Sustainable Investing in General Equilibrium

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Sustainable Investing

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

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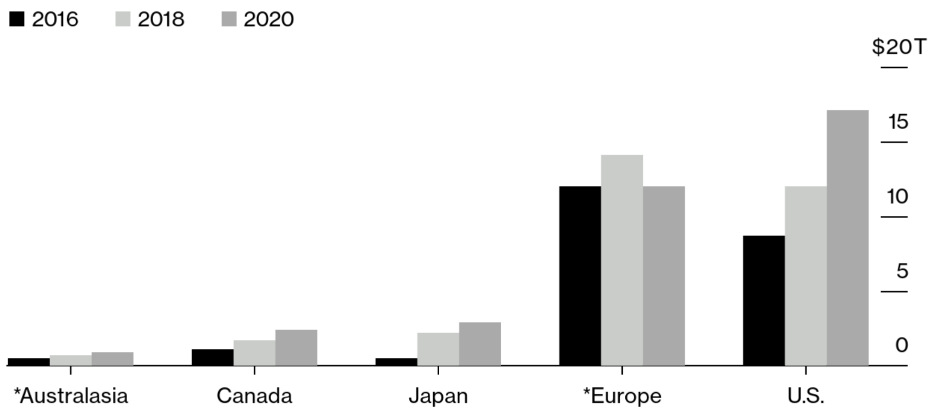
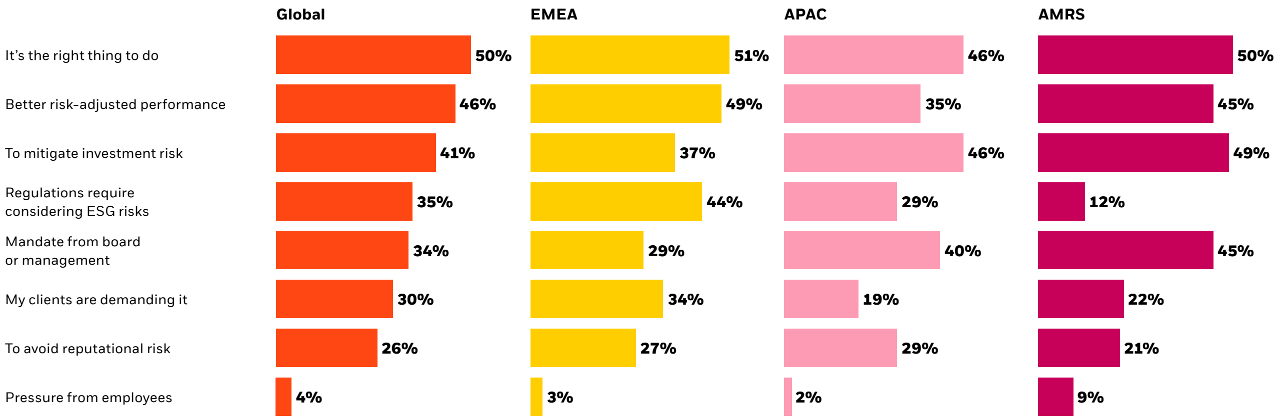
becoming a macroeconomic phenomenon



Sustainable Assets by Region, source: Global Sustainable Investment Alliance, 2020.

Why do investors demand sustainable assets



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

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

▷ Laura Starks, "Sustainable Finance and ESG Issues: Value vs Values," *Journal of Finance (2023)*

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
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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

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-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

$$f'(k) = \theta$$

θ: opportunity cost of funds, taken as given by firm

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- stock price (claim on period 1 output)

$$q = f(k)/\theta \quad \Longrightarrow \quad q = f(k)/f'(k), \quad \text{increasing in } k$$

- notation: q, k, θ = **clean** $\tilde{q}, \tilde{k}, \tilde{\theta}$ = **dirty**

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

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

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

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- **Benchmark**: $U = u(c_0^B) + \beta u(c_1^B)$

Optimal Portfolio Choice

- **Advocate**

$$\textbf{clean}: \; u'(c_0^A) = \beta\theta u'(c_1^A) + v \qquad \textbf{dirty}: \; u'(c_0^A) \geq \beta\tilde{\theta} u'(c_1^A) - \tilde{v}$$

