Sustainable Investing in Equilibrium

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Motivation

- Growing interest in **sustainable investing**
  - Objectives: Financial + ESG (**E**nvironmental, **S**ocial, **G**overnance)
Growing interest in **sustainable investing**
- Objectives: Financial + ESG (**E**nvironmental, **S**ocial, **G**overnance)

**Example: BlackRock** (January 2020):
- “We believe sustainability should be our new standard for investing... our goal is to be the global leader in sustainable investing.”
- “Currently, every active investment team at BlackRock considers ESG factors in its investment process... By the end of 2020, all active portfolios and advisory strategies will be fully ESG integrated ... [BlackRock will then assess] ESG risk with the same rigor that it analyzes traditional measures such as credit and liquidity risk.”
What We Do

- We build a general *equilibrium model* of sustainable investing
  - Model is very simple, tractable

- Analyze **financial and real effects** of sustainable investing
  - Effects on asset prices, society
Main Theoretical Results

- Greener assets have lower **alphas**
  - Because agents have green tastes & green assets hedge **climate risk**
  - Green assets have negative alphas, brown assets have positive alphas
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- **Greener assets can outperform when** **ESG factor** **performs well**
  - ESG factor captures shifts in customers’ and investors’ tastes
  - **Two-factor pricing**: Market + ESG factor
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  - But they earn an “investor surplus”
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- Sustainable investing leads to **positive social impact**
  - Green firms invest more, brown firms less
  - Firms become greener
Outline

1. Baseline model
2. Example
3. Extension: Climate risk
4. Extension: ESG factor
5. Extension: Social impact
Model Overview

FIRMS

[Diagram showing a bag of money and a diverse group of people surrounding the earth]
Model Overview

FIRMS

INVESTORS
Model Overview

FIRMS

INVESTORS
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FIRMS
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FIRMS

INVESTORS
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$g_n < 0$

$g_n > 0$

FIRMS

INVESTORS
Model Overview

\[ g_n \begin{cases} < 0 & \text{FIRMS} \\ > 0 & \text{INVESTORS} \end{cases} \]

\[ d_i \begin{cases} > 0 & \text{red heart} \\ = 0 & \text{snowflake} \end{cases} \]
Model

- One period (from 0 to 1)
- **Firms** $n = 1, \ldots, N$
  - ESG characteristics $g$ ($N \times 1$)
    - $g_n > 0$: “green” firm, positive externalities
    - $g_n < 0$: “brown” firm, negative externalities
  - Excess stock returns $\tilde{r} = \mu + \tilde{\epsilon}$, where $\tilde{\epsilon} \sim N(0, \Sigma)$
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- **Agents** \( i \) (continuum), with CARA utility \(-e^{-A_i \tilde{W}_{1i} - b'_i X_i}\)
  - Financial
  - Nonfinancial
Model

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- **Agents** \( i \) (continuum), with CARA utility \(-e^{-A_i \tilde{W}_{1i}} - b'_i X_i\)
  - \( A_i \): Absolute risk aversion of agent \( i \)
  - \( \tilde{W}_{1i} = W_{0i} (1 + r_f + X'_i \tilde{r}) \): Wealth of agent \( i \) at time 1
One period (from 0 to 1)

**Firms** \( n = 1, \ldots, N \)
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**Agents** \( i \) (continuum), with CARA utility \(-e^{-A_i \tilde{W}_1 i} - b'_i X_i\)
- \( A_i \): Absolute risk aversion of agent \( i \)
- \( \tilde{W}_1 i = W_0 i (1 + r_f + X'_i \tilde{r}) \): Wealth of agent \( i \) at time 1
- \( X_i \): Portfolio weights of agent \( i \) \((N \times 1)\)
- \( b_{i,n} = d_i g_n \): Nonpecuniary benefit agent \( i \) derives from holding stock \( n \)
  - \( d_i \geq 0 \) is agent \( i \)’s “ESG taste”
Solving the Model

