Sustainable Investing in Equilibrium

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Overview

- Growing interest in **sustainable investing**
  - Objectives: Financial + ESG (Environmental, Social, Governance)

- We build a simple **equilibrium model** of sustainable investing

- Analyze **financial and real effects** of sustainable investing
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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  - ESG factor captures shifts in customers’ and investors’ tastes
  - **Two-factor pricing**: Market + ESG factor
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  - Green firms invest more, brown firms less
  - Firms become greener
Model Overview

FIRMS
Model Overview

FIRMS

INVESTORS
FIRMS

INVESTORS
FIRMS
Model Overview

FIRMS

INVESTORS
Model Overview

FIRMS

INVESTORS

HIGH

LOW
Model Overview

\[ g_n < 0 \quad \text{FIRMS} \quad g_n > 0 \]

INVESTORS

\[
\begin{array}{cc}
\text{Heart} & \text{Sad}\ \\
\text{Snowflake} & \text{Happy}
\end{array}
\]
Model Overview

\[ g_n < 0 \quad \text{or} \quad g_n > 0 \]

**FIRMS**

**INVESTORS**

\[ d_i > 0 \]

\[ d_i = 0 \]
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 $-e^{-A_i \tilde{W}_{1i}} - b_i'X_i$
  - $A_i$: 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
  - $X_i$: 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”
Equilibrium Expected Returns: Market-Level

- **Equity premium:**

\[
\mu_M = a \sigma_M^2
\]
where \(\mu_M = x'\mu\), \(\sigma_M^2 = x'\Sigma x\), \(x\) = market portfolio weights, \(\bar{d} = \frac{1}{n} \sum_{i=1}^{n} d_i\) (i.e., \(\bar{d} \equiv \int_{w_i}^1 w_i d_i\)), \(x'g > 0 \Rightarrow \mu_M\) is decreasing in \(\bar{d}\), \(x'g < 0 \Rightarrow \mu_M\) is increasing in \(\bar{d}\), and assume \(x'g = 0\) (market portfolio is ESG-neutral).
Equilibrium Expected Returns: Market-Level

- **Equity premium:**

\[ \mu_M = a \sqrt{\sigma^2_M} - \frac{\bar{d}}{a} x'g \]

where \( \mu_M = x'\mu, \sigma^2_M = x'\Sigma x \), \( x = \) market portfolio weights, \( \bar{d} = \) average \( d_i \) across agents (i.e., \( \bar{d} \equiv \int_i w_i d_i di \), \( w_i \equiv \frac{W_{0i}}{\int_i W_{0i} di} \))

- \( x'g > 0 \Rightarrow \mu_M \) 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:

\[ \alpha_n = -\frac{d}{g_n} < 0 \]

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

- Expected excess return on agent \( i \)'s portfolio:

\[
E(\tilde{r}_i) = \mu_M - \delta_i \left( \frac{d}{a^3} g' \Sigma^{-1} g \right) > 0
\]

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

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

- Agent $i$’s equilibrium portfolio weights:

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

“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
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
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

- Parameters:
  - \( \mu_M = 0.08, \sigma_M = 0.20 \) per year, market model \( R^2 = 30\% \)
  - \( \Sigma = \sigma^2 u' + \eta^2 I_N, \quad x = (1/N) \iota, \beta = \iota, \quad g'g = 1 \)

- Vary \( \lambda \) and \( \Delta = \) maximum certain return ESG investor is willing to sacrifice to invest in her desired portfolio rather than in \( M \)
  - \( \Delta \equiv r^*_{esg} - r^*_M \), where \( r^*_{esg} \) 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
ESG vs. Non-ESG Expected Portfolio Return

\[ \mathbb{E}\{\tilde{r}_{esg}\} - \mathbb{E}\{\tilde{r}_{non}\} = -2\lambda\Delta \leq 0 \]
Alphas of ESG Investors: The Role of $\lambda$

$$\alpha_{esg} = -2\lambda(1 - \lambda)\Delta \leq 0$$
Alphas of ESG Investors: The Role of $\Delta$

$$\alpha_{esg} = -2\lambda(1 - \lambda)\Delta \leq 0$$

Graph showing the relationship between $\alpha_{ESG}$ and $\Delta$ for different values of $\lambda$. The graph includes lines for $\lambda = 0.1$ or $0.9$, $\lambda = 0.2$ or $0.8$, $\lambda = 0.3$ or $0.7$, and $\lambda = 0.5$.
Investor Surplus

\[ I \equiv \alpha_{esg} - (-\Delta) = \Delta[1 - 2\lambda(1 - \lambda)] \geq 0 \]
Alphas of Non-ESG Investors

\[ \alpha_{\text{non}} = 2\lambda^2 \Delta \geq 0 \]
Size of the ESG Industry (\(=\) Aggregate ESG Tilt)

\[
\text{Aggregate ESG tilt} = 0.04 = 0.03 = 0.02 = 0.01
\]
Agent $i$’s utility:

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

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

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

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

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

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

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

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

Greener stocks have lower alphas for two reasons: tastes and risk
Strength of ESG concerns can change over time

- “Investor” channel: $\tilde{d}$ shifts ($\Delta \tilde{d}$)
- “Customer” channel: Demand for firms’ products shifts ($\tilde{z}_g$)
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: $\tilde{\epsilon} = \tilde{z}_h h + \tilde{f}_g g + \zeta$, 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

- 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

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

- If Corr($\tilde{f}_g, \tilde{C}$) $\neq$ −1 then **multiple factors** capture ESG risk
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: $\frac{k_n}{2} (\Delta K_n)^2$
  - ESG adjustment costs: $\frac{\omega_n}{2} (\Delta g_n)^2$
Green tastes have **positive social impact**:

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

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

- All firms choose to become **greener**
Firm-Level Social Impact

- Green firms invest more, brown less

\( S_\alpha(\tilde{\alpha}) - S_\alpha(0) \)

\( g_{0,n} \)
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
Agents Care about Aggregate Social Impact

- Assume each agent’s utility is increasing in $S ≡ \sum_{n=1}^{N} S_n$:

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

- Original utility function $V(\tilde{W}_{1i}, X_i)$
- Addition $h_i(S)$ does not affect asset prices, investment, or $S$
- Because agents are infinitesimally small

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

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