- **Benchmark**

$$\textbf{clean}: \; u'(c_0^B) \geq \beta\theta u'(c_1^B) \qquad \textbf{dirty}: \; u'(c_0^B) = \beta\tilde{\theta} u'(c_1^B)$$

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

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

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$\Longrightarrow$ no composition effect ($k = \tilde{k}$), positive scale effect

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

$\Longrightarrow$ clean composition effect ($k > \tilde{k}$), positive scale effect

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

$\Longrightarrow$ clean composition effect ($k > \tilde{k}$), ambiguous scale effect

Equilibrium: Case 1

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

$$\theta = \tilde{\theta} \quad \Longrightarrow \quad k = \tilde{k}$$

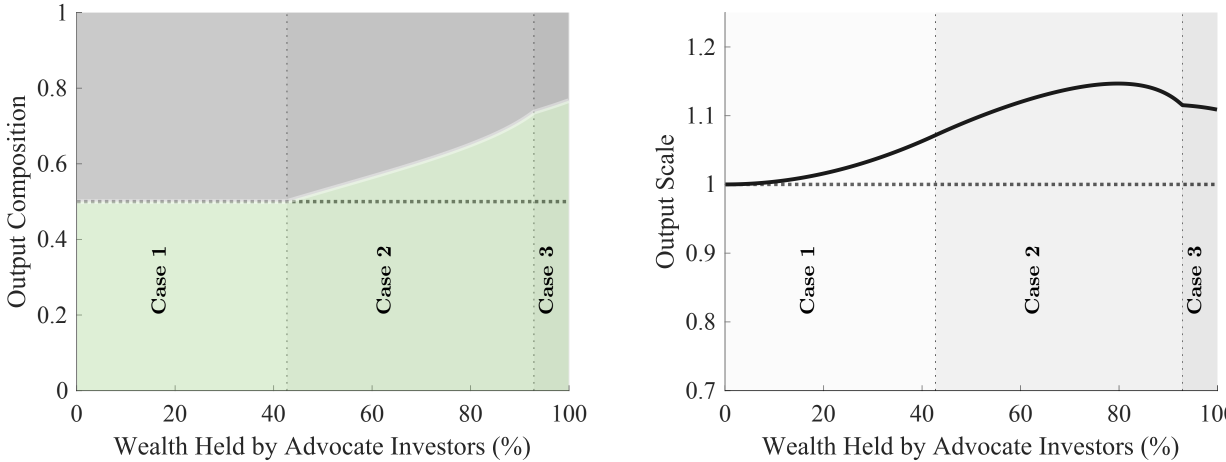
capital composition symmetric, but saving demand higher, so capital level is higher

$$\text{with, } u(c) = \ln c \text{, saving demand for Advocate} = \frac{\beta + vqz}{1 + \beta + vqz} w_0^A = qz$$

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

▸ Case2 ▸ Case3

Equilibrium: Numerical Example



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

$\tilde{v} = 0$ $v = 0$

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 $v \gtrless \tilde{v}$

- 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 θ 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:

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

with

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

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

g_n: neutral sustainability score, $v(g_n) = 0$ example

EQUILIBRIUM

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 so $k(g) = k(g^*(t))$

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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

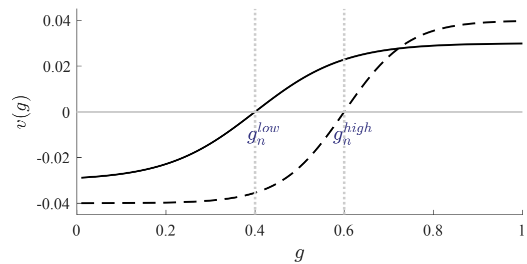
$$f'(k(g)) = \rho + \delta - v(g) \int_{g_n}^{1} [f(k(j)) - \delta k(j)] \phi(j) dj, \quad \text{for} \quad g \geq g_n,$$