- Agent $i$ chooses $X_i$ to max expected utility, taking $\mu$ as given:

$$X_i^* = \frac{1}{a} \Sigma^{-1} \left( \mu + \frac{1}{a} b_i \right)$$

- $a$: relative risk aversion, assumed equal across agents ($a_i \equiv A_i W_{0i}$)

- Market clearing:

$$\int_i w_i X_i^* \, di = x$$

where $x$ are market portfolio weights and $w_i \equiv \frac{W_{0i}}{\int_i W_{0i} \, di}$

- Solve for equilibrium $\mu$
Equilibrium Expected Returns: Market-Level

● **Equity premium:**

\[ \mu_M = a\sigma_M^2 - \frac{-\bar{d}xa}{a} < 0 \]

where \( \mu_M = x'\mu, \sigma_M^2 = x'\Sigma x, \) and \( \bar{d} \equiv \int_i w_i d_i di \)

- \( x'g > 0 \) \( \Rightarrow \) \( \mu_M \) is decreasing in \( \bar{d} \)
- \( x'g < 0 \) \( \Rightarrow \) \( \mu_M \) is increasing in \( \bar{d} \)

● Assume \( x'g = 0 \) (market portfolio is ESG-neutral)
Equilibrium Expected Returns: Firm-Level

Expected excess stock returns:

$$\mu = \mu_M \beta - \frac{d}{a} g$$

Greener stocks have lower alphas:

$$\alpha_n = -\frac{d}{a} g < 0$$

Brown stocks have positive alphas.
Equilibrium Expected Returns: Firm-Level

- Expected excess stock returns:
  \[ \mu = \bar{\mu}_M \beta - \frac{-d}{a} g \]

- Greener stocks have lower alphas:
  \[ \alpha_n = \frac{-d}{a} g_n \]

Green stocks have negative alphas
Brown stocks have positive alphas
Equilibrium Expected Returns: Agent-Level

- Expected excess return on agent $i$'s portfolio:

$$E(\tilde{r}_i) = \mu_M - \delta_i \left( \frac{\tilde{d}}{a^3} g' \Sigma^{-1} g \right)$$

where $\delta_i \equiv d_i - \bar{d}$. Note:

- $\delta_i \uparrow \Rightarrow E(\tilde{r}_i) \downarrow$
- $\delta_i > 0 \Rightarrow E(\tilde{r}_i) < \mu_M$
- $\delta_i < 0 \Rightarrow E(\tilde{r}_i) > \mu_M$
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- $\delta_i < 0 \Rightarrow E(\tilde{r}_i) > \mu_M$

- Agent $i$'s expected utility is increasing in $\delta_i^2$

$$EU(\delta_i) = e^{-\frac{\delta_i^2}{2a^2}} g' \Sigma^{-1} g \times \left\{ EU(\delta_i = 0) \right\}$$
Portfolio Tilts

Agent $i$’s equilibrium portfolio weights:

$$X_i = x + \frac{\delta_i}{a^2} \left( \Sigma^{-1} g \right)$$

“ESG tilt”

Three-fund separation:

1. Riskless asset
2. Market portfolio, $x$
3. “ESG portfolio”, $\Sigma^{-1} g$

- Agents with $\delta_i > 0$ (i.e., $d_i > \bar{d}$) go long the ESG portfolio
- Agents with $\delta_i < 0$ (i.e., $d_i < \bar{d}$) go short the ESG portfolio
- Agents with $\delta_i = 0$ (i.e., $d_i = \bar{d}$) hold the market

No dispersion in ESG preferences $\Rightarrow$ All agents hold the market
Portfolio Tilts

- Agent \( i \)'s equilibrium portfolio weights:

\[
X_i = x + \frac{\delta_i}{\sigma^2} (\Sigma^{-1} g)
\]

- **Three-fund separation:**
  1. Riskless asset
  2. Market portfolio, \( x \)
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  - Agents with \( \delta_i > 0 \) (i.e., \( d_i > \bar{d} \)) go long the ESG portfolio
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- No dispersion in ESG preferences \( \Rightarrow \) All agents hold the market
Example

