SUSTAINABLE INVESTING IN GENERAL EQUILIBRIUM

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SUSTAINABLE INVESTING

"investment practices aiming to achieve financial returns + environmental/social value"
SUSTAINABLE INVESTING

"investment practices aiming to achieve financial returns + environmental/social value"

becoming a macroeconomic phenomenon

**WHY DO INVESTORS DEMAND SUSTAINABLE ASSETS**

<table>
<thead>
<tr>
<th>Factor</th>
<th>Global</th>
<th>EMEA</th>
<th>APAC</th>
<th>AMRS</th>
</tr>
</thead>
<tbody>
<tr>
<td>It’s the right thing to do</td>
<td>50%</td>
<td>51%</td>
<td>46%</td>
<td>50%</td>
</tr>
<tr>
<td>Better risk-adjusted performance</td>
<td>46%</td>
<td>49%</td>
<td>35%</td>
<td>45%</td>
</tr>
<tr>
<td>To mitigate investment risk</td>
<td>41%</td>
<td>37%</td>
<td>46%</td>
<td>49%</td>
</tr>
<tr>
<td>Regulations require considering ESG risks</td>
<td>35%</td>
<td>44%</td>
<td>29%</td>
<td>12%</td>
</tr>
<tr>
<td>Mandate from board or management</td>
<td>34%</td>
<td>29%</td>
<td>40%</td>
<td>45%</td>
</tr>
<tr>
<td>My clients are demanding it</td>
<td>30%</td>
<td>34%</td>
<td>19%</td>
<td>22%</td>
</tr>
<tr>
<td>To avoid reputational risk</td>
<td>26%</td>
<td>27%</td>
<td>29%</td>
<td>21%</td>
</tr>
<tr>
<td>Pressure from employees</td>
<td>4%</td>
<td>3%</td>
<td>2%</td>
<td>9%</td>
</tr>
</tbody>
</table>

EMEA = Europe, Middle East and Africa; APAC = Asia-Pacific; AMRS = North and South America.

A fast growing literature evaluating empirical evidence of impact on stock prices/returns/portfolios includes:

Sustainable Investing: Motivating Example

Consider a private investor with $100K portfolio to invest in two companies: PVH and H&M sustainability scores (S&P Global) in 2023: PVH = 30 (medium-low), H&M = 59 (high)

- "benchmark" holdings: $50K in PVH and $50K in H&M
- "advocate" holdings: $0K in PVH and $100K in H&M

**Question**: Do advocate holdings have an impact on capital allocation in PVH vs H&M?
SUSTAINABLE INVESTING: THIS PAPER

what we do:

• model dynamic production economy with heterogeneous firms and households

• key assumption: households have preferences for sustainable assets

• focus on impact on scale and composition (clean vs dirty) of aggregate output

preview of results:

• scale effect on agg. output ambiguous in short-run

• composition tilts to cleaner output in long-run

• no difference between stock prices/returns across clean and dirty in short-run
Sustainable Investing: This Paper

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- model dynamic production economy with heterogeneous firms and households
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- scale effect on agg. output ambiguous in short-run
- composition tilts to cleaner output in long-run
- no difference between stock prices/returns across clean and dirty in short-run
Plan of the Talk

- two-period model with two firms
  - modeling preferences for sustainable assets
  - role of general equilibrium
  - example of composition and scale effects

- full model
  - steady state
two firms, clean and dirty, producing the same output using the same technology, \( f(.) \)

- firms own capital \( k_0 \), choose next period \( k \) to max stock value
- solution requires

\[
f'(k) = \theta
\]

\( \theta \): opportunity cost of funds, taken as given by firm
**TWO-PERIOD MODEL: FIRMS**

two firms, **clean** and **dirty**, producing the same output using the same technology, \( f(.) \)

- firms own capital \( k_0 \), choose next period \( k \) to max stock value
- solution requires
  \[
  f'(k) = \theta
  \]

\( \theta \): opportunity cost of funds, taken as given by firm

- stock price (claim on period 1 output)
  \[
  q = \frac{f(k)}{\theta} \quad \implies \quad q = \frac{f(k)}{f'(k)}, \quad \text{increasing in } k
  \]

- notation: \( q, k, \theta = \text{clean} \quad \tilde{q}, \tilde{k}, \tilde{\theta} = \text{dirty} \)
TWO-PERIOD MODEL: HOUSEHOLDS

live for two periods, consume, and save by holding stocks,
TWO-PERIOD MODEL: HOUSEHOLDS

live for two periods, consume, and save by holding stocks, **two types**: 