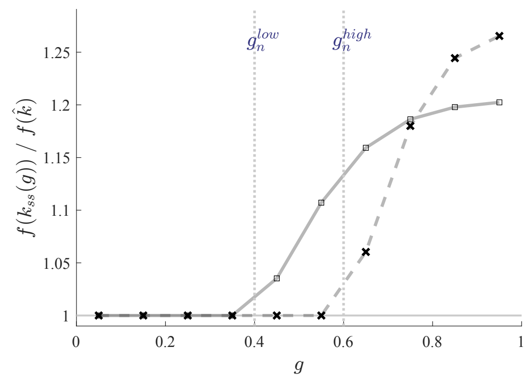
and

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

insight: allocation $k(g)$ depends on $v(g)$, distribution of capital, $k(j)$, and scores, $\phi(j)$

Steady State: Example





scale and composition for two alternative sustainability preference functions, $v(g)$, under **empirical** $\phi(g)$

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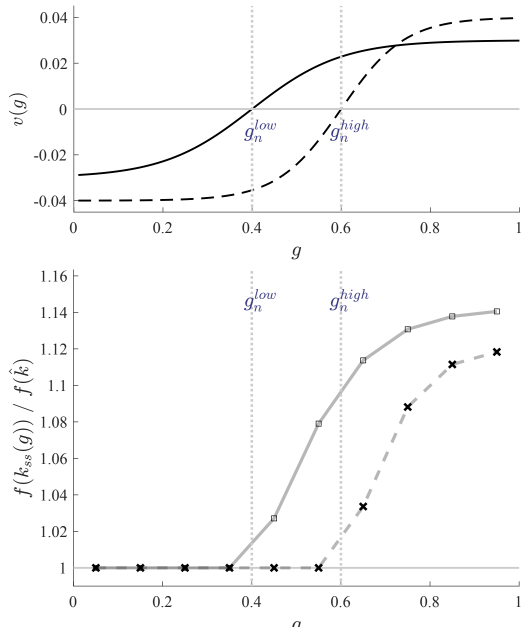

scale and composition for two alternative sustainability preference functions, $v(g)$, under **uniform** $\phi(g)$

Thank you!

EQUILIBRIUM: CASE 2

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

$$\theta < \tilde{\theta} \quad \Longrightarrow \quad k > \tilde{k}$$

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

$$\text{saving demand for Advocate} = \frac{\beta + vq}{1 + \beta + vq} w_0^A = q$$

intuition: as k increases, q increases, so saving demand satisfied via valuation effect; Advocate is marginal investor so opportunity costs of funds θ lower than $\tilde{\theta}$

back

Equilibrium: Case 3

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

$$\theta < \tilde{\theta} \quad \Longrightarrow \quad k > \tilde{k}$$

capital composition favors clean, saving demand ambiguous

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

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

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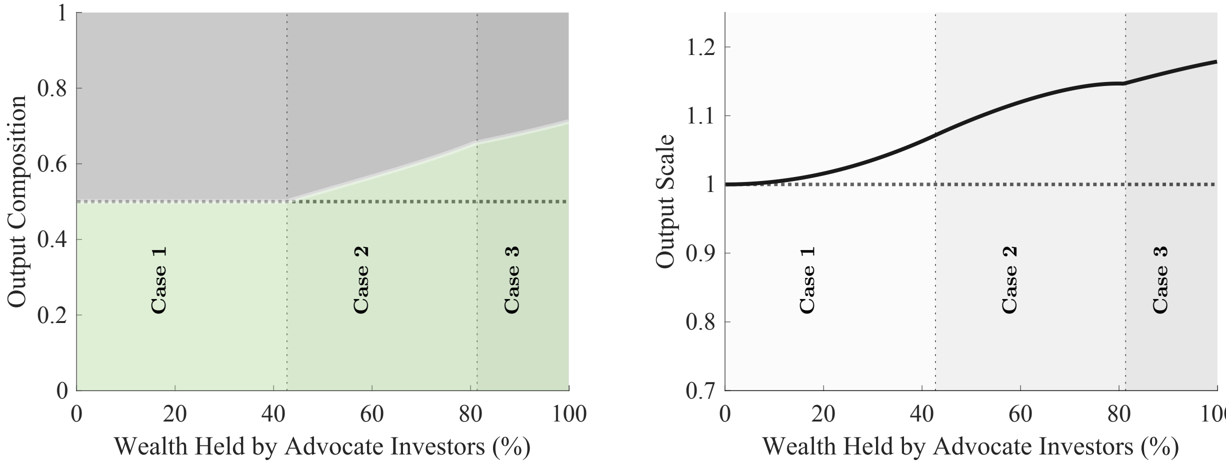
Equilibrium: Numerical Example