- Two types of agents:
  - **ESG** investors: \( d_i = d > 0 \) ... Fraction \( \lambda \) of total wealth
  - **Non-ESG** investors: \( d_i = 0 \) ... Fraction \( 1 - \lambda \) of total wealth
Two types of agents:

- **ESG** investors: $d_i = d > 0 \ldots$ Fraction $\lambda$ of total wealth
- **Non-ESG** investors: $d_i = 0 \ldots$ Fraction $1 - \lambda$ of total wealth

Portfolio weights:

\[
X_{\text{esg}} = x + (1 - \lambda) \frac{d}{a^2} \Sigma^{-1} g
\]
\[
X_{\text{non}} = x - \lambda \frac{d}{a^2} \Sigma^{-1} g
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Example

- Two types of agents:
  - **ESG** investors: $d_i = d > 0 \ldots$ Fraction $\lambda$ of total wealth
  - **Non-ESG** investors: $d_i = 0 \ldots$ Fraction $1 - \lambda$ of total wealth

- Portfolio weights:

\[
X_{esg} = x + (1 - \lambda) \frac{d}{a^2} \Sigma^{-1} g
\]

\[
\lambda = 0 \Rightarrow X_{non} = x - \lambda \frac{d}{a^2} \Sigma^{-1} g
\]
Example

- Two types of agents:
  - **ESG** investors: \( d_i = d > 0 \) ... Fraction \( \lambda \) of total wealth
  - **Non-ESG** investors: \( d_i = 0 \) ... Fraction \( 1 - \lambda \) of total wealth

- Portfolio weights:

  \[
  \lambda = 1 \Rightarrow X_{\text{esg}} = x + (1 - \lambda) \frac{d}{a^2} \Sigma^{-1} g
  \]

  \[
  X_{\text{non}} = x - \lambda \frac{d}{a^2} \Sigma^{-1} g
  \]
Add simplifying assumptions:

- One-factor structure: $\Sigma = \sigma^2 \iota \iota' + \eta^2 I_N$
- Equal values and betas across firms: $x = (1/N)\iota$, $\beta = \iota$
- Distribution of $g$: $\iota'g = 0, g'g = 1$

Five free parameters: $a$, $\sigma$, $\eta$, $\lambda$, and $d$

- Choose $a$ and $\sigma$ so that $\mu_M = 0.08$, $\sigma_M = 0.20$ per year
- Choose $\eta$ so that market model regression $R^2$ is 30%

- Vary $\lambda$ over (0, 1)
- Vary $d$ after converting it to $\Delta$, maximum certain return ESG investor is willing to sacrifice to invest in her desired portfolio rather than in $M$
  - $\Delta \equiv r^*_{\text{esg}} - r^*_M$, where $r^*_{\text{esg}}$ is the ESG investor’s certainty equivalent excess return when investing in the optimal ESG portfolio, and $r^*_M$ is her certainty equivalent if forced to hold the market instead
  - Four values of $\Delta$: 1, 2, 3, and 4% per year
$E\{\tilde{r}_{esg}\} - E\{\tilde{r}_{non}\} = -2\lambda \Delta$
Alphas of ESG Investors: The Role of $\lambda$

$$\alpha_{esg} = -2\lambda(1 - \lambda)\Delta$$
Alphas of ESG Investors: The Role of $\Delta$

\[ \alpha_{esg} = -2\lambda(1 - \lambda)\Delta \]
Investor Surplus

\[ I \equiv \alpha_{esg} - (-\Delta) = \Delta[1 - 2\lambda(1 - \lambda)] \]
Alphas of Non-ESG Investors: The Role of $\lambda$

$$\alpha_{\text{non}} = 2\lambda^2 \Delta$$

![Graph showing the relationship between $\alpha_{\text{non}}$ and $\lambda$ for different $\Delta$ values, with lines for $\Delta = 0.01$, $\Delta = 0.02$, $\Delta = 0.03$, and $\Delta = 0.04$.]
Alphas of Non-ESG Investors: The Role of $\Delta$

\[ \alpha_{\text{non}} = 2\lambda^2 \Delta \]
Aggregate ESG tilt (i.e., aggregate ESG-driven investment that deviates from the market, divided by the market’s total value)

\[ T = \int_{i:d_i>0} w_i T_i \, di \]

where

\[ T_i = \frac{1}{2} \nu' |X_i - x| \]

with two types of agents,

\[ T = \lambda (1 - \lambda) \sqrt{\Delta^2 a} \]