• Advocate: 
  \[ U = u(c_{A0}) + \beta u(c_{A1}) + G \]

  \[ G: \] "sustainable wealth," index of sustainability of portfolio held 
  \[ G = vqz - \bar{v}\bar{q}\bar{z}, \] 
  \[ v, \bar{v} > 0 \]
  \[ z = \] holdings of clean stocks, and 
  \[ \bar{z} = \] holdings of dirty stocks 

  \[ \frac{\partial U}{\partial z} = vq > 0 \]: non-pecuniary marginal return for holding clean stocks 

  \[ \frac{\partial U}{\partial \bar{z}} = -\bar{v}\bar{q} < 0 \]: non-pecuniary marginal return for holding dirty stocks 

• Benchmark: 
  \[ U = u(c_{B0}) + \beta u(c_{B1}) \]
TWO-PERIOD MODEL: HOUSEHOLDS

live for two periods, consume, and save by holding stocks, two types:

• Advocate: \( U = u(c_0^A) + \beta u(c_1^A) + G \)

\( G \) : "sustainable wealth," index of sustainability of portfolio held
TWO-PERIOD MODEL: HOUSEHOLDS

live for two periods, consume, and save by holding stocks, two types:

- **Advocate**: \[ U = u(c_0^A) + \beta u(c_1^A) + G \]

\[ G : \text{"sustainable wealth," index of sustainability of portfolio held} \]

example (linear index): \[ G = vqz - \tilde{v}\tilde{q}\tilde{z}, \quad v, \tilde{v} > 0 \]

\( z = \text{holdings of clean stocks, and } \tilde{z} = \text{holdings of dirty stocks} \)
**Two-Period Model: Households**

live for two periods, consume, and save by holding stocks, **two types:**

- **Advocate:** $U = u(c_0^A) + \beta u(c_1^A) + \mathcal{G}$

$\mathcal{G}$: "sustainable wealth," index of sustainability of portfolio held

example (linear index): $\mathcal{G} = vqz - \tilde{v}q\tilde{z}$, $v, \tilde{v} > 0$

$z =$ holdings of **clean** stocks, and $\tilde{z} =$ holdings of **dirty** stocks

$\partial U / \partial z = vq > 0$: non-pecuniary marginal return for holding clean stocks

$\partial U / \partial \tilde{z} = -\tilde{v}q < 0$: non-pecuniary marginal return for holding dirty stocks
**Two-Period Model: Households**

live for two periods, consume, and save by holding stocks, **two types:**

- **Advocate:**
  \[ U = u(c^A_0) + \beta u(c^A_1) + \mathcal{G} \]

  \( \mathcal{G} \) : "sustainable wealth," index of sustainability of portfolio held

  example (linear index):
  \[ \mathcal{G} = vqz - \bar{\varphi}\tilde{z}, \quad v, \bar{\varphi} > 0 \]

  \( z \) = holdings of **clean** stocks, and \( \tilde{z} \) = holdings of **dirty** stocks

  \[ \frac{\partial U}{\partial z} = vq > 0: \text{non-pecuniary marginal return for holding clean stocks} \]

  \[ \frac{\partial U}{\partial \tilde{z}} = -\bar{\varphi} \tilde{q} < 0: \text{non-pecuniary marginal return for holding dirty stocks} \]

- **Benchmark:**
  \[ U = u(c^B_0) + \beta u(c^B_1) \]
**Optimal Portfolio Choice**

- **Advocate**

  \[
  \text{clean} : \quad u'(c_0^A) = \beta \theta u'(c_1^A) + \nu \quad \text{dirty} : \quad u'(c_0^A) \geq \beta \tilde{\theta} u'(c_1^A) - \tilde{\nu}
  \]

- **Benchmark**

  \[
  \text{clean} : \quad u'(c_0^B) \geq \beta \theta u'(c_1^B) \quad \text{dirty} : \quad u'(c_0^B) = \beta \tilde{\theta} u'(c_1^B)
  \]

  note: total outstanding shares normalized to 1 for both clean and dirty
EQUILIBRIUM: THREE CASES

\( w_0^A \) initial wealth of Advocate; scale is compared to agg. output when \( \nu = \bar{\nu} = 0 \)
**EQUILIBRIUM: THREE CASES**