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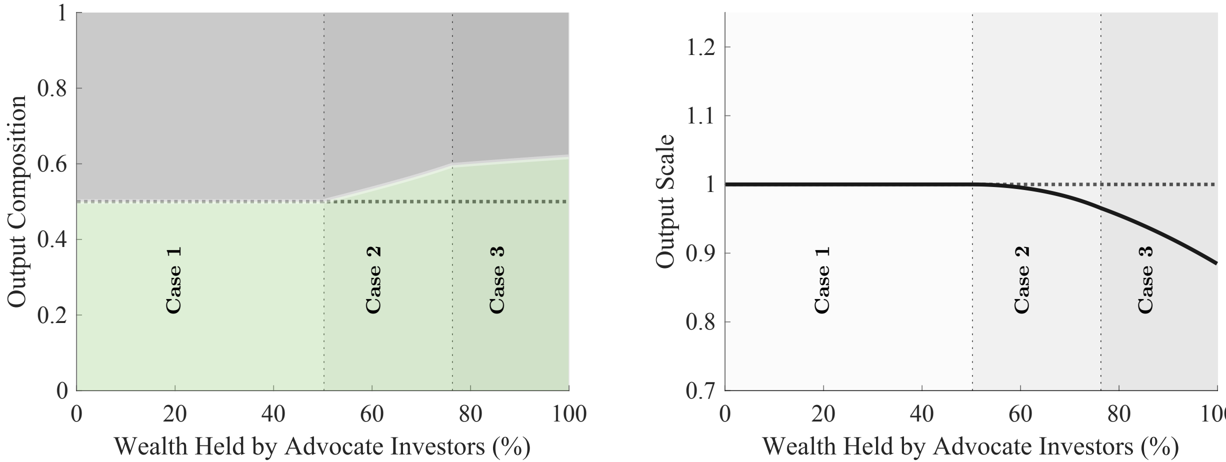

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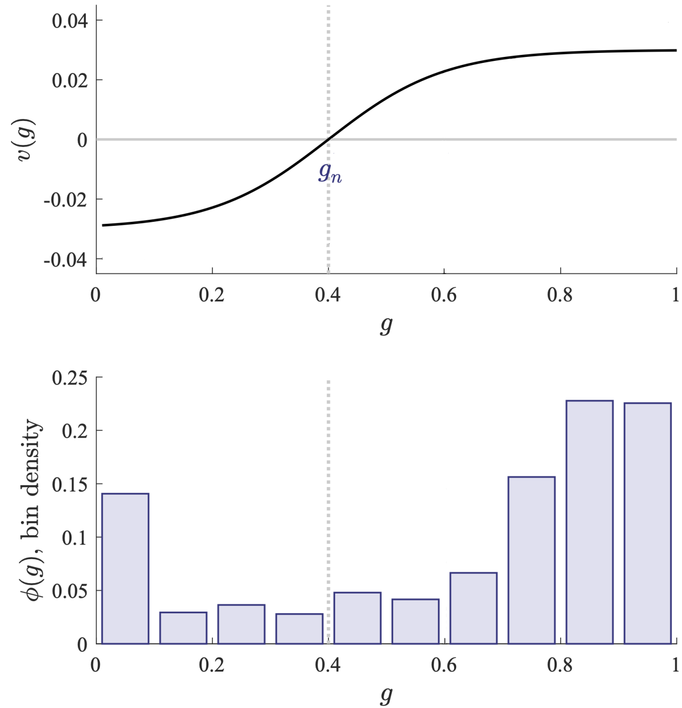
Appendix



example of preference function $v(g)$ and observed empirical density $\phi(g)$ (employment)

back

Global growth in sustainable investment

BACK

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

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

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.