To get \( \nu' |g| \), assume \( g_n \) is normally distributed across 100 stocks.
Size of the ESG Industry

- Aggregate ESG tilt (i.e., aggregate ESG-driven investment that deviates from the market, divided by the market’s total value)

\[ T = \int_{i:d_i>0} w_i T_i \, di \]

where

\[ T_i = \frac{1}{2} \varepsilon |X_i - x| \]

- With two types of agents,

\[ T = \lambda (1 - \lambda) \sqrt{\Delta} \varepsilon |g| \]

- To get \( \varepsilon |g| \), assume \( g_n \) is normally distributed across 100 stocks
Size of the ESG Industry: The Role of $\lambda$

$$T = \lambda (1 - \lambda) \sqrt{\frac{\Delta N}{a\pi}}$$
Size of the ESG Industry: The Role of $\Delta$

\[ T = \lambda(1 - \lambda)\sqrt{\frac{\Delta N}{a\pi}} \]
Agent $i$’s utility:

$$-e^{-A_i \tilde{W}_i - b'X_i} - c_i \tilde{C}$$

where \textit{climate} $\tilde{C} \sim N(0, 1)$

- $c_i \geq 0 \implies$ Agents dislike low realizations of $\tilde{C}$
- Let $\bar{c} \equiv \int_i w_i c_i di$
Expected excess returns in equilibrium:

\[ \mu = \mu_M \beta - \frac{\bar{d}}{a} g + \bar{c} \left( 1 - \rho_{MC}^2 \right) \psi \]

where \( \psi = \) slopes on \( \tilde{C} \) in a regression of \( \tilde{\epsilon} \) on both \( \tilde{C} \) and \( \tilde{\epsilon}_M \)
Expected excess returns in equilibrium:

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where $\psi =$ slopes on $\tilde{C}$ in a regression of $\tilde{\epsilon}$ on both $\tilde{C}$ and $\tilde{\epsilon}_M$

Greener stocks likely better hedge climate risk: $\text{Corr}(\psi_n, g_n) < 0$
Expected excess returns in equilibrium:

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\mu = \mu_M \beta - \frac{\bar{d}}{a} g + \bar{c} (1 - \rho_{MC}^2) \psi
\]

where \( \psi \) = slopes on \( \tilde{C} \) in a regression of \( \tilde{\epsilon} \) on both \( \tilde{C} \) and \( \tilde{\epsilon}_M \)

Greener stocks likely better hedge climate risk: \( \text{Corr}(\psi_n, g_n) < 0 \)

If \( \psi_n = -\xi g_n \), where \( \xi > 0 \), then

\[
\alpha_n = - \left[ \frac{\bar{d}}{a} + \bar{c} (1 - \rho_{MC}^2) \xi \right] g_n
\]

Greener stocks have lower alphas for two reasons: tastes and risk
Agent $i$’s equilibrium portfolio weights:

$$X_i = x + \frac{\delta_i}{a^2} \left( \Sigma^{-1} g \right) - \frac{\gamma_i}{a} \left( \Sigma^{-1} \sigma_{\epsilon \tilde{C}} \right)$$

where $\gamma_i \equiv c_i - \bar{c}$ and $\sigma_{\epsilon \tilde{C}} \equiv \text{Cov}(\tilde{\epsilon}_n, \tilde{C})$.
Agent $i$’s equilibrium portfolio weights:

$$X_i = x + \frac{\delta_i}{a^2} (\Sigma^{-1} g) - \frac{\gamma_i}{a} (\Sigma^{-1} \sigma_{\epsilon C})$$

where $\gamma_i \equiv c_i - \bar{c}$ and $\sigma_{\epsilon C} \equiv \text{Cov}(\tilde{\epsilon}_n, \tilde{C})$