\( w_0^A \) initial wealth of Advocate; scale is compared to agg. output when \( v = \bar{v} = 0 \)

- **Case 1**: when \( w_0^A \) is low, Benchmark is marginal investor for clean and dirty

  \[ \implies \text{no composition effect} \ (k = \bar{k}), \text{positive scale effect} \]
Equilibrium: Three Cases

$w^A_0$ initial wealth of Advocate; scale is compared to agg. output when $v = \bar{v} = 0$

- **Case 1**: when $w^A_0$ is low, Benchmark is marginal investor for clean and dirty
  
  $\Rightarrow$ no composition effect ($k = \bar{k}$), positive scale effect

- **Case 2**: when $w^A_0$ is medium, Advocate is marginal for clean, Benchmark for dirty
  
  $\Rightarrow$ clean composition effect ($k > \bar{k}$), positive scale effect
**Equilibrium: Three Cases**

\( w_0^A \) initial wealth of Advocate; scale is compared to agg. output when \( v = \bar{v} = 0 \)

- **Case 1:** when \( w_0^A \) is low, Benchmark is marginal investor for clean and dirty

  \( \Rightarrow \) no composition effect \( (k = \bar{k}) \), positive scale effect

- **Case 2:** when \( w_0^A \) is medium, Advocate is marginal for clean, Benchmark for dirty

  \( \Rightarrow \) clean composition effect \( (k > \bar{k}) \), positive scale effect

- **Case 3:** when \( w_0^A \) is high, Advocate is marginal for clean and dirty

  \( \Rightarrow \) clean composition effect \( (k > \bar{k}) \), ambiguous scale effect
**Equilibrium: Case 1**

Benchmark is marginal investor in both clean and dirty ($z < 1, \tilde{z} = 0$)

$$\theta = \tilde{\theta} \implies k = \tilde{k}$$

capital composition symmetric, but saving demand higher, so capital level is higher

with, $u(c) = \ln c$, saving demand for Advocate $= \frac{\beta + vqz}{1 + \beta + vqz} w_{0}^{A} = qz$

**intuition:** desired holdings of clean stocks make Advocate effectively more patient, additional saving demand lowers opportunity cost of funds for both clean and dirty firm since marginal investor is Benchmark
**EQUILIBRIUM: NUMERICAL EXAMPLE**

specifications: $f(k) = k^{1/3}$, $k_0 = \tilde{k}_0 = 1$, $\beta = 0.9$, $v = \bar{v} = 1$
**Taking Stock**

compared to an economy with no advocate investors ($v = \tilde{v} = 0$)

- impact on aggregate output can be positive or negative, depending on $v \geq \tilde{v}$

- composition effect depends on the “size” of advocate investors, $w_0^A$

- scale effect can happen without composition effect

▷ implication for empirical analysis:

in Case 1, both $q$ and $\tilde{q}$ increase, while $\theta$ and $\tilde{\theta}$ drop, so no empirically discernible difference across clean and dirty firms from stock prices/returns!
**Full Model**

infinite horizon, continuum of firms indexed by sustainability score $g \in [0, 1]$, density $\phi(g)$

Advocate preferences:

$$
\int_0^\infty e^{-\rho t} \left[ u(c^A(t)) + G(t) \right] dt
$$

with

$$
G(t) = \int_0^1 v(g)z(g,t)q(g,t)\phi(g) dg
$$

$v(g)$: function capturing non-pecuniary return from assets with score $g$

$g_n$: neutral sustainability score, $v(g_n) = 0$
The equilibrium consists of a sustainability score threshold $g^*(t)$ such that

- for $g > g^*(t)$, the marginal investor is Advocate, so $k(g) > k(g^*(t))$
- for $g \leq g^*(t)$, the marginal investor is Benchmark, so $k(g) = k(g^*(t))$
The equilibrium consists of a sustainability score threshold $g^*(t)$ such that

- for $g > g^*(t)$, the marginal investor is Advocate, so $k(g) > k(g^*(t))$
- for $g \leq g^*(t)$, the marginal investor is Benchmark, so $k(g) = k(g^*(t))$

The dynamic path for $g^*(t)$ obeys:

$\dot{g}^*(t) < 0$ when $g^*(t) > g_n$ (corresponding to Case 1)
$\dot{g}^*(t) > 0$ when $g^*(t) < g_n$ (corresponding to Case 3)
STEADY STATE

