about ESG-related issue had fewer negative ESG-related incidents (i.e. chemical spills)