Four-fund separation. Add **climate-hedging portfolio** $\Sigma^{-1} \sigma_{\epsilon C}$

- Maximum-correlation mimicking portfolio for $\tilde{C}$
- Favors **green** stocks over **brown**
Strength of ESG concerns can change over time

- “Investor” channel: $d$ shifts ($\Delta d$)
- “Customer” channel: Demand for firms’ products shifts ($\tilde{z}_g$)

We show: $\tilde{\epsilon} = \tilde{z}_h + \tilde{f}_g + \tilde{\zeta}$, where the ESG factor has two components:

$\tilde{f}_g = \tilde{z}_g + 1_{\text{investor channel}} (\Delta d)$

Green (brown) stocks perform better (worse) than expected if ESG concerns strengthen unexpectedly via either channel.
**Extension: ESG Factor**

- **Strength of ESG concerns can change over time**
  - “Investor” channel: $\tilde{d}$ shifts ($\Delta \tilde{d}$)
  - “Customer” channel: Demand for firms’ products shifts ($\tilde{z}_g$)

- **We show:**
  $$\tilde{\varepsilon} = \tilde{z}_h \ h + \tilde{f}_g \ g + \zeta,$$
  where the **ESG factor** has two components:
  $$\tilde{f}_g = \tilde{z}_g + \frac{1}{a} (\Delta \tilde{d})$$

- **Green (brown) stocks perform better (worse) than expected** if ESG concerns strengthen unexpectedly via either channel
Two-Factor Asset Pricing Model

- $\text{Corr}(\tilde{f}_g, \tilde{C}) < 0$ (bad climate news $\Rightarrow$ tastes shift toward green)
Two-Factor Asset Pricing Model

- Corr($\tilde{f}_g, \tilde{C}$) < 0 (bad climate news $\Rightarrow$ tastes shift toward green)

- If Corr($\tilde{f}_g, \tilde{C}$) = $-1$ then **two-factor pricing** holds:

  $$\tilde{r} = \theta \tilde{r}_M + g (\tilde{f}_g + \mu_g) + \tilde{\nu}$$

  where $\theta = h/x' h$ and

  $$\mu_g = \mu_M \beta_g - \bar{d}/a - \bar{c} \left(1 - \rho_{MC}^2\right)$$

  - market risk
  - investors’ tastes
  - climate risk
Two-Factor Asset Pricing Model

- \( \text{Corr}(\tilde{f}_g, \tilde{C}) < 0 \) (bad climate news \( \Rightarrow \) tastes shift toward green)

- If \( \text{Corr}(\tilde{f}_g, \tilde{C}) = -1 \) then **two-factor pricing** holds:

\[
\tilde{r} = \theta \tilde{r}_M + g(\tilde{f}_g + \mu_g) + \tilde{\nu}
\]

where \( \theta = h/x' h \) and

\[
\mu_g = \mu_M \beta_g - \bar{d}/a - \bar{c} \left(1 - \rho_{MC}^2\right)
\]

- If \( \text{Corr}(\tilde{f}_g, \tilde{C}) \neq -1 \) then **multiple factors** capture ESG risk
Effect of ESG Risk on Market Betas

- **Market beta** of firm $n$:

\[
\beta_n = \beta_g \cdot g_n + \beta_h h_n + \frac{1}{\sigma_M^2} \Lambda_n x
\]

where

\[
\beta_g = \left( \frac{\text{Cov}\{\tilde{f}_g, \tilde{z}_h\}}{\text{Var}\{\tilde{z}_M\}} \right) / \sigma_M^2
\]

- Bansal, Wu, and Yaron (2018) find green stocks outperform brown stocks in good times but underperform in bad times.