In steady state

\[ g^*(t) = g_n \]

capital allocation obeys

\[ f'(k(g)) = \rho + \delta - v(g) \int_{g_n}^{1} \left[ f(k(j)) - \delta k(j) \right] \phi(j) dj, \quad \text{for} \quad g \geq g_n, \]

and

\[ f'(k(g)) = \rho + \delta, \quad \text{for} \quad g < g_n. \]

**insight**: allocation \( k(g) \) depends on \( v(g) \), distribution of capital, \( k(j) \), and scores, \( \phi(j) \)
scale and composition for two alternative sustainability preference functions, \( v(g) \), under empirical \( \phi(g) \)
Steady State: Example

scale and composition for two alternative sustainability preference functions, $v(g)$, under uniform $\phi(g)$
Thank you!
EQUILIBRIUM: Case 2

Advocate is marginal investor in clean, Benchmark in dirty \((z = 1, \bar{z} = 0)\)

\[ \theta < \bar{\theta} \implies k > \bar{k} \]

capital composition favors clean, saving demand higher, so capital level is higher

\[
\text{saving demand for Advocate} = \frac{\beta + vq}{1 + \beta + vq} w^A_0 = q
\]

intuition: as \(k\) increases, \(q\) increases, so saving demand satisfied via valuation effect;
Advocate is marginal investor so opportunity costs of funds \(\theta\) lower than \(\bar{\theta}\)
**Equilibrium: Case 3**

Advocate is marginal investor in clean and dirty \((z = 1, \tilde{z} > 0)\)

\[
\theta < \tilde{\theta} \implies k > \tilde{k}
\]

capital composition favors clean, saving demand ambiguous

saving demand for Advocate

\[
\text{saving demand for Advocate} = \frac{\beta - \sigma(\bar{v})}{1 + \beta - \sigma(\bar{v})} \left[ w_0^A + q \left(1 - \frac{f'(k)}{f'(\tilde{k})}\right) \right] = q + \tilde{z}\tilde{q}
\]

**intuition:** two competing effects: since \(\sigma(\bar{v}) > 0\), Advocate investor has lower incentive to save to avoid holding dirty stocks, but higher \(q\) pushes saving demand upward, so overall effect ambiguous
**EQUILIBRIUM: NUMERICAL EXAMPLE**

Specifications: \( f(k) = k^{1/3} \), \( k_0 = \bar{k}_0 = 1 \), \( \beta = 0.9 \), \( v = 1 \), \( \bar{\sigma} = 0 \)
**Equilibrium: Numerical Example**

![Graph showing wealth held by advocate investors and output composition divided into cases.](chart.png)

**Specifications:** \( f(k) = k^{1/3} \), \( k_0 = \tilde{k}_0 = 1 \), \( \beta = 0.9 \), \( v = 0 \), \( \bar{v} = 1 \)
example of preference function $v(g)$ and observed empirical density $\phi(g)$ (employment)
GLOBAL GROWTH IN SUSTAINABLE INVESTMENT

Table A1. Snapshot of global sustainable investing assets, 2016-2018-2020 (USD billions)

<table>
<thead>
<tr>
<th>REGION</th>
<th>2016</th>
<th>2018</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Europe*</td>
<td>12,040</td>
<td>14,075</td>
<td>12,017</td>
</tr>
<tr>
<td>United States</td>
<td>8,723</td>
<td>11,995</td>
<td>17,081</td>
</tr>
<tr>
<td>Canada</td>
<td>1,086</td>
<td>1,699</td>
<td>2,423</td>
</tr>
<tr>
<td>Australasia*</td>
<td>516</td>
<td>734</td>
<td>906</td>
</tr>
<tr>
<td>Japan</td>
<td>474</td>
<td>2,180</td>
<td>2,874</td>
</tr>
<tr>
<td><strong>Total (USD billions)</strong></td>
<td><strong>22,839</strong></td>
<td><strong>30,683</strong></td>
<td><strong>35,301</strong></td>
</tr>
</tbody>
</table>

Source: ?.
Notes: Conversions from local currencies to US dollars were at the exchange rates prevailing at the date of reporting. In 2020, Europe includes Austria, Belgium, Bulgaria, Denmark, France, Germany, Greece, Italy, Spain, Netherlands, Poland, Portugal, Slovenia, Sweden, the UK, Norway, Switzerland, Liechtenstein.

* Europe and Australasia have enacted significant changes in the way sustainable investment is defined in these regions.