Effect of ESG Risk on Market Betas

**Market beta** of firm $n$:

$$
\beta_n = \left( \frac{\text{Var}\{\tilde{f}_g, \tilde{z}_h\}}{\text{Var}\{\tilde{\varepsilon}_M\}} \right) \frac{1}{\sigma^2_M} \Lambda_n x + \beta_g g_n + \beta_h h_n + \frac{1}{\sigma^2_M} \Lambda_n x
$$

where

$$
\beta_g = \left( x' h \right) \frac{\text{Cov}\{\tilde{f}_g, \tilde{z}_h\}}{\sigma^2_M} > 0 \Rightarrow \beta_n \text{ is } \uparrow \text{ in } g_n \Rightarrow \text{Greener stocks are riskier}
$$


$$
\text{Cov}\{\tilde{f}_g, \tilde{z}_h\} < 0 \Rightarrow \beta_n \text{ is } \downarrow \text{ in } g_n \Rightarrow \text{Browner stocks are riskier}
$$

Adverse climate shock $\Rightarrow \tilde{f}_g > 0, \tilde{z}_h < 0$?

Albuquerque, Koskinen, Zhang (2019) find lower $\beta$s for greener firms
Social impact of firm $n$:

$$S_n \equiv g_n K_n$$

where $K_n$ is the firm’s operating capital
Extension: Social Impact

- **Social impact** of firm $n$:

  \[ S_n \equiv g_n K_n \]

  where $K_n$ is the firm’s operating capital

- **Firm maximizes its market value** by choosing $\Delta K_n$ and $\Delta g_n$
  - Firm is endowed with capital $K_{0,n}$ and ESG characteristic $g_{0,n}$

- Firm’s cash flows at time 1: $\Pi_n K_n$ minus adjustment costs
  - Capital adjustment costs: $\frac{\kappa_n}{2} (\Delta K_n)^2$
  - ESG adjustment costs: $\frac{\omega_n}{2} (\Delta g_n)^2$
Green tastes have **positive social impact**: 

\[ S_n(\tilde{d}) > S_n(0) \]
Green tastes have **positive social impact**: 

\[ S_n(\bar{d}) > S_n(0) \]

- **Green firms invest more** (cost of capital ↓)
  - **Brown firms invest less** (cost of capital ↑)

- All firms choose to become **greener**:

\[ \Delta g_n (\bar{d}) = \frac{\bar{d}}{a\omega_n} > 0 \]
Aggregate Social Impact: The Role of $\lambda$

- Firms become greener
- Green firms invest more, brown less
Aggregate Social Impact: The Role of $\Delta$

Firms become greener
Green firms invest more, brown less
Assume each agent’s **utility is increasing in** \( S \equiv \sum_{n=1}^{N} S_n \):

\[
U(\tilde{W}_{1i}, X_i, S) = V(\tilde{W}_{1i}, X_i) + h_i(S)
\]

*original utility function*

*\( h_i(S) > 0 \)*
Assume each agent’s utility is increasing in $S \equiv \sum_{n=1}^{N} S_n$:

$$U(\tilde{W}_{1i}, X_i, S) = V(\tilde{W}_{1i}, X_i) + h_i(S)$$

- Addition of $h_i(S)$ does not affect asset prices, investment, or $S$
  - Because agents are infinitesimally small

$\Rightarrow$ Social impact is caused by the inclusion of $X_i$, not $S$, in $U$
Conclusions

In our equilibrium model of sustainable investing,

- Greener assets have lower **alphas**
  - Because agents have green tastes & green assets hedge **climate risk**
  - Green assets have negative alphas, brown assets have positive alphas

- Greener assets can outperform when **ESG factor** performs well
  - ESG factor captures shifts in customers’ and investors’ tastes
  - **Two-factor pricing**: Market + ESG factor

- ESG-motivated investors earn lower **expected returns**
  - But they earn an “investor surplus”

- ESG **industry’s size** increases with dispersion in ESG preferences

- Sustainable investing leads to **positive social impact**
  - Green firms invest more, brown firms less
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